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Environmental regulation and eco-industry trade: Theory and evidence from the European Union

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Abstract

In this paper, we theoretically and empirically study the impact of environmental taxation on trade in environmental goods (EGs). Using a trade model in which the demand for and supply of EGs are endogenous, we show that the relationship between environmental taxation and demand for EGs follows a bell-shaped curve. Above a cutoff tax rate, a higher pollution tax rate can reduce the bilateral trade of EGs because there are too many low-productivity suppliers of EGs. Our empirical results confirm our main findings using data regarding the EU-27 countries. We also theoretically and empirically show that environmental taxation has a monotonically positive impact on the extensive margin of trade. Furthermore, we show that if countries apply an environmental tax rate equals to the "optimal" tax rate, 4.03% (*e.g.*, the tax rate maximizing international trade of EGs), then trade in EGs would experience an increase of 22 percentage points.

Keywords: environmental goods, international trade, environmental taxation

JEL Classification: F12, F18, Q56

Régulation environnementale et développement international commerce de l'éco-industrie

Résumé

Dans cet article, nous étudions théoriquement et empiriquement l'impact de la taxation environnementale sur le commerce international des biens environnementaux (EG). A partir d'un modèle d'économie internationale dans lequel la demande et l'offre d'EG sont endogènes, nous montrons que la relation entre la fiscalité environnementale et la demande d'EG suit une courbe en forme de cloche. Au-dessus d'un seuil de taux d'imposition, un accroissement de la fiscalité environnementale peut réduire les importations d'EG, en raison de l'entrée de nouveaux fournisseurs d'EG à faible productivité favorisant l'accroissement des prix. Nos résultats empiriques confirment nos principales conclusions en utilisant des données des pays de l'UE-27. Nous montrons également théoriquement et empiriquement que la fiscalité environnementale a un impact positif sur le nombre de pays en mesure d'exporter des biens EG. En outre, nous montrons que si les pays appliquaient une taxe environnementale égale à la taxe "optimale", à savoir $4,03\%$ (par exemple, le taux qui maximisent le commerce international des biens EG), le commerce des biens EG augmenterait de 22 points de pourcentage.

Mots-clés: biens environnementaux, technologie propre, commerce international, taxation environnementale

Classification JEL: F12, F18, Q56

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1. Introduction

The acceleration of trade in environmental goods and services (EGS) and the development of an "eco-industry" supplying these products to polluting firms is at the heart of the sustainable development strategies of the World Trade Organization (WTO), Asian-Pacific Economic Cooperation (APEC) forum, and European Union (EU).[1] According to OECD (2006), "*The environmental goods and services industry consists of activities which produce goods and services to measure, prevent, limit, minimise or correct environmental damage to water, air and soil, as well as problems related to waste, noise and eco-systems*." Policymakers have adopted different measures to force firms to acquire environmentally friendly technologies and equipment to prevent and abate pollution. This has created an increasingly large market for EGS (Sauvage, 2014). Indeed, a distinguishing characteristic of the EGS market is that its growth is largely been driven by public intervention. Although environmental regulations play a decisive role in creating demand for EGS, which, in turn, boosts international trade in EGS, little attention has been devoted to the effects of national environmental regulations on trade in EGS.

Policymakers and academics have paid considerable attention to the impacts of lower tariffs on trade in environmental goods (EGs).[2] For example, Lovely and Popp (2011) find that economic integration increases access to environmentally friendly technologies and leads to earlier adoption. The liberalization of trade in EGs is likely to generate two distinct effects. First, firms will probably increase their pollution abatement efforts because of the lower prices resulting from an import tariff reduction. Second, because of reduced costs of environmental compliance following trade liberalization, governments will be encouraged to set more ambitious environmental standards (Copeland and Taylor, 2004). However, recent contributions have shown that lower tariffs may yield less stringent environmental policies (Nimubona, 2012; Tsai *et al.*, 2015). More generally, the literature regarding trade liberalization and the environment is inconclusive (Kreickemeier and Richter, 2014; Baghdadi *et al.*, 2013; Managi *et al.*, 2009; Frankel and Rose, 2005; Copeland and Taylor, 2004; Cole and Elliot, 2003).[3]

[1] See annex C of the 2012 leaders' declaration at http://www.apec.org/Meeting-Papers/Leaders-Declarations/2012/2012_aelm/2012_aelm_annexC.aspx (accessed January 03, 2013)
and Article 31.3 of the Doha Declaration of the WTO at http://www.international.gc.ca/media/comm/news-communiques/2014/01/24a.aspx (accessed January 25, 2014).

[2] APEC economies are working to reduce tariffs on a list of EGs to five percent or less by 2015 and will explore opportunities for building on this initiative within the WTO in 2014. See the communique from the 2014 Davos meeting at http://www.international.gc.ca/media/comm/news-communiques/2014/01/24a.aspx (accessed January 25, 2014).

[3] This ambiguity comes from three channels that transmit the effects of trade on environmental quality. First, better access to international markets induces more production, which, *ceteris paribus*, harms environmental quality (scale effect). Second, this effect can be magnified if falling trade barriers favor trade in pollution-intensive goods (composition effect). Third, by raising real income per capita, international trade can induce the develop-

The literature is silent regarding the impact of environmental policies on trade in EGs. However, demand from polluting firms for abatement activities and clean technologies could be created by environmentally related taxes (or other environmental regulations). Indeed, higher emission tax rates make the use of EGs or clean technologies more attractive to polluting firms, thus increasing these firms' willingness to pay for EGs. It is expected that more stringent environmental policies will induce a higher demand for EGS and may favor international trade in EGs.

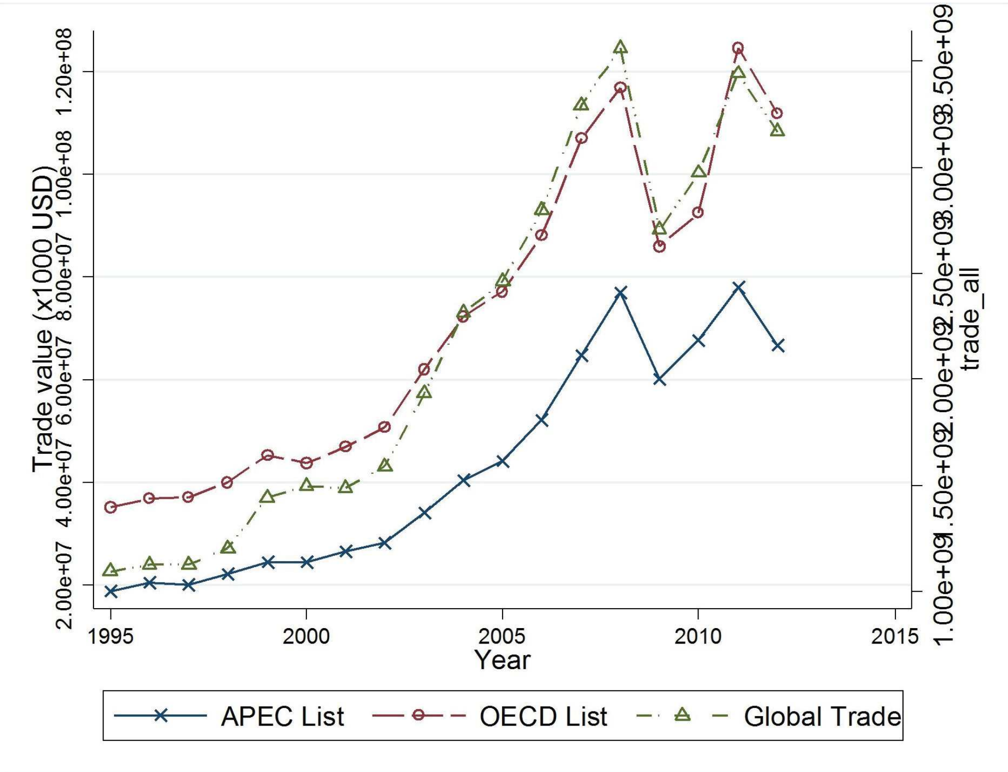
In this paper, we theoretically and empirically study the impact of environmental taxation on trade in EGs. To do so, we first develop a trade model in which demand for and supply of EGs are endogenous and adjust in response to the pollution tax rate. In accordance with the empirical evidence, we assume that the suppliers of EGs are *heterogeneous* and operate under *oligopolistic* competition (see Sinclair-Desgagné, 2008; Perino, 2010; David *et al.*, 2011). It follows that the price of EGs does not completely reflect their marginal cost but rather depends on both the price elasticity of demand and the dispersion of production costs in the eco-industry. Hence, emission taxes modify the demand for EGs both directly and indirectly through their impacts on the market prices of EGs as the number and average productivity of EGs suppliers adjusts. Our framework captures the interplay among polluting firms' adoption technology decisions, EG prices and environmental taxation.

Our theory reveals that with an endogenous market structure, the relationship between the pollution tax rate and trade in EGs is nonlinear because two opposing effects are at work. On one hand, the demand for EGs from polluting firms increases with environmental taxation, *ceteris paribus*. On the other hand, a higher tax burden favors the entry of EG suppliers with higher marginal costs of production, thus leading to higher EGs prices, which, in turn, reduces demand for EGs. Our analysis reveals a bell-shaped curve between environmental taxation and demand for EGs. Starting from low pollution tax rates, a higher tax burden increases demand for EGs while their prices remain relatively low. However, above a cutoff tax rate, a higher tax burden strongly increases the price of EGs, thereby reducing demand for EGs. In other words, excessive pollution taxation can reduce bilateral trade in EGs because too many low-productivity firms enter the market.

To test our predictions, we constructed a dataset regarding trade in EGs. Building such a dataset is difficult for at least two reasons. First, a well-accepted, standardized definition of EGs in statistical terms is lacking. There is no international consensus regarding the definition of EGs, as some products are used for both environmental and non-environmental purposes. Nevertheless, the OECD and APEC provide lists of environmental products for discussion purposes in international negotiations. Our sample concerns 112 products (coded at the 6-digit harmonized system (HS6) level) from the OECD list and 54 HS6 codes from the APEC list (the two

ment of clean technologies (technical effect).

Figure 1: International trade of EGs (APEC and OECD Lists) and N-EGs within the EU-27



Source: UNCOMTRADE.

lists have only 27 HS6 codes in common).[4] Second, we need information about environmental taxation for different countries and years. We examine the member states of the EU-27 because data regarding their environmental taxes (on energy, transport, pollution and resources) are available. Therefore, the dataset comprises the bilateral trade flows of the EU-27 members at the HS6 level. Figure 1 indicates that within the EU, trade in EGs has recently experienced continuous growth. The differences in trade in EGs between the OECD and APEC lists is very small. In addition, the growth rates of trade of EGs and non-EGs (N-EGs) are similar.[5]

The bilateral trade equation that we estimate is derived from our theory. Our gravity-type equation of bilateral trade in EGs differs from the standard gravity model (Anderson, 2010). Indeed, we cannot only use the importing country's income (which measures its absorption capacity) because the stringency of environmental regulations also strongly drives the size of the market for EGs. Thus, our theoretical model yields a gravity equation that considers a country's environmental taxation in addition to its income. Furthermore, the relationship between imports of EGs and the pollution tax rate prevailing in a country is non-log-linear in equilibrium. Remember that the standard gravity model specifies bilateral trade as a log-linear function of country-specific variables (see, *e.g.*, Anderson, 2010). Such a difference occurs because we use

[4]See Table A1 in Appendix A.
[5]N-EGs exclude the EGs included on the OECD and APEC lists (a merged list).

a Cournot model instead of a monopolistic competition model (or a perfect competition model) to take into account the characteristics of the eco-industry (Sinclair-Desgagné, 2008). It follows that the markup over the marginal cost is not constant but rather depends on environmental taxation, so bilateral trade is not a log-linear function of the environmental tax rate.

Although our gravity equation exhibits a different structure than that of the standard approach, we must address similar econometric issues. To estimate the extensive margins (the number of trading partners) and the intensive margins, we use flexible specifications that take into account the doubly bounded nature of the data and the Poisson pseudo-maximum likelihood procedure, respectively (Santos Silva and Tenreyro, 2006; Santos Silva *et al.*, 2014). The results of the empirical analysis of EU-27 countries confirm our main findings. By controlling for endogeneity bias, our estimations show that higher environmental taxation increases the number of importers and exporters (the extensive margin) of EGs. More precisely, considering the extensive margin of trade, our results indicate an increase in environmental taxation of 1 percentage point will be followed by an increase of approximately 5% in the number of trading partners. Hence, a strict environmental policy has a large influence on the number of countries exporting EGs. In addition, our estimations reveal that when considering the APEC list, higher environmental taxation boosts the international development of the eco-industry sector (the intensive margin), provided that the tax burden is not excessively high. Indeed, our estimates reveal that an environmental tax rate higher than 4.03% (measured as the ratio of environmental tax revenue to GDP) can discourage international trade in EGs. Thus, in the EU, the level of environmental taxation (measured as the ratio of environmental tax revenues to GDP, which ranges from 1.57% to 3.87% in 2012) can be increased because it is still on the increasing side of the bell-shaped curve. Our analysis shows that if countries apply an environmental tax rate equal to the "optimal" tax rate, 4.03% (*e.g.*, the tax rate maximizing international trade of EGs), then trade of EGs of the APEC list would experience an increase of 22 percentage points.

