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INTERNATIONAL TRADE OF ENVIRONMENTAL GOODS IN GRAVITY MODELS

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International trade of environmental goods in gravity models

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Table of Contents

List of Tables

List of Figures

Abstract

Environmental goods are goods used or produced by industry that reduce air and water pollution and optimize the use of resources in production. Despite six of the 17 UN Sustainable Development Goals explicitly calling for resilient and sustainable development, the diffusion of such goods is still low, especially in developing countries. Only sporadic research on the determinants of international trade of environmental goods is available. Based on the OECD classification of environmental goods, we fill this gap by adopting a gravity model, using trade data over a time span of 15 years from 1999 to 2014 across 71 countries. The central message of this paper is that innovation capacity and environmental regulatory stringency are key determinants of environmental goods trade. We specifically provide evidence that: 1) the international trade of environmental goods is likely to be promoted by increasing innovation capacity, and 2) a substitution effect exists between environmental regulatory stringency and the trade of environmental goods. In line with empirical literature on traditional gravity models, cultural ties, geographical proximity and financial uncertainty also play a role.

1 Introduction

The new Agenda 2030 contains environmental and climate change objectives. Sustainable Development Goal 12 focuses specifically on “responsible consumption and production”, while Sustainable Development Goal 13 promotes “tak[ing] urgent action to combat climate change and its impacts”. Whereas there is wide consensus on the need of coordinated action at global level to protect the environment and promote sustainability, the policymakers are still uncertain about the modalities for reconciling economic growth and environmental protection.

Measures to protect the environment often involve costs that can hamper the growth process of firms (Roesen and Guenther, 2015). The costs for environmentally friendly actions may displace investments of precious resources to buy inputs. The challenge is even more evident when we consider that other SDGs also refer to economic goals such as SDGs 8 “decent work and economic growth” and SDG 9 “industry, innovation and infrastructure”.

Policymakers face the challenge of simultaneously addressing different SDGs. Decision makers have to manage trade-offs and promote synergies across different goals; the search for synergies is particularly important from a policy perspective.

Countries in the process of transitioning towards higher income levels seek development paths that combine growth and environmental protection targets. One straightforward means for countries to combine economic growth and environmental protection is the production of environmental goods. The development of environmental goods in emerging markets would be an indication of an increasing interest of economic actors in sustainability and in the business opportunities environmental protection can stimulate.

As emphasized by Steenblik (2005, p. 6): “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. This includes cleaner technologies, products and services that reduce environmental risk and minimise pollution and resource use”. This definition was established by the OECD (Organisation for Economic Co-operation and Development)/Eurostat Informal Working Group, which inspired the classification of exports of environmental goods to facilitate the elaboration of a manual national statistical offices can use to measure their national environmental industries (Sugathan, 2013). Three categories emerge from this classification: 1) pollution management goods; 2) cleaner technologies and products; and 3) resource management groups.

This is a classification of environmental goods, including the intermediate and final goods used by industries to reduce pollution or more environmentally friendly final goods.

Other classifications have been introduced in the literature. For example, the objective of the APEC (Asia-Pacific Cooperation) classification is to identify industries in which the progressive reduction of tariffs could have a positive impact on trade and economic growth in the Asia-Pacific region. The World Bank (2008) has proposed a list of 43 climate friendly goods, including a variety of products such as solar collectors and system controllers, wind-turbine parts and components, stoves, grates and cookers and hydrogen fuel cells.

In this paper, we use the OECD classification of environmental goods because it was conceived for purposes that are more in line with the issues being investigated in the present study. Steenblick (2005, p. 5) claims that: "The OECD's interest in environmental goods and services arose as part of its work on environmental policy and industrial competitiveness". The relationship between environmental policy and industrial competitiveness plays a pivotal role in this paper.

Other classifications are not generally exhaustive. According to APEC[1], the APEC list of environmental goods is limited on purpose: "Since the aim of the APEC list was to obtain more favourable tariff treatment for environmental goods, APEC member economies limited themselves to considering only those specific goods that could be readily distinguished by customs agents and treated differently for tariff purposes. For this reason, issues related to "like products", products defined by particular processes or production methods, and products defined by their life-cycle impacts, were not addressed, with the result that some goods were left off the list that could be included on the OECD list". The different nature of the two lists is reflected in the very different lists of products. Only one-third of the APEC classification overlaps with that developed by the OECD (Sugathan, 2013).

The OECD's list is more suitable for conducting studies: "The OECD list was the result of an exercise intended to illustrate, primarily for analytical reasons, the scope of the "environment industry." The selection of categories of goods could therefore be broad, because there were no specific policy consequences of adding products to the list"[2]. The OECD's list has the widest coverage (151 unique HS codes vs 104 APEC products and 43 goods of the World Bank list).

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[1] http://egs.apec.org/more-articles/10-environmental-goods-a-comparison-of-the-oecd-and-apec-lists
[2] Ibid

The relevant literature includes studies that have used the OECD classification of exports of environmental goods in the context of quantitative and qualitative analyses. Blazejczak et al. (2009) predict the expenditure of environmental goods for Germany using a modelling exercise. Yoo and Kim (2011) analyse the benefits of improving market access for environmental goods in the Republic of Korea. Baltzen and Jensen (2015) conduct a similar exercise but take the impact of trade liberalization in environmental goods on low-income countries into consideration. Interestingly, they find that the impact on low-income countries is trivial. Tamini and Sorgho (2016) find similar results for a larger sample of 167 countries. Dutz and Sharma (2012) calculate the share of environmental goods in total exports for countries with different levels of income and find that environmental goods represent a non-trivial share of total exports in high-income countries. The Industrial Development Report (2016) reinforces the existence of a positive relationship between the levels of GDP per capita and exports per capita (United Nations Industrial Development Organization, 2016). Sauvage (2014) provides conceptual and empirical evidence that environmental policy positively affects countries' specialization in environmental products, but they do not provide econometric evidence. The most relevant literature in the field is Costantini and Crespi (2008) and Costantini and Crespi (2010) and Costantini and Mazzanti (2012), who study the determinants of bilateral trade flows of energy technology goods (in accordance with the OECD classification) between industrialized countries as exporters to all world countries as importers.

The present work supplements previous literature by analysing all categories of environmental goods included in the OECD's list and a more comprehensive dataset including bilateral trade flows of developed and developing countries and a more updated time coverage. The gravity model is one of the most successful empirical models in the literature (Anderson and van Wincoop, 2003). In the present study, we adopt this approach to enhance the traditional gravity model with variables related specifically to the environmental goods market. The results are relevant for the policy debate.

Section 2 introduces the methodology, Section 3 describes the data, Section 4 presents the results, Section 5 describes robustness tests and the final section concludes.

2 Methodology

The empirical model is borrowed from traditional literature on the gravity model and is enhanced using complementary strands of research. The equation is established as follows:

Equation 1:

$$EXP_{i,j,k,t} = \alpha + \beta_1 GDP_{i,t} + \beta_2 GDP_{j,t} + \beta_3 DIST_{i,j} + \beta_4 \frac{PATAPP_{i,t}}{PATAPP_{j,t}} + \beta_5 ENTAX_{j,t} + \beta_6 UNCER_{i,j,t} + \beta_7 z_{i,j} + u_i + u_j + F_t + \epsilon_{i,j,k,t}$$

where i is country i, j is country j, $EXP_{i,j,k,t}$ represents exports of environmental goods k from country i to country j in time t. GDP is gross domestic product. $DIST$ denotes the geographical distance between the most populated cities of countries i and j. These two variables translate into the economics domain of the traditional gravitational equation:

Equation 2:

$$GF = \frac{M_i * M_j}{D^2 i,j}$$

In Equation 2, the gravitational force is directly proportional to the masses of the objects (M_i and M_j) and indirectly proportional to the distance between them ($D^2_{i,j}$). In economics, the gravity model predicts bilateral trade flows based on sizes of the economies (often using GDP measurements) and distance between the two units (Tinbergen, 1962).

The underlying hypothesis is that exports from country i to country j increase when the capacity of countries to export and import increases (i.e. the size of GDP of both the importing and exporting countries), and decrease when transaction costs rise. Transaction costs in terms of transport costs are approximated by the distance between countries.

The block of variables *z* represents other "traditional" dummy variables introduced into gravity models representing shared borders, colony legacies and common language. The basic hypothesis is that closeness, common language and the perception of a common history reduce transaction costs (Anderson and van Wincoop, 2003).