Related literature. The impacts of environmental taxation on the competitiveness and location of polluting industries have received much attention in the trade literature. Stricter environmental regulation is potentially harmful to the competitiveness of firms because of higher production costs, which may lead to the relocation of dirty industries to countries with lower environmental taxation (Copeland and Taylor, 2004; Letchumanan and Kodama, 2000; Levinson, 2009; Muradian *et al.*, 2002). In contrast, according to the Porter hypothesis, more stringent but properly designed environmental regulations may induce innovation and, in turn, enhance competitiveness. However, this body of literature disregards the effects of environmental taxation on trade in EGs.

Recent empirical contributions have analyzed the relationships between environmental regulation and export performance in the EU-15 countries (Costantini and Mazzanti, 2012), the energy sector among OECD countries (Costantini and Crespi, 2008), and US environmental product manufacturers (Becker and Shadbegian, 2008). Unlike these studies, we provide clear microeconomic foundations for the relationship between environmental regulation and export flows in EGs.

Our study also contributes to a growing body of trade and environment literature that considers the production of EGs under imperfect competition in the eco-industry (Baumol 1995; Avery and Boadu 2004; Canton *et al.*, 2008; David and Sinclair-Desgagné, 2010; Greaker and Rosendahl, 2008; Nimubona, 2012; Schwartz and Stahn, 2014). Theoretical approaches commonly consider a closed economy with a price-taking polluting industry that contracts out EGs from identical suppliers competing *à la* Cournot (with a fixed number of EGs providers). In our framework, polluting firms and EGs suppliers are heterogeneous in terms of productivity. Unlike Melitz (2003), we only assume that the producers of conventional goods are heterogeneous with respect to their environmental efficiency. Hence, the mass of firms purchasing EGs is endogenous because firms differ in terms of their pollution-reducing capabilities. In addition, we consider free entry into the eco-industry. This assumption is associated with the fact that EGs suppliers are heterogeneous in terms of production costs, which plays a crucial role in our results.

Note that Perino and Requate (2012) find that the theoretical relationship between the rate of advanced technology adoption and the stringency of environmental policy has an inverted U shape. Their approach is very different from ours because it includes neither an output market, nor an eco-industry. Their result is driven by the assumption that the marginal abatement cost curves of conventional and new technologies intersect. Without this assumption, we also show the existence of a non-monotonic relationship between environmental policy stringency and the rate of technology adoption.

The rest of the paper is organized as follows. Section 2 describes our model and presents our main predictions. The data and the empirical model are detailed in Section 3, whereas Section 4 provides the results and analysis of the estimations. We conclude in Section 5.

2. Theory

We consider a multi-country model with one upstream industry providing a tradable EG that is used by a downstream industry producing a polluting product. We focus on end-of-pipe pollution abatement. In each country, a tax rate is applied to each unit of pollution. In our approach, firms decide whether to purchase EGs to reduce their level of pollution. We assume that polluting firms are heterogeneous in terms of their ability to reduce emissions and that countries are heterogeneous in terms of their ability to develop an EGs-producing industry.

It should be noted that our model cannot capture all characteristics of the EGs industry. Indeed, this industry includes not only the production of cleaner technologies, but also the production of products and services that reduce environmental risk and minimize pollution and resource use. However, our approach allows us to explain why some countries export/import EGs and the magnitude of bilateral trade in this type of product.

2.1. The polluting industry (or downstream industry)

The profit of a polluting firm located in country j producing variety υ is given by

$$\pi_j(\upsilon) = p_j(\upsilon)q_j(\upsilon) - c_j(\upsilon) - g_j(\upsilon)$$

where p_j and q_j are the output price and quantity, c_j is the production cost, and g_j is the cost associated with pollution. Each firm produces its variety under monopolistic competition, and the representative consumer has a standard constant-elasticity-of-substitution utility function over the final good. In this case, the demand for a variety υ can be expressed as follows: $q_j(\upsilon) = p_j(\upsilon)^{-\varepsilon} P_j^{\varepsilon-1} E_j$, where ε is the constant elasticity of substitution, P_j is the price index, and E_j is the expenditure level for the final good produced in country j.[6] Hence, the sales of a firm producing in country j are given by

$$p_j(\upsilon)q_j(\upsilon) = p_j(\upsilon)^{1-\varepsilon} P_j^{\varepsilon-1} E_j \tag{1}$$

with

$$P_j = \left[\int_{\Omega_j} p_j(\upsilon)^{1-\varepsilon} \mathrm{d}\upsilon\right]^{\frac{1}{1-\varepsilon}}$$

where Ω_j is the set of varieties available in country j.

In each country, we assume that production technology requires a single input, labor, such that $q_j = \kappa_j l_j$, where the parameter κ_j represents the technological parameter, and l_j is the labor. Labor is inelastically supplied in a competitive market and is chosen as the numeraire. These assumptions imply a unit wage. The cost associated with production is given by $q_j/\kappa_j + f_j$, where f_j is the fixed production cost (paid in terms of the numeraire).

We consider that abatement activity uses environmental goods purchased from the eco-industry (a_j) and requires a fixed requirement ϕ_j in labor. The abatement activity, which is related to treatment/capture, recycling, disposal, and pollution prevention, requires labor dedicated to this activity. For simplicity, we consider a fixed labor need. Hence, the costs associated with pollution are given by

$$g_j(\upsilon) = t_j e_j(\upsilon) + z_j a_j + \phi_j$$

[6] Implicitly, we assume that the final good produced by the polluting industry is not tradable between countries. We could assume that the final product can be traded. However, such an extension would make the formal analysis more complex without adding new results.

where a_j is the quantity of EGs purchased by the firm, z_j is the price of the EG used in country j, t_j is the environmental taxation, and e_j is the quantity of pollution, which is expressed as follows:

$$e_j(v) = \xi_j q_j(v) - \varphi^\eta \frac{a_j^{1-\alpha}}{1-\alpha} \tag{2}$$

with $\xi_j > 0$, $\eta > 0$ and $\alpha < 1$. Hence, the level of emissions for a firm is proportional to the production of the final product and decreases with abatement activity. We assume diseconomies of scale in the use of abatement services ($\alpha < 1$), and φ reflects the ability of firms to reduce pollution for the same level of EGs. The effects of abatement activities (a_j) increase with firm efficiency φ. We consider the fact that firms belonging to the final sector differ in $\varphi \in [\varphi_{\min}, \infty)$, such that the level of pollution varies across firms adopting an abatement technology. Then, the profit of the firm is

$$\pi_j(v) = p_j(v)q_j(v) - (\kappa_j^{-1} + t_j\xi_j)q_j(v) - f_j + \psi_j(\varphi)$$

with

$$\psi_j(\varphi) \equiv t_j\varphi^\eta \frac{a_j^{1-\alpha}}{1-\alpha} - z_j a(v) - \phi_j. \tag{3}$$

Note that if the firm does not purchase EGs, then it has to pay a tax equal to $t_j\xi_v q_j(v)$. It follows that a firm makes a non-negative profit associated with the use of EGs provided that $\psi_j(\varphi) \geq 0$.

Because firms produce under monopolistic competition, each producer sets its price and its demand for the EG, treating the price index P_j as given. The first-order conditions, given by $\mathrm{d}\pi_j/\mathrm{d}p_j = 0$ and $\mathrm{d}\pi_j/\mathrm{d}a_j = 0$, lead to

$$p_j(v) = \frac{\varepsilon}{\varepsilon - 1}\left(\kappa_j^{-1} + t_j\xi_j\right) \tag{4}$$

The price is given by a constant markup $\varepsilon/(\varepsilon - 1)$ over the marginal cost $1/\kappa_j + t_j\xi_v$. As expected, a higher tax rate raises the marginal cost and, in turn, the prices set by the firms. Note that the price of the final product (p_j) does not vary among polluting firms located in the same country, even if their levels of emissions differ. Indeed, we have assumed that the marginal impact of production on emissions (ξ_j) does not vary among firms and an identical technological parameter (κ_j). In contrast, the demand for the EG ($a_j(v)$) differs across firms as $\mathrm{d}\pi_j/\mathrm{d}a_j = 0$, which yields

$$a_j(\varphi) = \left(\frac{\varphi^\eta t_j}{z_j}\right)^{1/\alpha}. \tag{5}$$

The demand for the environmental product is positively affected by the pollution tax rate and the ability of firms to reduce their emissions. More interestingly, the positive effect of the pollution tax rate on demand for the EG increases with firm productivity. In other words, the effect of pollution taxation on the diffusion of EGs is strong in countries that host high-productivity firms. Inserting (5) into (3) yields the profit associated with the use of EGs by a φ-type firm:

$$\psi_j(\varphi) = \varphi^{\frac{\eta}{\alpha}} t_j^{\frac{1}{\alpha}} z_j^{-\frac{1-\alpha}{\alpha}} \frac{\alpha}{1-\alpha} - \phi_j. \tag{6}$$

Hence, $a_j(v) > 0$ if and only if $\varphi > \overline{\varphi}_j$ with $\overline{\varphi}_j$ such that $\psi(\overline{\varphi}_j) = \phi_j$ or, equivalently,

$$\overline{\varphi}_j = t_j^{\frac{-1}{\eta}} z_j^{\frac{1-\alpha}{\eta}} \left[\frac{(1-\alpha)\phi_j}{\alpha}\right]^{\frac{\alpha}{\eta}}.$$

In other words, *the probability of purchasing the environmental good is positively related to the pollution tax rate* and negatively related to the fixed and variable costs associated with the use of the abatement technology. For a given z_j, if t_j tends to zero, then $\overline{\varphi}_j$ tends to infinity, such that no polluting firms introduce an abatement technology.

We now determine the mass of firms adopting an abatement technology. We assume that the polluting firms do not have *a priori* knowledge of their ability to curb pollution (φ). Indeed, introducing an abatement technology pulls a firm away from its core competency. In addition, we consider that firms are risk neutral and must pay a sunk cost equal to f_e units of labor to enter the abatement market.

Hence, the demand of the downstream industry for EGs is given by $A_j = \int_{\Omega_j^e} a_j(\varphi)\mathrm{d}G(\varphi)$, where Ω_j^e is the set of firms using the EG, and $G(\varphi)$ is the cumulative density function of φ. Using (5), we obtain the aggregate demand for EGs in country j:

$$A_j = M_j^e \int_{\overline{\varphi}_j}^{\infty} \varphi^{\eta/\alpha} \left(\frac{t_j}{z_j}\right)^{1/\alpha} \frac{g(\varphi)}{1-G(\overline{\varphi}_j)} \mathrm{d}\varphi \tag{7}$$

where M_j^e is the mass of firms purchasing EGs in country j, and $1 - G(\overline{\varphi}_j)$ is the probability of purchasing EGs. Note that $M_j^e = [1 - G(\overline{\varphi}_j)]M_j$, where M_j is the total mass of firms in country j.