The other three variables included in the equation represent the innovative part of the present study. The variable ($\frac{PATAPP_{i,t}}{PATAPP_{j,t}}$) denotes the impact of environmental innovation on exports. Innovation is represented by green patent applications. The rationale is that the magnitude of exports tends to be positively correlated to the exporter's innovation capacity and negatively correlated to the importing country's innovation capacity. The importer will tend to import more technologically intensive goods, including environmental goods, if its capacity to innovate is limited. Using micro data of firm exports and international patent activity, Chalioti et al. (2016) find that Greek innovative exporters, identified by their patent filing activity, have substantially higher export revenues. The variable ($UNCER_{i,j,t}$) represents uncertainty approximated by exchange rate volatility. Rahman and Serletis (2009) find that exchange rate uncertainty has a negative and significant effect on US exports. The present paper tests a similar hypothesis for the entire set of countries in our sample. The final interesting variable is ($ENTAX_{j,t}$), which represents environmental taxes. We test the Porter and van der Lynde hypothesis (1991) using this variable. We explore whether environmental regulations trigger countries' competitiveness[3]. We expect a negative sign for the coefficient (β_5), meaning that environmental taxes in the importing country generate a reduction in imports and stimulate domestic production of environmental goods.

The model is estimated using a fixed effects approach with country effects (μ_i) and (μ_j) and time annual fixed effects (F_t). The fixed effects approach adopted in this paper follows Anderson and van Wincoop (2003) on the basis of standard gravity models described in the literature, and differs from standard fixed effects models (Greene, 2003), assuming an unobservable component correlated to covariates (μ_{ij}). Data are transformed into log terms according to standard procedures in econometrics.

3 Data

This section presents the database used for the gravity model analysis and describes the computations of technological innovation and environmental policy variables for which the analyses were conducted to assess the drivers and market friction of trade in environmental goods.

The main data source for export data ($EXP_{i,j,k,t}$) is the International Trade Statistics database maintained by the United Nations Statistics Division. The advantage of this database is that it contains trade values up to the HS 6-digits disaggregated level for 170 countries since 1962, i.e. it presents a global picture of shifts in bilateral trade flows based on consistently compiled data of all available countries and not based on any estimation by the authors. Following Baldwin

[3] To test the Porter and van der Lynde hypothesis, Costantini and Mazzanti (2012) analyse whether an environmental tax in the exporting country stimulates firms' competitiveness and the volume of trade. In the present study, we apply the Porter and van der Lynde hypothesis, namely that an environmental tax in the importing country induces domestic firms to increase competitiveness and to gradually replace imports with local products.

and Taglioni (2006), the trade values denominated in US dollars are considered at current prices to attenuate any potential bias from deflation[4].

In line with previous literature (Anderson & van Wincoop, 2003; Helpman, Melitz & Rubinstein, 2008; Grosjean, 2011), a battery of country-specific conditions is controlled in the analysis. The Centre d' Etudes Prospectives et d'Informations Internationales (CEPII) database contains cross-sectional data of country-specific geographical conditions for each country pair, i.e. distance, common official language, contiguity and colonial ties. This allows us to assess any changes in bilateral trades that are attributable to country-specific geographical conditions and closed proximity advantages.

Green patent data is obtained from the OECD patent database, with coverage from 1999 to 2014 across 101 countries. Unlike traditional studies that use the absolute number of patent applications as a proxy for technological innovation, we measure the relative innovation indicator ($PATAPP_{i,j,t}$) for each country pair (i, j). The number of green patent applications is scaled by the number of total applications to account for country-size effect (Marinova & McAleer, 2003) (i) The environmental innovation indicator is measured in relative terms between the exporter and importer in each country pair to gauge the exporter's environmental innovation capacity in each bilateral trade flow.

With regard to the demand-side policy variable, the importing country's environment-related tax revenue ($ENTAX_{j,t}$) is derived from the OECD database with coverage from 1994 to 2014. Like the technological innovation variable, the environment-related tax revenue is scaled by GDP to account for the county-size effect. Recent literature (Andersson, 2017) uses econometric analyses to determine the significance of the institutional and policy context to explain environmental performance.

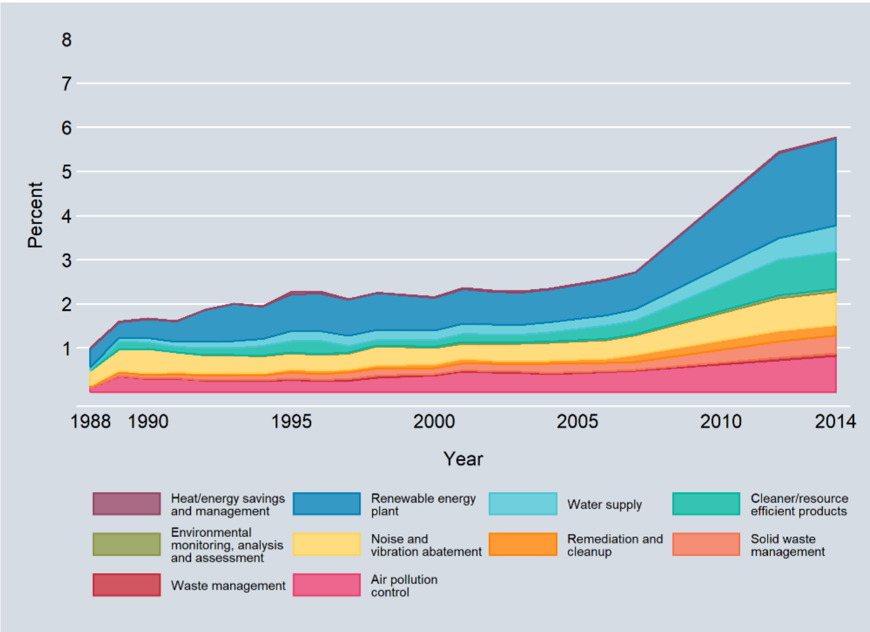
We follow Dell'Ariccia (1998) using relative exchange rate fluctuations ($UNCER_{i,j,t}$) in each of the bilateral trade flows to represent uncertainty in macroeconomics. The monthly exchange rate series can be found in the International Monetary Fund (IMF)'s International Financial Statistics (IFS) since 1955. The relative exchange rates are expressed in the exporting country's currency converted from exchange rates denominated in US dollars. Next, we measure the standard annual deviation based on monthly relative exchange rates' volatility for each of the country pairs across years.

[4] Inappropriate deflation creates biases via spurious correlations and for this reason, deflation is not adopted in the current study. Note, however, that time or country dummies replace deflation by capturing relevant effects (Baldwin and Taglioni, 2006).

Because the focus of this paper is on trade in environmental goods, we adopt the OECD classification of 151 environmental goods (OECD, 2005). The final panel sample covers 619,712 country-year observations from 2000 to 2014, across 38 developing countries and 33 developed countries[5] (see Appendix 1 for the list of countries). Descriptive statistics on environmental goods show that their share in exports has been increasing in both developed and developing countries. In 2014 alone, the share of environmental goods was around 8 per cent in developed economies and about 6 per cent in developing economies. The surge of renewable energy plants plays a major role in the growth of environmental goods in both country groups (Figure 1).

Figure 1 **Share of developing and developed countries in total environmental goods and share of each environmental goods category**

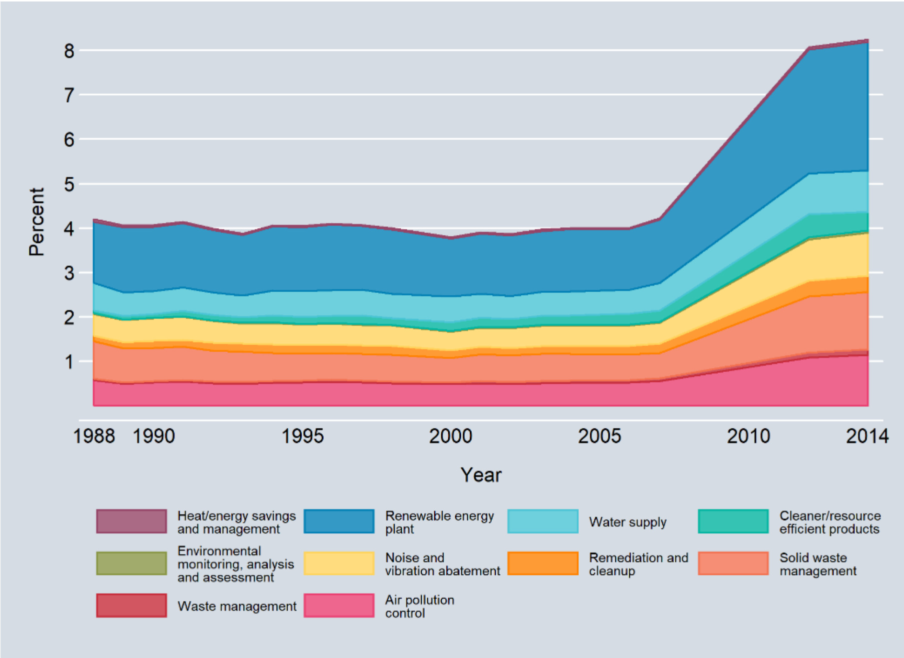
Figure 1a **Export shares of environmental goods in developing countries**