We assume that φ follows a Pareto distribution with a lower bound $\varphi_{\min}$ for the support of the productivity distribution and a shape parameter γ, such that $G(\varphi) = 1 - (\varphi/\varphi_{\min})^{-\gamma}$, and $g(\varphi) = \gamma\varphi_{\min}^{\gamma}\varphi^{-\gamma-1}$. Smaller values of the shape parameter γ correspond to greater dispersion in productivity. We assume that $\varphi_{\min} = 1$ without loss of generality, such that $\gamma > \eta/\alpha$ for the distribution of firm revenue associated with the use of EGs will have a finite mean. Using the Pareto productivity distribution assumption, A_j can be rewritten as follows:

$$A_j = \left(\frac{t_j}{z_j}\right)^{1/\alpha} \frac{\gamma}{\gamma - \eta/\alpha} \overline{\varphi}_j^{\eta/\alpha} M_j^e \tag{8}$$

where $(t_j/z_j)^{1/\alpha}\gamma(\gamma - \eta/\alpha)^{-1}\overline{\varphi}_j^{\eta/\alpha}$ can be viewed as the intensive margin (average demand)

and M_j^e as the extensive margin of imports, respectively.[7]

We have to determine M_j^e, $\overline{\varphi}_j$ and the total mass of firms in country j (denoted M_j). The free-entry condition in the downstream industry implies that $\pi_j(\upsilon) = 0$. Firms adopting an abatement technology have higher profits than do other firms, and firms enter the market as long as their profits without an abatement technology reach zero (we allow the two types of firms coexist in equilibrium). Hence, M_j is such that $p_j q_j = (\kappa_j^{-1} + t_j \xi_j) q_j(\upsilon) + f_j$. Using (1) and (4), the last equality becomes $p_j^{1-\varepsilon} P_j^{\varepsilon-1} E_j = \varepsilon f_j$. Because $P_j = M_j^{\frac{1}{1-\varepsilon}} p_j$, we obtain

$$M_j = E_j / \varepsilon f_j. \tag{9}$$

A manufacturer enters the "green market" as long as the expected value of entry is higher than the sunk cost of entry. The expected profit of a manufacturer prior to entering the green market is given by $[1 - G(\overline{\varphi}_j)]\pi_j^e$, where π_j^e is the expected profit associated with the use of EGs conditional on successful entry, and $1 - G(\overline{\varphi}_j) = \overline{\varphi}_j^{-\gamma}$. Because the *ex post* productivity distribution of firms purchasing the EG is $g(\varphi)/[1 - G(\overline{\varphi}_j)]$, using (6) we have

$$\pi_j^e = \int_{\overline{\varphi}_j}^{\infty} \psi(\varphi) \frac{g(\varphi)}{1 - G(\overline{\varphi}_j)} \mathrm{d}\varphi = \frac{\eta \phi_j}{\alpha\gamma - \eta}.$$

Because $\overline{\varphi}_j$ is such that $\overline{\varphi}_j^{-\gamma} \pi_j^e = f_e$, we obtain

$$\overline{\varphi}_j^{\gamma} = \frac{\eta/\alpha}{(\gamma - \eta/\alpha)} \frac{\phi_j}{f_e}. \tag{10}$$

Because $M_j^e = \overline{\varphi}_j^{-\gamma} M_j$, we obtain

$$M_j^e = \frac{(\gamma - \eta/\alpha)}{\eta/\alpha} \frac{f_e}{\phi_j} \frac{E_j}{\varepsilon f_j}. \tag{11}$$

Hence, by inserting (10) and (11) into (8), we obtain the aggregate demand for EGs:

$$A_j = z_j^{-1/\alpha} t_j^{1/\alpha} E_j \overline{\varphi}_j^{-(\gamma - \eta/\alpha)} \Lambda_j \tag{12}$$

with

$$\Lambda_j \equiv \frac{\gamma}{\gamma - \eta/\alpha} \frac{1}{\varepsilon f_j}$$

such that $A_j \to 0$ when $\overline{\varphi} \to \infty$. As expected, the aggregate demand for EGs depends positively on the tax rate and negatively on the price of the EG (z_j). However, we have to consider the

[7] In the literature, the term extensive margin refers to the growth in exports stemming from the emergence of new destinations (*e.g.*, Felbermayr and Kohler, 2006), new exported varieties (*e.g.*, Hummels and Klenow, 2005), or the participation of new firms in export markets (Chaney, 2008; Helpman *et al.*, 2008). Growth in trade at the intensive margin refers to an increase in the volume of trade between existing partners, in the volume of trade of existing varieties or in the export volume of firms currently engaged in export activities.

impact of the tax rate on price formation. As we will see below, the price of the EG increases with the tax rate, thus implying an ambiguous effect of the pollution tax rate on the demand for EGs.

2.2. Eco-industry (the upstream industry)

Each EG provider specializes in a type of pollution (an industry) that is specific to each industry. We consider a representative EG producer in each country. The EG producers serve each country j under oligopolistic competition. The profit of an EG supplier located in country i is given by $\pi_i = \sum_j \Pi_{ij}$, with

$$\Pi_{ij} \equiv (z_j - c_{ij})a_{ij} - F \tag{13}$$

where $c_{ij} \equiv \tau_{ij}/\theta_i$ is the marginal cost of serving market j, τ_{ij} is an iceberg trade cost between countries i and j, and θ_i is the productivity of the firm. F is the fixed cost of distributing and adapting to serve market j, and a_{ij} is the volume of the EG supplied by the firm. The EG provider sets its quantity a_{ij} knowing A_j (see (7)), but it does not internalize the impact of its choice on the mass of polluting firms purchasing EGs. The market clearing condition implies that $A_j = a_{ij} + \sum_k a_{kj}$, where a_{kj} is the supply of rivals located in country $k \neq i$. Using (7) implies

$$a_{ij} + \sum_k a_{kj} = \frac{\gamma}{\gamma - \eta/\alpha}\left(\frac{t_j}{z_j}\right)^{1/\alpha} M_j \overline{\varphi}_j^{-(\gamma-\eta/\alpha)}.$$

Equivalently, the inverse demand of country j is

$$z_j = t_j \Lambda_j^{\alpha}\left(a_{ij} + \sum_k a_{kj}\right)^{-\alpha}.$$

Maximizing Π_{ij} with respect to a_{ij} leads to

$$a_{ij} = \frac{m_{ij}}{\alpha z_j} A_j \quad \text{with} \quad m_{ij} \equiv z_j - c_{ij}$$

where a_{ij}/A_j is the share of imports of country j from country i, and m_{ij} is the margin of an exporter located in country i serving country j. As expected, this share and the margin decrease with bilateral trade costs (τ_{ij}) and increase with the productivity prevailing in the exporting country. As a result, bilateral trade volumes in EGs are higher between more industrialized countries.

Using the market clearing condition $A_j = \sum_k a_{kj}$ (including $k = i$), we obtain the equilibrium price:

$$z_j^* = \frac{N_j}{N_j - \alpha}\overline{c}_j \quad \text{with} \quad \overline{c}_j \equiv \frac{\sum_k \tau_{kj}/\theta_k}{N_j} \tag{14}$$

where $\overline{c}_j$ is the unweighted average cost to produce the EGs consumed in country j, and N_j is the number of firms (or trade partners) supplying the EGs consumed in country j. As expected, lower trade barriers, more producers, and high elasticity of demand for EGs (low α) reduce the price of EGs. Note that in a heterogeneous-cost Cournot oligopoly, total output A_j decreases with the average cost, regardless of the cost distribution, for a given number of firms (see Van Long and Soubeyran, 1997; Février and Linnemer, 2004). Consequently, under free entry, pollution taxation can also modify the average cost of a change in the number of firms and, thus, in the demand for EGs.

We now determine the number of firms (and the average cost of) supplying an abatement technology in country j. A supplier of EGs serves country j as long as $\Pi_{ij} \geq 0$ (equivalently, $c_{ij} \leq c_j^{\max}$):

$$c_j^{\max} \equiv z_j \left[1 - \left(\frac{\alpha F}{z_j A_j} \right)^{1/2} \right]. \tag{15}$$

The cutoff cost level $c_j^{\max}$ is defined as the level at which a firm would just stay in market j. In equilibrium, only firms with $c_{ij} \leq c_j^{\max}$ can stay in the market. Using (12), it is straightforward to check that $\partial c_j^{\max} / \partial t_j > 0$ for a given z_j. Hence, *ceteris paribus*, a higher tax burden in a country allows more firms with lower productivity to serve that market and, therefore, implies a higher average cost of $\bar{c}_j$. As a result, *a higher pollution tax rate has an ambiguous effect on the demand for environmental products* A_j. If the tax burden has a positive direct effect on the demand for EGs, there exists a negative indirect effect through an increase in the average marginal cost of production (and in the price of the EG).

Because the number of firms responds to a change in the tax burden, we need to specify the cost distribution c_{ij} to study the impact of t_j on z_j^*. We assume, without loss of generality, that the marginal production cost of the i^{th} firm serving country j is given by $c_{ij} = c_0 i^{\mu}$, with $c_0 > 0$ and $\mu > 0$. Hence, the supplier of EGs located in country j produces at the lowest marginal cost c_0, whereas the marginal cost of producing EGs is higher in country i. Consequently, if N_j producers of EGs serve country j, then the highest marginal cost is given by $c_j^{\max} = c_0 N_j^{\mu}$, and $\bar{c}_j = c_0 \frac{1}{N_j} \sum_{i=1}^{N_j} i^{\mu}$. From (14), it follows that $\partial z_j^* / \partial N_j > 0$, as long as the elasticity of the average cost to a change in the number of EG producers $((\partial \bar{c}_j / \partial N_j) \cdot (N_j / \bar{c}_j))$ is greater than $\alpha / (N_j - \alpha)$. In other words, such a configuration occurs when the cost distribution is not too concave (*i.e.*, when μ is not excessively low) and when the price elasticity of demand for a EG $(1/\alpha)$ is sufficiently high. Because the suppliers of EGs are heterogeneous in terms of their production costs, an increased number of firms has two opposite effects on equilibrium prices. On the one hand, more firms make competition tougher through more fragmented individual demand (A_j / N_j). On the other hand, less efficient firms can enter the market, thereby inducing a higher average cost. The net effect on equilibrium prices is positive when the cost distribution is not too concave. Using $\Pi_{ij}(c_j^{\max}) = 0$, we obtain

$$\frac{\partial N_j}{\partial t_j} = \frac{-\partial \Pi_{ij}(c_j^{\max})/\partial t_j}{(\partial \Pi_{ij}/\partial z_j)\cdot(\partial z_j/\partial N_j)}$$

where $\partial\Pi_{ij}/\partial t_j > 0$ (*via* an increase in A_j). Some standard calculations show that $\partial\Pi_{ij}/\partial z_j < 0$ when $c_{ij} < z_j(1-\alpha)/(1+\alpha)$. This condition holds when the price elasticity of demand for a EG ($1/\alpha$) is sufficiently high. Remember that when $1/\alpha$ is not excessively low, we also have $\partial z_j^*/\partial N_j > 0$. Hence, *an increase in the pollution tax rate can favor the entry of less efficient suppliers, thus implying an increase in the average cost and the equilibrium price of EGs* when the price elasticity of demand for an EG is not excessively low.

2.3. Environmental taxation and equilibrium trade

We are now equipped to study the impact of environmental taxation when the price of EGs adjusts to a change in the tax burden. The impact of the pollution tax rate on the demand for EGs is given by

$$\frac{\mathrm{d}A_j}{\mathrm{d}t_j} = \frac{A_j}{t_j}\cdot\frac{1-\varepsilon_{z,t}}{\alpha} \quad \text{with} \quad \left.\frac{\mathrm{d}^2 A_j}{\mathrm{d}t_j^2}\right|_{\varepsilon_{z,t}=1} = -\frac{A_j}{t_j}\cdot\frac{1}{\alpha}\cdot\frac{\mathrm{d}^2 z_j}{\mathrm{d}t_j^2}\cdot\frac{t}{z}$$

with $\varepsilon_{z,t} \equiv \frac{\mathrm{d}z_j}{\mathrm{d}t_j}\frac{t_j}{z_j} > 0$. Clearly, a higher tax burden increases the demand for EGs provided that the tax elasticity of the EG price ($\varepsilon_{z,t}$) is not excessively high. It follows that there exists a tax rate that maximizes the demand for the EG when the relationship between the price and the tax burden is positive and convex. In this case, there is a bell-shaped relationship between environmental taxation and demand for EGs. Starting from pollution tax rates, a higher tax burden increases demand for EGs. Above the cutoff tax rate, an increase in the price of EGs increases the tax burden and reduces demand for EGs. Hence, excessively high pollution tax rates can reduce bilateral trade in EGs because there are too many low-productivity entrants.

We have showed that a higher pollution tax rate favors the entry of new firms/countries and may reduce demand for EGs when the tax burden reaches high values. Consequently, the effect of tax rate on bilateral trade is ambiguous as

$$\frac{\mathrm{d}a_{ij}}{\mathrm{d}t_j} = \left(\varepsilon_{z,t}\frac{\alpha c_{ij}}{m} + 1 - \varepsilon_{z,t}\right)\frac{1}{\alpha}\cdot\frac{a_{ij}}{t_j}$$

which is positive if and only if

$$c_{ij} > \frac{\varepsilon_{z,t}-1}{\varepsilon_{z,t}(1+\alpha)-1} z_j(t_j)$$

It follows that exports from countries with low production costs decrease when the tax burden increases because new firms/countries serve the market. Even though the output sizes of low-production-cost countries attain high values, their market shares erode when the pollution tax rates increase.

3. Data and empirical strategy

The objective of our empirical application is to check the validity of our theory. More precisely, we test whether (i) a higher pollution tax rate increases the number of partner countries (a positive effect of environmental taxation on the extensive margin) and (ii) whether we observe a bell-shaped relationship between the pollution tax rate and bilateral trade in EGs (a non-linear effect of environmental taxation on the intensive margin).

3.1. Data description

Our study covers the period of 1995-2012. We examine the imports of the EU member states from their EU trading partners because data regarding environmental taxes are available for these countries. We describe our two main data sources about EGs trade and taxation. The description of the data used and descriptive statistics are presented in Appendix A.