Source: Authors' elaboration based on UN Comtrade (2016), The World Bank (2016) and OECD (2005).
Note: income classification: The World Bank (2013), GNI per capita in US$ (Atlas methodology)

[5] Countries are classified as developing countries based on the World Bank Analytical Classifications (presented in the WDI), using GNI per capita in US$ (Atlas methodology) in 2013, excluding those countries which had a high income level during 1987–2013, for instance, American Samoa (1987–89) and Hungary (2008–11).

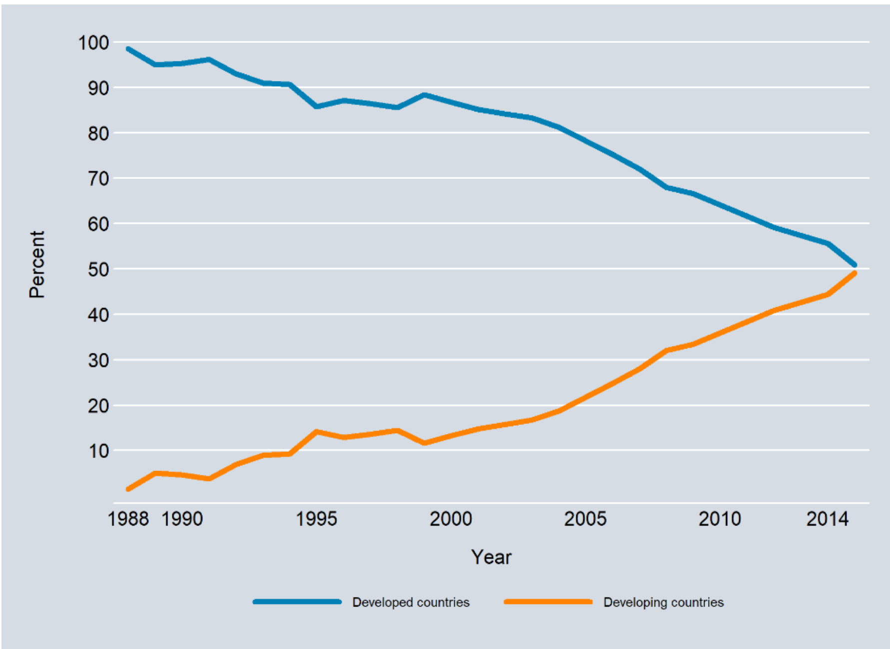
Figure 1b **Export share of environmental goods in developed countries**



Source: Authors elaboration based on UN Comtrade (2016), The World Bank (2016) and OECD (2005).
Notes: income classification: The World Bank (2013), GNI per capita in US$ (Atlas methodology)

Despite developed countries playing a dominant role in terms of share of environmental goods in total exports, developing countries are catching up.

Figure 2 **Share of developing and developed countries in total environmental goods**



Source: Authors elaboration based on UN Comtrade (2016), The World Bank (2016) and OECD (2005).
Notes: income classification: The World Bank (2013), GNI per capita in US$ (Atlas methodology).

4 Results

All of the coefficients' signs are in line with the hypotheses and are strongly significant with a 1 per cent significance level. The GDP of the importer and of the exporter ($GDP_{i,t}$ and $GDP_{j,t}$) have a positive coefficient meaning that bilateral trade exchange depends on the size of the economies involved. Transaction costs play a role in the trade of environmental goods. Countries struggle to market environmental goods when they are geographically distant ($DIST_{i,j}$) and are therefore more keen to trade environmental goods if they share a common language, if they have historical links and if they share a border. The capacity to innovate plays a role in explaining exchanges of technologically intensive goods such as environmental goods. The variable ($\frac{PATAPP_{i,t}}{PATAPP_{j,t}}$) shows a positive sign which reflects the higher capacity of those countries at the environmental technological frontier to export environmental goods and the need to import such goods by countries that are struggling to innovate. As expected, uncertainty ($UN \quad R_{i,j,t}$) proxied by exchange rate volatility plays a negative role in the international market and shows a negative sign. Interestingly, the variable ($ENTAX_{j,t}$) shows a negative sign. The importing country tends to import less environmental goods when environmental policies are introduced in the country. As a consequence of the introduction of domestic environmental taxes, the importing country does not respond by increasing imports of environmental goods but by increasing their domestic production. This finding is in line with the Porter and van der Lynde hypothesis and complements the findings of Sauvage (2014, p. 2) who claims that: "Regulatory stringency thus spurs the development of a market for a whole range of equipment specifically meant for preventing and abating pollution". The R^2 of the regression is 0.29 and satisfactory when compared to the standard econometrics literature. The results are quite similar for developed and developing countries. Former colonial ties and bilateral exchange rates are the only variables that are not significant for developing countries.