There is no universally accepted definition of EGS. For example, there is no consensus with the WTO regarding the definition of EGS. The difficulty in reaching a consensus lies in the fact that some products are used for both environmental and non-environmental purposes. In addition, there is no guarantee that a product reported in an EGS list has a lower environmental impact than that of another product. Despite this difficulty, some organizations compile lists of environmental products that inform multilateral discussions. The lists composed by the APEC and OECD are used as references for EG classification. Based on the EU definition of EGs,[8] the OECD list developed in 1997 was brought up to date in 2012 and was established on the basis of general categories of goods and services used to measure, prevent and reduce environmental damage and to manage natural resources. It identifies EGs based on the HS6 trade nomenclature. However, this system does not allow the isolation of products that are used only for environmental purposes. The APEC list, which was created between 1998 and 2000, identifies EGs according to national customs nomenclatures using eight- or ten-digit codes. It is more pragmatic and more precise than the OECD list. Because of technological progress, no list can be exhaustive, and each must allow for regular updates. The goods referenced in the OECD and/or APEC lists include a wide variety of basic industrial products, such as valves, pumps and compressors, that can be specifically employed for environmental purposes. Table 1 reports the subgroups of EGs from these lists. Because we exclude services, our sample concerns 112

[8] See at http://ec.europa.eu/eurostat/statistics-explained/index.php/Environmental_goods_and_services_sector #Database).

Table 1: Sub groups of the Lists of EGs

		OECD List	APEC List
A	POLLUTION MANAGEMENT		
A1	Air pollution control	×	×
A2	Waste water management	×	×
A3	Solid waste management	×	×
A4	Remediation and cleanup	×	
A5	Noise and vibration abatement	×	×
A6	Environmental monitoring, analysis and assessment	×	×
B	CLEANER TECHNOLOGIES AND PRODUCTS		
B1	Cleaner/resource efficient technologies and processes	×	
B2	Cleaner/resource efficient products	×	
C	RESOURCES MANAGEMENT GROUP		
C1	Water supply	×	
C2	Renewable energy plant	×	×
C3	Energy/heat savings and management	×	×

Source: Steenblik (2005); Sugathan (2013).

HS6 products from the OECD list, 54 HS products from the APEC list. When we merge the two lists, we obtain a list of 138 HS6 products (also referred as a merged list hereafter). As shown in Table A1 reported in Appendix A, only 27 products are common to the two lists. The detailed lists of EGs are presented in Steenblik (2005) and Sugathan (2013).

The data comprise the bilateral trade flows of the EU member states and were collected at the HS6 level. Trade data regarding EGs were obtained from the UN Comtrade database. As mentioned in the introduction (see Figure 1), there was continuous growth in EG trade over this period, and there are no significant differences in trade in EGs between the APEC list and the OECD list. We provide additional summary statistics for the trade data in Appendix A. Note that even though the two lists are different, with one exception, the leading importing and exporting countries are the same (see Appendix B for more details).

We now describe our variables capturing environmental taxation. As defined by the EU, "*an environmental tax is one whose tax base is a physical unit (or a proxy of a physical unit) of something that has a proven, specific negative impact on the environment.*"[9] There are four types of environmental taxes: (i) energy taxes, (ii) transport taxes, (iii) pollution taxes and (iv) resource taxes. The EU data provide information regarding environmental taxation as *the ratio of total environmental tax revenue to GDP*for each EU member state. Descriptive statistics are reported in Table 2.[10]

[9]See http://ec.europa.eu/eurostat/web/environment/environmental-taxes

[10]Note that energy taxes represent the highest share of overall environmental tax revenue, accounting for approximately 75% of the EU-27 total in 2012 (see Table 2). The second-highest environmental tax revenues are from transport taxes, representing 20% of the EU-27 total in 2012. Pollution and resource taxes represent a small share (approximately 5%) of total environmental tax revenues (see Table 2). This category of taxes was implemented

Table 2: Statistics on environmental taxes within the EU-27 (in % of GDP)

	1995			2012		
	Pollution and resource taxes	Energy taxes	Total Environmental taxes	Pollution and resource taxes	Energy taxes	Total Environmental taxes
Mean	0.099	2.141	3.005	0.150	1.914	2.571
Variance	0.022	0.225	0.375	0.025	0.180	0.375
Minimum	0.000	1.520	2.200	0.010	1.270	1.570
Maximum	0.530	3.120	4.420	0.650	3.100	3.870

Source: Eurostat.

3.2. Empirical model of extensive margin

As previously mentioned, our theoretical model implies a positive relationship between environmental taxation t_j and the number of countries serving country j. There are different identification problems to address.

First, our dependent variable is a count variable bounded from below by zero and from above by the number of available trading partners. The doubly bounded nature of the data implies that the partial effects of the regressors on the conditional mean of the extensive margin (the dependent variable) cannot be constant and must approach zero as the conditional mean approaches its bound (Santos Silva *et al.*, 2014). Thus, standard count data estimators (such as the Poisson maximum likelihood estimator or the negative binomial estimator) may be unsuitable. These approaches ignore the upper bound of the number of trading partners. Therefore, we follow Santos Silva *et al.* (2014) and use a flexible specification that takes into account the doubly bounded nature of the data. Let $\overline{N}$ denote the maximum number of trading partners that can potentially serve each country and N_{jt} the number of countries serving country j in year t. It is possible to write the conditional expectation of the number of countries exporting to j as $E(N_{jt}|\boldsymbol{x}_{jt})$, where $\boldsymbol{x}_{jt}$ denotes a set of explanatory variables. By construction, $0 \leq N_{jt} \leq \overline{N}$; thus, the expected value of the number of countries exporting to j in year t can be expressed as

$$E(N_{jt}|\boldsymbol{x}_{jt}) = \overline{N} \times f\left(\boldsymbol{x}'_{jt}\boldsymbol{\beta}\right) \tag{16}$$

where $\boldsymbol{\beta}$ is a vector of parameters, $f\left(\boldsymbol{x}'_{jt}\boldsymbol{\beta}\right) = 1 - [1 + \lambda \exp\left(\boldsymbol{x}'_{jt}\boldsymbol{\beta}\right)]^{-\frac{1}{\lambda}}$ is the probability that a randomly drawn country will export to j, and $\lambda > 0$ is the shape parameter. The estimated model is

$$E(N_{jt}|\boldsymbol{x}_{jt}) = \overline{N}\left(1 - [1 + \lambda \exp\left(\beta_0 + \beta_1 t_{jt} + \boldsymbol{\beta}_2 \boldsymbol{W}_{jt}\right)]^{-\frac{1}{\lambda}}\right) \tag{17}$$

where t_{jt} is environmental taxation expressed as the revenue share of GDP, and $\boldsymbol{W}_{jt}$ is a set of control variables. In (17), the parameter of interest is β_1 for the environmental taxation variable,

more recently than the others in Europe.

which is expected to be positive.

Second, we have to control for taxes being endogenous (Tosun, 2013; Vollenweider, 2013; Castro, Hörnlein and Michaelowa, 2014; Harding *et al.*, 2016). We use the two-year lagged value of the environmental tax rate as an instrument. Durbin-Wu-Hausman tests reveal that these lagged values are exogenous with respect to current-period effects.

Third, our estimation includes various control variables ($\boldsymbol{W}_{jt}$). We introduce year-fixed effects. In addition, we have to control for time-varying, country-specific determinants. Because countries differ in terms of the global tax burden imposed on industries, the effect of a given change in environmental taxation may vary across countries. To control for international differences in terms of business taxation, we introduce a measure of total tax income less environmental tax income as a share of GDP. Indeed, a high global tax burden can make firms more sensitive to changes in environmental taxation. In other words, national industries facing the same level of environmental taxation may exert different pollution abatement effort because their global tax burden differs.

We also consider the number of international environmental agreements (IEAs) signed by a country as a proxy of environmental regulation stringency, which could determine the demand for EGs in the country. Compliance with IEAs requires more stringent domestic policy. Thus, having signed an IEA signals high environmental sensibility and a government's willingness to harmonize its environmental policy with international standards to make it more effective (Rose and Spiegel, 2010; Vollenweider, 2013), thus implying higher demand for EGs. However, stringent domestic policy could be linked to the ability of the domestic industry to comply with the policy. In this case, stringent domestic policy reveals that the country has a competitive advantage in producing EGs (Steinberg and VanDeveer, 2012; Birkland, 2014), so stricter environmental policy does not imply more imports of EGs.[11] Because of these two potential effects, we do not have expectations regarding the sign of the estimated coefficient of this variable. We also control for the possibility that the number of IEAs is endogenous (Simmons, 2010; Tosun, 2013; Vollenweider, 2013; Castro *et al.*, 2014). Following Egger *et al.* (2011), we use the GDP per capita, land area, trade openness index and share of EG production (from the APEC and OECD lists) in total industrial production as instruments.[12]

Furthermore, to control for the potential demand for EGs from the importing countries, we consider public expenditures on environmental protection as a control variable.[13] As shown by Costantini and Mazzanti (2012), investments in innovation boost exports of EGs. By intro-

[11]Note also that following the Porter hypothesis, more stringent domestic policy could enhance innovation, which may in turn improve the competitiveness of domestic firms (Ambec *et al.*, 2013; Rubashkina *et al.*, 2015).

[12]Land area and the share of EGs in total industrial production have a positive impact on the number of treaties, whereas trade openness has a negative impact. These results are available upon request.

[13]These data are available from EUROSTAT (http://appsso.eurostat.ec.europa.eu/nui/show.do?).

ducing public expenditures on environmental protection, we control for domestic policies that could boost domestic eco-industries (a supply-side effect) and/or demand for EGs. We have no expectation about the sign of the coefficient associated with the latter variable. We also introduce a variable *Eurozone* that takes the value 1 for a destination country in the eurozone.

3.3. Empirical model of the intensive margin

We derive a gravity-type trade equation (Anderson and van Wincoop, 2003). From the framework developed in Section 2, we use the value of the total output of country i given by $Y_i = \sum_j z_j a_{ij}$ with $z_j a_{ij} = \frac{1}{\alpha} m_{ij} A_j$. In equilibrium, Y_i equals the total sales to all destination countries j, such that

$$Y_i = \Pi_i / \alpha \tag{18}$$

where $\Pi_i \equiv \sum_j m_{ij} A_j$ can be interpreted as an "outward multilateral resistance" (see Anderson, 2010). By inserting (11), (14), (18) and (10) into (12), we obtain the export sales of EGs:

$$z_j a_{ij} = \frac{Y_i E_j}{\Pi_i \left[z_j^*(t_j) \right]^{\frac{1}{\alpha}}} \overline{\varphi}_j^{-(\gamma - \eta/\alpha)} \Lambda_j t_j^{1/\alpha} m_{ij}(t_j) \tag{19}$$

Equation (19) provides the bilateral trade equation to be estimated. This trade equation shares some similarities with the standard gravity model of bilateral trade flows (Anderson, 2010). The level of imports is a function of the sizes of exporting country (through Y_i) and of importing country (through E_j). Furthermore, as in Anderson and Yotov (2010), Π_i captures outward multilateral resistance (OMR). In addition, because $z_j^* = N_j \overline{c}_j / (N_j - \alpha)$, with $\overline{c}_j = (\sum_k \tau_{kj}/\theta_k)/N_j$, $\overline{c}_j$ can be viewed as inward multilateral resistance (IMR). [14] The OMR subsumes the impact of outward policies frictions and technologies available in the downstream industry, and affects the probability of using an abatement technology. The IMR consistently aggregates inward frictions and subsumes the impact of international technology available in the eco-industry, and affects the probability of using an abatement technology and, thus, of demanding EGs.

However, our equation (19) differs from the standard gravity model. First, in the case of EGs, we cannot only use national income E_j because the size of the market for EGs also depends on environmental regulations and the share of firms purchasing EGs. This is why our gravity equation considers environmental taxation in addition to income. Second, as shown above, the relationship between the export sales of EGs and the pollution tax rate prevailing in the importing country is non-log-linear in equilibrium. Recall that the standard gravity model specifies

[14] The OMR indexes are defined as if the sellers in each country shipped to a single world market, whereas the IMR indexes are defined as if buyers in each country imported from a single country. The two indexes consistently aggregate bilateral trade costs and decompose their incidence on producers and consumers. See Anderson (2010), Anderson and Yotov (2010) and Olivero and Yotov (2012) for further discussions.

bilateral trade as a log-linear function of the income of the two trading partners. This second difference arises from the fact we use a Cournot model instead of monopolistic or perfect competition models.[15] In our framework, the markup over the marginal cost ($m_{ij}(t_j)$) is not constant but instead depends on environmental taxation. It follows that bilateral trade is not a log-linear function of the environmental tax rate.

Therefore, we estimate a reduced-form equation (19):

$$a_{ijt} = \alpha_1 t_{jt} + \alpha_2 t_{jt}^2 + \boldsymbol{\rho} \boldsymbol{X}_{ijt} + \epsilon_{ijt} \tag{20}$$

where a_{ijt} is the bilateral trade value in year t, t_{jt} is the environmental taxation expressed as the environmental tax revenue share of GDP (as mentioned above), $\boldsymbol{X}_{ijt}$ is a vector of control variables, and ϵ_{ijt} is a mean-zero disturbance term. Regarding the extensive margin model, we control for the possibility that taxes are endogenous using the two-year lagged value of taxes as an instrument. Because we introduce tax variables as simple and squared values, we test the hypothesis of a non-linear relationship between environmental taxation and bilateral trade in EGs.

Santos Silva and Tenreyro (2006) suggest the use of a Poisson pseudo-maximum likelihood (PPML) procedure to estimate the multiplicative form of the gravity equation. They showed that the PPML procedure yields consistent estimates in the presence of heteroskedasticity. We estimate a multiplicative form of the gravity equation using the PPML estimator with Eicker-White robust standard errors to consistently estimate equation (20).

The vector of control variables $\boldsymbol{X}_{ijt}$ includes the business tax burden, which is measured as total tax revenues minus environmental tax revenues as a percent of GDP, the numbers of IEAs signed by the origin country and the destination country, and public expenditures on environmental protection in the origin and destination countries (for the same reasons as explained for the extensive margin). As for the extensive margin model, we control for the possibility that the number of IEAs is endogenous. We expect a positive effect of the number of IEAs and public expenditures on environmental protection on the intensive margin.

We also consider the variables suggested in the literature about gravity models (Anderson and van Wincoop, 2004; Head and Mayer, 2013) for country pairs: distance, common legal system and shared borders. Furthermore, the *Eurozone* variable takes the value 1 if the (origin or destination) country is in the eurozone, and the *Productivity* variable measures the (log) value of output per worker in the manufacturing sector in the destination and origin countries to capture the economic performance of the countries and, thus, implicitly of the downstream industry.

Finally, we include exporter-, importer-, and year-fixed effects, and the standard errors are clus-

[15] In the standard approach, the price paid by the end consumer is the factory-gate price times a trade cost.

tered by country pair. Because our key variable (t_{jt}) varies both over time and across countries, we cannot include time-varying exporter or importer fixed effects.[16] To check the robustness of our results, we use alternative specification to control for the presence of unobserved time-invariant bilateral factors that influence the relationship (Baier and Bergstrand, 2007; Raimondi *et al.*, 2012; Fally, 2015).[17]

4. Empirical results

4.1. The extensive margin of trade

The results of the model of the extensive margin of trade are reported in Table 3, while Table 4 reports the average marginal effect of environmental taxation. Our results suggest that increasing environmental taxation boosts the number of trading partners. Using the results of the estimations and the mean number of trading partners throughout the entire dataset, the increase in the number of trading partners following an increase in environmental taxation of 1 percentage point is 4.99%, 4.85% and 5.11% for the APEC, OECD and merged lists, respectively. An interesting result is the negative impact on the extensive margin of public expenditures on environmental protection and, when significant, the number of signed IEAs. These results suggest that these measures are oriented toward domestic industry or industries with old trading partners (see Table 3).

Table 3: Estimated results of the extensive margin model

	Estimated coefficients – Imports from EU partners (maximum = 27)					
	APEC List		**OECD List**		**Merged List**	
Variables	Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.
Environmental taxes (% of GDP)	0.304***	0.088	0.343***	0.104	0.391***	0.103
Total consumption of EGs	0.411***	0.087	0.410***	0.101	0.443***	0.091
Public expenditures in env. protection	-0.136***	0.043	-0.087**	0.043	-0.125***	0.045
Number of signed IEA	-0.06	0.041	-0.118***	0.043	-0.062	0.04
Non environmental taxes (%of GDP)	-0.009*	0.005	-0.017***	0.006	-0.017***	0.006
Belonging in Euro zone	-0.335***	0.08	-0.316***	0.095	-0.361***	0.086
Number of observations	268		268		268	
Log pseudo-likelihood (R-squared)	-71.54 (0.93)		-66.18 (0.95)		-64.32 (0.96)	

*Notes: ***, **, * indicate significance at 1%, 5% and 10% respectively. Estimates of fixed effects omitted for brevity. s.e.: standard errors.*

[16] See, *e.g.*, Novy (2013) and Fally (2015) for recent applications and Head and Mayer (2013) for an overview.

[17] Using panel data, this would help solve problems associated with omitted variables bias (Martıinez-Zaroso *et al.*, 2009).

Table 4: Average marginal effect of environmental taxation

	APEC List		OECD List		Merged List	
Estimator	Marginal effect	s.e.	Marginal effect	s.e.	Marginal effect	s.e.
Imports from EU partners (maximum = 27)	1.058***	0.194	1.035***	0.173	1.095***	0.171

*Notes: ***, **, * indicate significance at 1%, 5% and 10% respectively. s.e.: standard errors computed using the Delta method.*

4.2. The intensive margin of trade

The results of our estimations are presented in Table 5. Columns 1 and 2 report the results for the EG lists of APEC and the OECD, respectively. Column 3 presents the estimation results for the merged list; column 4 lists the results for N-EGs. Finally, in columns 5 and 6, we report the results of the estimations when we consider bilateral trade in *all* goods without environmental variables. Our preferred sample includes only the EGs included in the APEC list, as this list is more precise than that of the OECD.

Standard gravity variables. The effects of the standard variables on bilateral trade (distance, contiguity, and common legal system) are as expected. The estimated coefficients associated with distance are similar to those reported in the literature (*e.g.*, Head and Mayer, 2013; Tsurumi *et al.*, 2015; He *et al.*, 2015). However, our results indicate that the magnitude of the coefficient associated with distance is greater for trade in N-EGs than that for trade in EGs. This finding can be explained by the relatively high concentration of the eco-industry (Nimubona, 2012; Tamini and Sorgho, 2018), thus implying lower substitution capabilities between countries of origin. Having a common legal system has a positive and significant impact on the intensity of trade. The coefficient associated with *contiguity* is non-significant, which indicates that a common border does not have an impact on the intensity of trade within the EU. The same result holds for being in the eurozone. The results presented in column 6 indicate that the coefficients associated with non-environmental variables do not vary significantly, thus implying that the inclusion of environmental variables does not alter the quality of the model.

Environmental taxation. Our results confirm the impact of environmental taxation on trade when trade in the EGs included in the APEC list is considered. Whereas the coefficients are significant for the APEC list, this is not the case for the OECD list (no coefficients are significant). This result seems to confirm that the OECD list of EGs is not sufficiently precise. For the APEC list of EGs, a non-monotonic, bell-shaped relationship between environmental taxes and trade is confirmed. The coefficient associated with environmental taxation is positive, whereas its squared value is negative. The cutoff tax rate is 4.03% ($= -\frac{(-9.67)}{2\times(-0.12)}$). Above this threshold, a higher pollution tax rate reduces bilateral trade in EGs. The estimated marginal effect of tax rate within our dataset is represented in Figure 2. It follows that for a large majority of countries, a marginal increase in environmental taxation would increase their imports of EGs because they are still on the increasing segment of the bell-shaped curve.

Table 5: Results of the estimations of the trade intensity model of EGs at aggregated level

		(1) **APEC List**		(2) **OECD List**		(3) **Merged List**	
Variables		Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.
Country of destination	Environmental taxes	0.967***	0.265	0.293	0.237	0.507**	0.217
	Environmental taxes - Squared	-0.121***	0.044	-0.026	0.039	-0.058*	0.034
	Number of signed IEA	0.005	0.353	0.801***	0.264	0.461*	0.270
	Log public expenditures	0.046	0.061	0.119**	0.057	0.120*	0.062
	Non environmental taxes	0.043***	0.015	-0.021*	0.012	0.008	0.015
	Log productivity	-0.322*	0.173	0.002	0.124	-0.166	0.149
	Euro zone (=1)	-0.343	0.234	0.056	0.086	-0.117	0.171
Country of origin	Number of signed IEA	-0.026	0.484	-0.166	0.353	-0.015	0.350
	Log public expenditures	-0.044	0.066	0.136**	0.057	0.063	0.058
	Log productivity	0.656***	0.178	0.446***	0.129	0.530***	0.134
	Euro zone (=1)	0.008	0.122	0.086	0.082	-0.000	0.077
Log distance		-0.824***	0.141	-0.909***	0.099	-0.911***	0.102
Contiguity		-0.007	0.103	0.003	0.069	-0.009	0.073
Common legal system		0.401***	0.090	0.472***	0.071	0.448***	0.073
Treaty in common		0.219*	0.128	0.376***	0.107	0.297***	0.100
Common language		-0.090	0.134	-0.082	0.112	-0.085	0.117
Fixed effects	Country of origin	Yes		Yes		Yes	
	Country of destination	Yes		Yes		Yes	
	Year	Yes		Yes		Yes	
Number of observations		4,198		4,198		4,198	
Clustering by country pair		Yes (524)		Yes (524)		Yes (524)	
Log pseudo-likelihood (R-squared)		-3.548e+0.7 (0.923)		-4.221e+0.7 (0.954)		-5.518e+0.7 (0.945)	

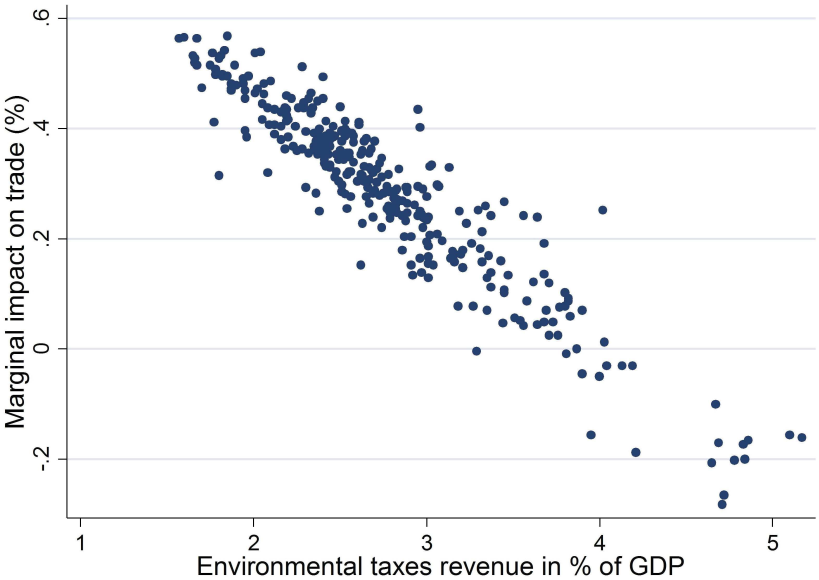
*Notes: ***, **, * indicate significance at 1%, 5% and 10% respectively. Estimates of fixed effects (country of origin, country of destination, year) are omitted for brevity. s.e.: standard errors.*

Table 5 *(cont'd)*

Variables		(4) **N-EGs** Coefficient	s.e.	(5) **All goods** Coefficient	s.e.	(6) **All goods** Coefficient	s.e.
Country of destination	Environmental taxes	0.174	0.212	0.189	0.208		
	Environmental taxes - Squared	-0.013	0.035	-0.015	0.034		
	Number of signed IEA	0.630**	0.278	0.625**	0.275		
	Log public expenditures	0.151***	0.034	0.150***	0.033		
	Non environmental taxes	-0.004	0.004	-0.003	0.004		
	Log productivity	0.172*	0.092	0.157*	0.088	0.345***	0.091
	Euro zone (=1)	0.103	0.065	0.090	0.069	0.045	0.064
Country of origin	Number of signed IEA	0.286	0.316	0.272	0.069		
	Log public expenditures	0.081*	0.042	0.078*	0.041		
	Log productivity	0.608***	0.098	0.601***	0.097	0.731***	0.090
	Euro zone (=1)	0.091	0.066	0.088	0.065	0.068	0.066
Log distance		-1.078***	0.072	-1.075***	0.071	-1.071***	0.072
Contiguity		0.087	0.065	0.081	0.064	0.071	0.065
Common legal system		0.450***	0.056	0.450***	0.056	0.483***	0.055
Treaty in common		0.177**	0.084	0.184**	0.083		
Common language		-0.056	0.094	-0.056	0.095	-0.051	0.095
Fixed effects	Country of origin	Yes		Yes		Yes	
	Country of destination	Yes		Yes		Yes	
	Year	Yes		Yes		Yes	
Number of observations		4,198		4,198		4,198	
Clustering by country pair		Yes (524)		Yes (524)		Yes (524)	
Log pseudo-likelihood (R-squared)		-7.314e+08 (0.966)		-7.612 e+08 (0.967)		-7.809e+08 (0.965)	

*Notes: ***, **, * indicate significance at 1%, 5% and 10% respectively. Estimates of fixed effects (country of origin, country of destination, year) are omitted for brevity. s.e.: standard errors.*

Figure 2: Marginal impact (in %) of environmental taxation – APEC List of EGs



It is also worth stressing that environmental taxation does not have a significant impact on trade in N-EGs. This suggests that our proxy (environmental taxation income) can be used as a measure of environmental taxation policy.

Public expenditure on environmental protection and signed international environmental agreements. We now discuss the effects of the other variables relative to the other environmental tools. The coefficients associated with the number of *IEA* in force in the destination and origin countries are positive but non-significant for the APEC list. As mentioned above, stringent domestic policy may reveal the competitive advantage of the destination country (Steinberg and VanDeveer, 2012; Birkland, 2014). When we consider the EGs on the OECD list, the number of IEAs in force in the destination country has a positive and significant effect on bilateral trade in EGs. However, the coefficient is also positive and significant for N-EGs. These results suggest that the number of *IEAs* in force may capture the competitiveness of countries producing not only EGs but also N-EGs, even if we control for productivity in the estimation.

Similarly, public expenditures on environmental protection as a percentage of GDP in the destination country have a non-significant impact on trade in EGs of the APEC list, whereas their impact is positive and significant when considering the OECD list and N-EGs. Hence, public expenditures on environmental protection as a percentage of GDP capture the effects of omitted variables. However, because the definition of EGs on the APEC list is more precise, we can conclude that public expenditures on environmental protection do not distort trade flows of EGs. Indeed, if the expenditures on environmental protection in the country of destination (origin) favor the growth of the domestic eco-industry at the expense of foreign eco-industries, we should observe a negative (positive) impact on bilateral trade in EGs. In contrast, a high non-environmental tax burden in the destination country seems to discourage the development of domestic eco-industry and to favor imports of EGs. However, as expected, the magnitude of its effect on trade is much lower than the environmental taxation effect.

Robustness check If we control for the multilateral resistance indices by introducing the standard set of exporter-time and importer-time fixed effects in our re-estimations, those fixed effects absorb the key variables of interest. However, failure to account for the time-varying resistances may mean that the current results are biased. As a robustness check, we estimate alternative specifications of the equation of trade. The results are reported in Table 6. In the first column (specification [**I**]), we employ a two-stage estimation procedure, where in the first stage, we use country-pairs and importer and exporter time-varying fixed effects; in the second stage, we use the estimates of the fixed effects as dependent variable, where the regressors include the country-specific policy variables of interest (see Fally, 2015). In the second column (specification [**II**]), we estimate the intensive margin model using country-pairs fixed effects and exporter time-varying fixed effects, whereas the importer fixed effects do not vary with time. Our estimations indicate that, overall, the results regarding environmental taxation are robust even if the absolute values of the coefficients are smaller.

Intensity of trade by subgroups of EGs on the APEC list. We use the APEC list of EGs to identify subgroups of products (see Table 2). We have six subgroups: air pollution control; waste water management; solid waste management; environmental monitoring, analysis and assessment + noise and vibration abatement; renewable energy plants; and energy/heat savings and management. To avoid endogeneity issues in taxes, we still use global environmental taxes instead of using specific taxes related to each subset.[18] We do not use specific environmental taxes related to a subgroup of EGs because our estimations may be plagued by reverse causality running from trade to taxation policy. We expect that the global environmental tax burden affects disaggregated trade patterns but not necessarily the reverse. Table 7 reports the results of the estimations.

For most of the subgroups of EGs, the structural variables (distance, contiguity, common legal system, and being in the eurozone) have signs and magnitudes and similar to those reported in the literature (Head and Mayer, 2013).

[18]It is energy taxes for trade in EGs in the energy sector ("renewable energy plant" and "energy/heat savings and management" in Group C of Table 1), pollution and resource taxes for the pollution management group ("air pollution control", "waste water management", "solid waste management", "environmental monitoring, analysis and assessment + noise and vibration abatement" in Group A of Table 1).

Table 6: Results of the estimations of alternative specifications of APEC list of EGs

		specification [I]		specification [II]	
Variables		Coefficient	s.e.	Coefficient	s.e.
Country of destination	Environmental taxes	0.653***	0.243	0.817***	0.242
	Environmental taxes - Squared	-0.081***	0.043	-0.090**	0.039
	Number of signed IEA	-0.426	0.289	-0.003	0.276
	Log public expenditures	0.066	0.051	0.110**	0.054
	Non environmental taxes	0.045***	0.014	0.048***	0.013
	Log productivity	-0.206	0.171	-0.182	0.147
	Euro zone (=1)	0.159	0.184	-0.279	0.193
Country of origin	Number of signed IEA	0.174	0.411		
	Log public expenditures	0.024	0.048		
	Log productivity	0.762***	0.208		
	Euro zone (=1)	-0.105	0.113		
Log distance		-0.318	0.530	-2.473***	0.111
Contiguity		3.160***	0.432	-0.093	0.132
Common legal system		-0.813	0.699	0.721***	0.137
Treaty in common		0.832	0.827	0.180*	0.112
Common language		-0.779**	0.383	0.947***	0.154
Fixed effects	Country of origin	Yes		Yes	
	Country of destination	Yes		Yes	
	Year	Yes		Yes	
Number of observations		4,198		4,198	
Clustering by country pair		Yes (524)		Yes (524)	
Log pseudo-likelihood (R-squared)		-10.23 e+06 (0.973)		-13.321 e+06 (0.974)	

*Notes: † squared term. ***, **, * indicate significance at 1%, 5% and 10% respectively. Estimates of fixed effects (country of origin, country of destination, year) are omitted for brevity. s.e.: standard errors.*

The bell-shaped curve of the relationship between environmental taxation and demand for EGs is observed for the following subgroups: “waste water management”, “solid Waste management”, “renewable energy plant” and “energy/heat savings and management”. The estimated marginal effect of the tax rate within our dataset is represented in Figure 3.

For the “air pollution control” and “environmental monitoring, analysis and assessment + noise and vibration abatement” subgroups, the estimated coefficients associated with environmental taxation have the expected signs, but at least one of them is non-significant.

Table 7: Results of the estimations of the trade intensity model of EGs at disaggregated level

		(1) **Air pollution control**		(2) **Waste water management**		(3) **Solid waste management**	
Variables		Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.
Country of destination	Environmental taxes	0.675	0.454	0.886**	0.372	1.274***	0.401
	Environmental taxes - Squared	-0.089	0.070	-0.146**	0.067	-0.149**	0.067
	Number of signed IEA	0.239	0.690	0.519	0.345	0.732*	0.377
	Log public expenditures	0.109	0.150	0.074	0.057	-0.006	0.377
	Non environmental taxes	-0.000	0.016	-0.002	0.008	-0.018	0.014
	Log productivity	-0.387	0.245	-0.191	0.159	-0.192	0.239
	Euro zone (=1)	-0.225	0.183	-0.045	0.086	0.134	0.105
Country of origin	Number of signed IEA	0.227	0.955	-0.387	0.496	0.370	0.737
	Log public expenditures	0.111	0.134	0.120	0.079	-0.171	0.109
	Log productivity	0.112	0.532	0.305*	0.178	0.350	0.258
	Euro zone (=1)	0.280	0.185	0.018	0.108	-0.175	0.274
Log distance		-0.751***	0.146	-0.837***	0.131	-1.006***	0.125
Contiguity		0.042	0.129	0.067	0.078	0.041	0.108
Common legal system		0.570***	0.101	0.507***	0.082	0.298***	0.105
Treaty in common		0.213	0.157	0.304***	0.105	0.289*	0.169
Common language		0.177	0.159	-0.019	0.123	-0.005	0.175
Fixed effects	Country of origin	Yes		Yes		Yes	
	Country of destination	Yes		Yes		Yes	
	Year	Yes		Yes		Yes	
Number of observations		4,198		4,198		4,198	
Clustering by country pair		Yes (524)		Yes (524)		Yes (524)	
Log pseudo-likelihood (R-squared)		-6.997e+06 (0.875)		-4.359e+06 (0.960)		-9.971e+06 (0.911)	

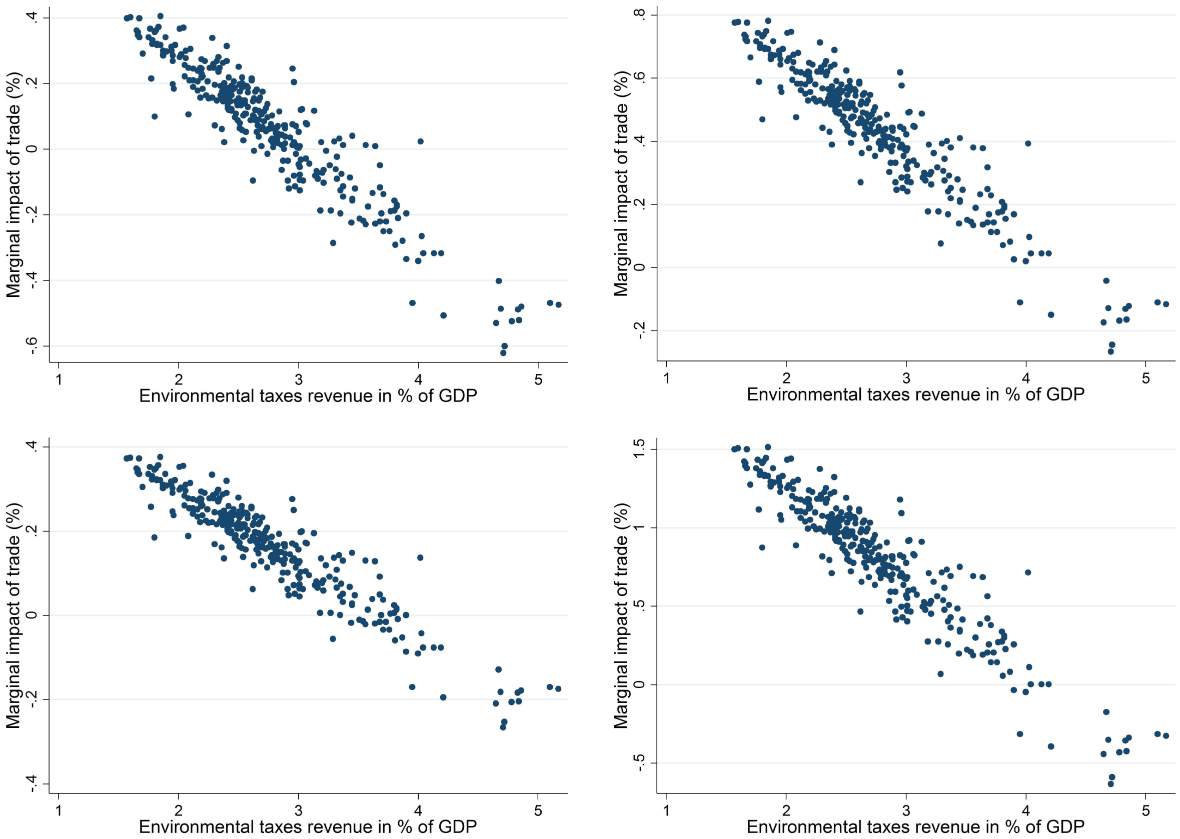
*Notes: ***, **, * indicate significance at 1%, 5% and 10% respectively. Estimates of fixed effects (country of origin, country of destination, year) are omitted for brevity. s.e.: standard errors.*

Table 7 *(cont'd)*

Variables		(4) **Environmental monitoring, analysis and assessment + noise and vibration abatement**		(5) **Renewable energy plant**		(6) **Energy/heat savings and management**	
		Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.
Country of destination	Environmental taxes	0.677*	0.364	0.700	0.507	2.519***	0.581
	Environmental taxes - Squared	-0.091	0.058	-0.076	0.078	-0.305***	0.095
	Number of signed IEA	0.613	0.405	-0.577	0.704	0.769	1.160
	Log public expenditures	-0.013	0.089	0.375**	0.173	-0.111	0.181
	Non environmental taxes	-0.024**	0.011	0.151***	0.038	0.023	0.026
	Log productivity	0.075	0.233	-1.089***	0.417	0.650*	0.384
	Euro zone (=1)	0.019	0.090	0.055	0.191	-2.295***	0.485
Country of origin	Number of signed IEA	-0.875	0.629	1.947**	0.807	-4.490***	1.338
	Log public expenditures	0.089	0.083	-0.172	0.143	-0.261	0.184
	Log productivity	0.861***	0.201	0.390	0.455	1.437***	0.489
	Euro zone (=1)	0.295**	0.150	-0.104	0.177	0.047	0.185
Log distance		-0.606***	0.157	-1.094***	0.251	-0.719***	0.275
Contiguity		-0.024	0.099	-0.122	0.166	-0.260	0.241
Common legal system		0.476***	0.100	0.300**	0.151	0.848***	0.230
Treaty in common		0.400***	0.147	0.062	0.183	-0.325	0.317
Common language		-0.219	0.135	-0.099	0.227	-0.175	0.289
Fixed effects	Country of origin	Yes		Yes		Yes	
	Country of destination	Yes		Yes		Yes	
	Year	Yes		Yes		Yes	
Number of observations		4,198		4,198		4,198	
Clustering by country pair		Yes (524)		Yes (524)		Yes (524)	
Log pseudo-likelihood (R-squared)		-1.275e+07 (0.945)		-2.440e+07 (0.790)		-4.967e+06 (0.825)	

*Notes: ***, **, * indicate significance at 1%, 5% and 10% respectively. Estimates of fixed effects (country of origin, country of destination, year) are omitted for brevity. s.e.: standard errors.*

Figure 3: Marginal impact (in %) of environmental taxation on trade of subgroup of products of the APEC List of EGs



4.3. Decomposing import adjustments along the intensive and extensive margins

We evaluate the expected change in aggregate imports, and its decomposition into extensive and intensive margins due to a change in the environmental tax rate t_{jt}. The expected change can be written as follows

$$A^e_{jt} - A_{jt} = N^e_{jt}\overline{a}^e_{jt} - N_{jt}\overline{a}_{jt}$$

where A_{jt} is the observed aggregate imports (for a given destination-year pair) and $\overline{a}_{jt}$ is the observed average import (at the destination-year pair level) with $A_{jt} = N_{jt}\overline{a}_{jt}$, while N^e_{jt} and $\overline{a}^e_{jt}$ are the expected number of trade partners and the expected average imports, respectively, if the level of environmental taxation prevailing in destination country j takes a new value (with $A^e_{jt} = N^e_{jt}\overline{a}^e_{jt}$). Aggregate imports can be decomposed into the number of trade partners that trade with country j N_{jt} – the extensive margin – and the average value of imports per destination-year $\overline{a}_{jt}$ – the intensive margin. Indeed, the expected change is also given by

$$A^e_{jt} - A_{jt} = \underbrace{N^e_{jt}\left(\overline{a}^e_{jt} - \overline{a}_{jt}\right)}_{\text{Intensive Margin}} + \underbrace{\overline{a}_{jt}\left(N^e_{jt} - N_{jt}\right)}_{\text{Extensive Margin}}$$

so that

$$\frac{A_{jt}^e - A_{jt}}{A_{jt}} = \frac{N_{jt}^e}{N_{jt}} \left(\frac{\overline{a}_{jt}^e - \overline{a}_{jt}}{\overline{a}_{jt}} \right) + \frac{N_{jt}^e - N_{jt}}{N_{jt}}$$

with

$$\frac{\overline{a}_{jt}^e}{\overline{a}_{jt}} = e^{\widehat{\alpha}_1 (t_{jt}^e - t_{jt}) + \widehat{\alpha}_2 [(t_{jt}^e)^2 - t_{jt}^2]} \quad \text{and} \quad \frac{N_{jt}^e}{N_{jt}} = \frac{1 - \left[1 + \widehat{\lambda} \exp\left(\widehat{\beta}_0 + \widehat{\beta}_1 t_{jt}^e + \widehat{\beta}_2 \boldsymbol{W}_{jt}\right)\right]^{-\frac{1}{\widehat{\lambda}}}}{1 - \left[1 + \widehat{\lambda} \exp\left(\widehat{\beta}_0 + \widehat{\beta}_1 t_{jt} + \widehat{\beta}_2 \boldsymbol{W}_{jt}\right)\right]^{-\frac{1}{\widehat{\lambda}}}}$$

where $\widehat{\lambda} = 0.201$. We consider two counterfactual scenarios. Using the results associated with the APEC list, we evaluate the expected change in aggregate imports if all countries apply an environmental tax rate equal to the minimum observed tax rate ($t_{jt}^e = \min t_{jt}$) and to the "optimal" taxation rate ($t_{jt}^e = 4.029$). It follows that applying an environmental tax rate equal to the minimum observed tax rate would induce a decrease of 54 percentage points of trade of EGs, while trade would experience an increase of 22 percentage points if applying the "optimal" taxation rate. Our counterfactual analysis also suggests that the effect of a change in environmental taxation on imports is primarily driven by the extensive margin. For example, if all countries apply an environmental tax rate equal to the minimum observed tax rate ($t_{jt}^e = \min t_{jt}$), the average decrease in imports can be decomposed into a 77% decrease at the extensive margin and a 33% decrease at the intensive margin.

5. Concluding remarks

Promoting the use of environmental technologies is expected to bring economic and environmental benefits worldwide. Thus, the acceleration of trade in EGs is at the heart of the sustainable development strategy of the EU. Policymakers and academics paid much attention to the impact of lower tariffs on trade in EGs, but the literature is silent regarding the impact of environmental policies on trade in EGs. However, higher emission tax rates could make the use of EGs or clean technologies more attractive to polluting firms, thus increasing their willingness to pay for EGs. It is expected that more stringent environmental policies would induce a higher demand for EGs and, possibly, favor international trade of EGs.

In this paper, we theoretically and empirically studied the impact of environmental taxation on trade in EGs. To reach our goal, we first developed a trade model in which the demand and supply of EGs are endogenous and adjust to the pollution tax rate. In accordance with empirical evidence, we assume that the suppliers of EGs are heterogeneous and operate under imperfect competition. Our theory reveals that (i) a higher pollution tax rate increases the number of partner countries (a positive effect of environmental taxation on the extensive margin) and (ii) there is a bell-shaped relationship between the pollution tax rate and bilateral trade in EGs (non-linear effect of environmental taxation on the intensive margin). Our empirical results confirm our main findings using data for the EU-27 countries when considering the APEC list of EGs. If we consider the OECD list of EGs, our results associated with the extensive margin hold, whereas the environmental tax policy has no effect on the intensive margin. However, the results obtained with the OECD list of EGs are very similar to the results when we consider non-EGs. This suggests that the OECD list of EGs, which is less restrictive than the APEC list, is not sufficiently precise to identify EGs.

References

Ambec, S., Cohen, M. A., Elgie, S., Lanoie, P. (2013). The Porter hypothesis at 20: can environmental regulation enhance innovation and competitiveness? *Review of Environmental Economics and Policy* 7(1): 2-22.

Anderson, J.E. (2010). The incidence of gravity. In *The gravity model in international trade. Advances and applications*. Edited by P.A.G. van Bergeijk and S. Brakman. Cambridge University Press: 71-87.

Anderson, J. E., van Wincoop, E. (2003). Gravity with gravitas: A solution to the border puzzle. *American Economic Review* 93(1): 170-192.

Anderson, J. E., van Wincoop, E. (2004). Trade costs. *Journal of Economic Literature* 42(3): 691-751.

Anderson, J. E., Yotov, Y.V., (2010). The Changing incidence of geography. *American Economic Review* 100(5): 2157-86.

Avery, B., Boadu, F. O. (2004). Global demand for US environmental goods and services. *Journal of Agricultural and Applied Economics* 36(01): 49-64.

Baghdadi, L., Martinez-Zarzoso, I., Zitouna, H. (2013). Are RTA agreements with environmental provisions reducing emissions?. *Journal of International Economics* 90(2): 378-390.

Baier, S. L., Bergstrand, J. H. (2007). Do free trade agreements actually increase members'international trade? *Journal of International Economics* 71(1): 72-95.

Baumol, W. J. (1995). Environmental industries with substantial start-up costs as contributors to trade competitiveness. Annual *Review of Energy and the Environment* 20: 71-81.

Becker, R. A., Shadbegian, R. J. (2008). The green industry: An examination of environmental products manufacturing. US Census Bureau Center for Economic Studies Paper No. CES-WP-08-34, available at https://www2.census.gov/ces/wp/2008/CES-WP-08-34.pdf.

Birkland, T. A. (2016). *An introduction to the policy process: Theories, concepts and models of public policy making*. Routledge.

Canton, L., Soubeyran, A., Stahn H. (2008). Environmental taxation and vertical cournot oligopolies: how eco-industries matter. *Environmental and Resource Economics* 40(3): 369-82.

Castro, P., Hörnlein, L., Michaelowa, K. (2014). Constructed peer groups and path dependence in international organizations: The case of the international climate change negotiations. *Global Environmental Change* 25: 109-120.

Chaney, T. (2008). Distorted gravity: the intensive and extensive margins of international trade. *American Economic Review* 98(4): 1707-1721.

Cole, M. A., Elliott, R. J. (2003). Determining the trade-environment composition effect: the role of capital, labor and environmental regulations. *Journal of Environmental Economics and Management* 46(3): 363-383.

Copeland, B., Taylor, M.S.. (2004). Trade, growth and the environment. *Journal of Economic Literature* 42(1): 7-71.

Costantini, V., Crespi, F. (2008). Environmental regulation and the export dynamics of energy technologies. *Ecological Economics* 66(2-3): 447-460.

Costantini, V., Mazzanti, M. (2012). On the green and innovative side of trade competitiveness? The impact of environmental policies and innovation on EU exports. *Research Policy* 41(1): 132-153.

David, M., Nimubona, A-D., Sinclair-Desgagne, B. (2011). Emission taxes and the market for abatement goods and services. *Resource and Energy Economics* 33(1): 179-191.

David, M., Sinclair-Desgagne, B. (2010). Pollution abatement subsidies and the eco-industry. *Environmental and Resource Economics* 45(2): 271-282

Fally, T. (2015). Structural gravity and fixed effects. *Journal of international economics* 97(1): 76-85.

Felbermayr, G.J., Kohler, W. (2006). Exploring the intensive and extensive margins of world trade. *Review of World Economy* 142(4): 642-674.

Février, P., Linnemer, L. (2004). Idiosyncratic shocks in an asymmetric Cournot oligopoly. *International Journal of Industrial Organization* 22(6): 835-848.

Frankel J.A., Rose, A.K., (2005). Is trade good or bad for the environment? Sorting out the causality. *Review of Economics and Statistics* 87(1): 85-91.

Greaker, M., Rosendahl, K. E. (2008). Environmental policy with upstream pollution abatement technology firms. *Journal of Environmental Economics and Management* 56(3): 246-259.

Harding, M., Vollebergh, H., Sen, S. (2016). Energy taxation in OECD countries: effective tax rates across countries, users, and fuels. In *The Economics and Political Economy of Energy Subsidies*: 41-59.

He, Q., Fang, H., Wang, M., Peng, B. (2015). Trade liberalization and trade performance of environmental goods: evidence from Asia-Pacific economic cooperation members. *Applied Economics* 47(29): 3021-3039.

Head, K., Mayer, T. (2002). Illusory border effects: distance mismeasurement inflates estimates of home bias in trade. Centre d'Etudes Prospectives et d'Informations Internationales (CEPII). Working Paper No. 2002-01, available at http://www.cepii.fr/PDF_PUB/wp/2002/wp2002-01.pdf.

Head, K., Mayer T. (2013). Gravity equations: workhorse, toolkit, and cookbook. In *Handbook of International Economics* Vol. 4, eds. Gopinath, Helpman,and Rogoff, North Holland: 135-195.

Helpman, E., Melitz, M.J., Rubinstein, Y. (2008). Estimating trade flow: trading partners and trading volumes. *Quarterly Journal of Economics* 123(2): 444-487.

Hummels, D., Klenow, P.J., (2005). The variety and quality of nation's exports. *American Economic Review* 95(3): 704-723.

Kreickemeier, U., Richter, P. M. (2014). Trade and the environment: The role of firm heterogeneity. *Review of International Economics* 22(2): 209-225.

Letchumanan, R., Kodama, F. (2000). Reconciling the conflict between thepollution-haven'hypothesis and an emerging trajectory of international technology transfer. *Research Policy* 29(1): 59-79.

Levinson, A. (2009). Technology, international trade, and pollution from US manufacturing. *American Economic Review* 99(5): 2177-2192.

Lovely, M , Popp, D. (2011). Trade, technology, and the environment: Does access to technology promote environmental regulation? *Journal of Environmental Economics and Management* 61(1): 16-35.

Managi, S., Hibiki, A., Tsurumi, T., (2009). Does trade openness improve environmental quality? *Journal of Environmental Economics and Management* 58(3): 346-363.

Martínez-Zarzoso, I., F. Nowak-Lehmann, D., Horsewood, N. (2009). Are regional trading agreements beneficial? Static and dynamic panel gravity models. *North American Journal of Economics and Finance* 20(1): 46-65.

Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica* 71(6): 1695-1725.

Muradian, R., O'Connor, M., Martinez-Alier, J. (2002). Embodied pollution in trade: estimating the 'environmental load displacement' of industrialised countries. *Ecological Economics* 41(1) 51-67.

Nimubona, A. D. (2012). Pollution policy and trade liberalization of environmental goods. *Environmental and Resource Economics* 53(3): 323-346.

Novy, D. (2013). International trade without CES: Estimating translog gravity. *Journal of International Economics* 89(2): 271-282.

OECD [Organization of Economic Cooperation and Development]. (2006). Étude sur la politique commerciale, Biens et services environnementaux. Pour une ouverture des marchés au service de l'environnement et du développement. Paris, France, available at http://www.oecd-ilibrary.org/fr/trade/biens-et-services-environnementaux_9789264026018-fr.

Olivero, M. P., Yotov, Y. (2012). Dynamic gravity: theory and empirical implications. *Canadian Journal of Economics* 45(1): 64-92.

Perino, G. (2010). Technology diffusion with market power in the upstream industry. *Environmental and Resource Economics* 46(4): 403-428.

Perino, G., Requate, T. (2012). Does more stringent environmental regulation induce or reduce technology adoption? when the rate of technology adoption is inverted u-shaped. *Journal of Environmental Economics and Management* 64(3): 456-467.

Raimondi V., Scoppola M., Olper, A. (2012). Preference erosion and the developing countries exports to the EU: a dynamic panel gravity approach, *Review of World Economics* 148(4): 707-732.

Rose, A.K., Spiegel, M.M. (2010). International arrangements and international commerce. In *The Gravity Model in International Trade*. Advances and Aplications. Ed. P.A.G van Bergeijk et S. Brakman. Cambridge University Press, Cambridge, UK: 255-277.

Rubashkina, Y., Galeotti, M., Verdolini, E. (2015). Environmental regulation and competitiveness: Empirical evidence on the porter hypothesis from european manufacturing sectors. *Energy Policy* 83: 288-300.

Santos Silva, J. M. C., Tenreyro, S. (2006). The log of gravity. *Review of Economics and Statistics* 88(4): 641-658.

Santos Silva, J.M.C., Tenreyro, S., Wei, K. (2014). Estimating the extensive margin of trade. *Journal of International Economics* 93(1): 67-75.

Sauvage, J. (2014). The Stringency of Environmental Regulations and Trade in Environmental Goods. OECD Working Paper, 2014-03, available at http://www.oecd-ilibrary.org/fr/trade/the-stringency-of-environmental-regulations-and-trade-in-environmental-goods_5jxrjn7xsnmq-en.

Schwartz, S., Stahn, H. (2014). Competitive permit markets and vertical structures: the relevance of imperfectly competitive eco-industries. *Journal of Public Economic Theory* 16(1): 69-95.

Simmons, B. (2010). Treaty compliance and violation. *Annual Review of Political Science* 13: 273-296.

Sinclair-Desgagné, B. (2008). The environmental goods and services industry. *International Review of Environmental and Resource Economics* 2(1): 69-99.

Steinberg, P. F., VanDeveer, S. D. (2012). *Comparative environmental politics: theory, practice, and prospects*. MIT Press.

Tamini, L.D., Sorgho, Z. (2018). Trade in Environmental Goods: Evidences from an Analysis Using Elasticities of Trade Costs. *Environmental and Resource Economics* 70(1): 53-75.

Tosun, J. (2013). Environmental policy change in emerging market democracies: Eastern Europe and Latin America compared. University of Toronto Press.

Tsai, T. H., Tu, K. I., Chiou, J. R. (2015). Tariffs and environmental taxes in the presence of environmental R&D. *Environmental and Resource Economics* 60(3): 413-431.

Tsurumi, T., Managi, S., Hibiki, A. (2015). Do Environmental Regulations Increase Bilateral Trade Flows?. *The BE Journal of Economic Analysis & Policy* 15(4): 1549-1577.

Van Long, N., Soubeyran, A. (1997). Cost heterogeneity, industry concentration and strategic trade policies. *Journal of International Economics* 43(1-2): 207-220.

Vollenweider, J. (2013). The effectiveness of international environmental agreements. *International Environmental Agreements: Politics, Law and Economics* 13(3): 343-367.

Appendix A Data description and sources

This study covers the period 1995-2012. The data comprise bilateral trade flows of EU-27 members and were collected at the HS-6 digit level. Trade data on EGs are obtained from the UN Comtrade database[19] referring to the EGs lists proposed by APEC and OECD. EGs trade is defined at the six-digit level using the harmonized system (HS6). As we exclude services, our sample concerns 112 goods for the OECD list, 54 for the APEC one and 138 for the composite list (see Table A1).

Table A1: Number of goods of APEC and OECD "adjusted" Lists of environmental goods

	Number of tariff lines (HS6 digit)
OECD's list	112
APEC 2012' list	54
Composite list	138
Overlap of the two lists	27

Previous studies have found that trade elasticities with respect to transport cost and other transaction cost variables are sensitive to the method used to proxy transport cost (Head and Mayer, 2002). We use the following indicator suggested by Head and Mayer (2002) to proxy transport cost:

$$d_{ij} = \sum_{g \in i} \left(\sum_{h \in j} \omega_h d_{gh} \right) \omega_g$$

where d_{gh} is the distance between the two sub-regions $g \in i$ and $h \in j$, while ω_g and ω_h represent the economic activity share of the corresponding sub-region. The *Centre d'Études Prospectives et d'Informations Internationales (CEPII)* uses the above formula to create a dataset. Data on language, legal system and sharing a common border also come from the CEPII database. Total consumption (expenditure?) on EGs is calculated using the following formula:

$$y_j = Production_j - Exports_j + Imports_j$$

where, for country j, $Production_j$ is industrial production in the EGs sector, $Exports_j$ are total exports of EGs and $Imports_j$ are total imports of EGs. Data on production come from United Nations Industrial Development Organization (UNIDO) Statistical Databases.[20] Our dataset for environmental treaties is constructed using the Environmental Treaties and Resource Indicators

[19] Data on trade were collected using World Integrated Trade Solution (WITS) software (See http://wits.worldbank.org/wits/).

[20] See at https://stat.unido.org/ [Accessed March 2, 2015] and the concordances at http://unstats.un.org/unsd/cr/registry/regot.asp?Lg=1 [Accessed January 25, 2015] and http://wits.worldbank.org/wits/product_concordance.html [Accessed January 25, 2015].

Table A2: Summary statistics of data for two selected years

Variables			2003 Mean	Std. Dev.	Minimum	Maximum
Weighted distance		km	1.34E+03	6.72E+02	1.61E+02	3.38E+03
Common legal system		Yes=1; No=0	0.275	0.447	0	1
Contiguity		Yes=1; No=0	0.133	0.341	0	1
Number of IEA		Unity	13.625	7.992	6	34
Number of IEA in common		=1 if > median	0.704	0.457	0	1
Value of imports	APEC List	10^3 USD	1.13E+05	2.47E+05	3.80E-01	1.78E+06
	OECD List	10^3 USD	2.04E+05	4.34E+05	1.39E+00	3.35E+06
	Merged List	10^3 USD	2.48E+05	5.18E+05	5.15E+01	3.82E+06
Total workers in the manufacturing sector			1.63E+06	1.94E+06	3.67E+04	7.12E+06
Toal production in the manufacturing sector		10^3 USD	3.79E+08	4.30E+08	8.78E+06	1.50E+09
Public expenditure in environmental protection		% of GDP	0.633	0.335	0.26	1.54
Non environmental taxes		% of GDP	37.56	5.74	27.332	46.567
Member of Eurozone		Yes=1; No=0	0.75	0.434	0	1

Variables			2012 Mean	Std. Dev.	Minimum	Maximum
Weighted distance		km	1.42E+03	7.25E+02	1.61E+02	3.78E+03
Common legal system		Yes=1; No=0	0.259	0.439	0	1
Contiguity		Yes=1; No=0	0.095	0.294	0	1
Number of IEA		Unity	10.286	7.22	4	34
Number of IEA in common		=1 if > median	0.316	0.465	0	1
Value of imports	APEC List	10^3 USD	9.59E+04	3.06E+05	1.01E-01	3.40E+06
	OECD List	10^3 USD	1.60E+05	4.94E+05	9.10E-02	4.97E+06
	Merged List	10^3 USD	1.94E+05	6.18E+05	0.00E+00	6.10E+06
Total workers in the manufacturing sector			1.04E+06	1.42E+06	2.29E+04	6.56E+06
Toal production in the manufacturing sector		10^3 USD	2.78E+08	4.22E+08	3.70E+06	1.91E+09
Public expenditure in environmental protection		% of GDP	0.573	0.243	0.22	1.38
Non environmental taxes		% of GDP	33.161	5.914	24.627	43.506
Member of Eurozone		Yes=1; No=0	0.607	0.489	0	1

(ENTRI) dataset produced by Columbia University.[21] GDP, population, land area, trade openness index are collected from the World Development Indicators database of the World Bank.[22] Table A2 presents some descriptive statistics of the variables of interest.

[21]See at http://sedac.ciesin.columbia.edu/data/set/entri-treaty-status-2012/data-download.
[22]See at http://data.worldbank.org/data-catalog/world-development-indicators

Appendix B Leading importing and exporting countries

Table B1 presents the relative share of trade for the five leading importing and exporting countries, for the years 1995, 2003 and 2012 and when considering the APEC and OECD Lists as well as N-EGs. Panel **a** of Table B1 indicates that even if the two lists are different, at one exception, the same countries are represented. However, in 2012, the share of imports of the five main importers is about 55% when considering the APEC List of EGs, while it is about 60% for the OECD List of EGs and for N-EGs. Even if the difference is not important, the demand of EGs included in the APEC List is less concentrated. Panel **b** shows that the picture is different when considering the share of exports of the five leading countries: the share is higher, at 65%, for the two lists of EGs, while it is about 60% for N-EGs, indicating a higher concentration of exports. However, the main five leading importers are also leading exporters and in both cases the shares of imports and exports of the other countries of European Union (ROE) increase over time.

Table B1: Relative share of trade for the leading importing and exporting countries

Panel a : Imports	**1995**		**2003**		**2012**	
	Country code	Share	Country code	Share	Country code	Share
APEC List	DEU	17.87%	DEU	15.83%	DEU	19.3%
	FRA	13.69%	FRA	13.51%	FRA	12.01%
	ITA	10.42%	GBR	10.02%	GBR	9.07%
	GBR	10%	ITA	9.1%	ITA	7.8%
	ESP	7.36%	ESP	7.36%	NLD	6.72%
	ROE	40.66%	ROE	44.18%	ROE	45.1%
OECD List	DEU	18.71%	DEU	19.82%	DEU	20.38%
	FRA	12.86%	FRA	11.91%	ITA	11.61%
	ITA	11.7%	ITA	10.55%	GBR	10.29%
	GBR	10.35%	GBR	9.93%	FRA	9.82%
	ESP	7.3%	ESP	7.57%	NLD	6.24%
	ROE	39.08%	ROE	40.22%	ROE	41.66%
N-EGs	DEU	23.74%	DEU	19.13%	DEU	20.36%
	FRA	14.04%	FRA	11.79%	FRA	11.93%
	GBR	12.02%	GBR	11.62%	GBR	10.09%
	ITA	11.04%	ITA	9.47%	BEL	9.35%
	NLD	7.54%	BEL	8.92%	NLD	8.12%
	ROE	31.62%	ROE	39.07%	ROE	40.14%
Panel b : Exports	**1995**		**2003**		**2012**	
	Country code	Share	Country code	Share	Country code	Share
APEC List	DEU	35.89%	DEU	35.06%	DEU	34.17%
	ITA	13.98%	FRA	12.28%	FRA	10.33%
	FRA	12.06%	GBR	10.96%	GBR	9.1%
	GBR	9.32%	ITA	7.43%	ITA	6.28%
	NLD	6.08%	ESP	5.91%	NLD	5.83%
	ROE	22.66%	ROE	28.36%	ROE	34.29%
OECD List	DEU	38.79%	DEU	35.34%	DEU	36.35%
	GBR	11.39%	FRA	10.97%	ITA	8.08%
	FRA	11.38%	ITA	8.98%	GBR	7.44%
	ITA	9.54%	GBR	8.89%	FRA	6.88%
	NLD	6.38%	ESP	5.97%	NLD	6.53%
	ROE	22.51%	ROE	29.85%	ROE	34.71%
N-EGs	DEU	24.93%	DEU	23.31%	DEU	22.68%
	FRA	14.25%	FRA	12.38%	FRA	11.9%
	ITA	11.35%	GBR	9.47%	GBR	9.99%
	GBR	11.11%	ITA	8.75%	BEL	7.7%
	NLD	9.76%	BEL	8.61%	NLD	7.52%
	ROE	28.6%	ROE	37.48%	ROE	40.21%

Notes: DEU: Germany; FRA: France; GBR: Great Britain; ITA: Italy; NLD: Netherlands; BEL: Belgium; ROE: Rest of the EU.

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