The dependent variable *export* is a log of export values of environmental goods from country i to country j denominated in US dollars (UN Comtrade, 2017). The main explanatory variables, *log (exporting country's GDP)* is the log of GDP of country i denominated in US dollars (World Bank, 2017), *log (importing country's GDP)* is the log of GDP of country j denominated in US dollars (World Bank, 2017), *log (environ. patents ratio)* is the log of the relative environmental pattern ratio of country i to country j (OECD, 2017), *log (importer environ. tax)* is the log of ratio of environmental tax revenues to GDP in country j denominated in US dollars (OECD, 2017), *log(distance)* is the log of the distance between the most populated cities in country i and country j denominated in kilometres (CEPII, 2017), *log (bilateral exchange rate)* is the log of the annual average volatility of monthly bilateral currency rates between country i and country j (IFS, 2017), *contiguity* is a dummy which equals 1 if country i and country j share a border and common language (CEPII, 2017), common official language is a dummy that equals 1 if country i and country j share an official or national languages and if the same language is spoken by at least 20 per cent of the population in the respective country (CEPII, 2017), colony is a dummy which equals 1 if country i and country j have colonial links (CEPII, 2017). The income classification is based on the World Bank (2013), GNI per capita in US$ (Atlas methodology) (see Appendix 1 for the list of countries).

Table 1 Results of the main regression results from the fixed effects model

VARIABLES	Fixed effects all countries	Fixed effects developed countries	Fixed effects developing countries
	(1)	(2)	(3)
log (exporting country GDP)	0.5289***	0.2593***	1.0435***
	(30.6721)	(10.9479)	(27.9749)
log (importing country GDP)	0.4150***	0.4107***	0.3659***
	(20.9314)	(17.6583)	(9.6478)
log (environ. patents ratio)	0.0908***	0.0365***	0.1195***
	(16.8718)	(5.0965)	(13.3952)
log (importer environ. tax)	-0.0529***	-0.0259*	-0.0787***
	(-3.9447)	(-1.6471)	(-3.0618)
log (distance)	-0.7731***	-0.7419***	-0.8780***
	(-154.4429)	(-129.0736)	(-77.0350)
log (bilateral exchange rate)	-0.0132***	-0.0193***	-0.0106
	(-2.7405)	(-3.0867)	(-1.3601)
Contiguity	0.9192***	1.0405***	0.6146***
	(54.4438)	(50.0715)	(19.6031)
Common official language	0.3801***	0.3724***	0.2655***
	(28.4768)	(21.5798)	(11.0438)
Colony	0.1856***	0.1992***	-0.0214
	(10.3552)	(10.1509)	(-0.4731)
Constant	-15.4977***	-8.8432***	-26.4089***
	(-23.0692)	(-10.1977)	(-20.0008)
Reporter dummy	Yes	Yes	Yes
Partner dummy	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes
Observations	619,712	429,737	189,975
R-squared	0.2933	0.2911	0.2680

Note: *t-statistics* in parentheses
*** p<0.01, two-tailed. ** p<0.05, two-tailed. * p<0.1, two-tailed.

5 Robustness tests

One possible bias that could affect the reliability of our results is endogeneity which arises when the explanatory variable is correlated with the error term. Possible causes of endogeneity can be misspecification (e.g. autocorrelation and heteroscedasticity) and the simultaneity bias. We use different methods to tackle each of these three issues.

For possible autocorrelation and heteroscedasticity, the paper adopts the Newey-West model by assuming first, second and third order autocorrelation (Wooldridge, 2008). By correcting for autocorrelation, the results in terms of significance and even magnitude are in line with those presented in Table 1.

For heteroscedasticity and simultaneity bias, we adopt the Hausmann-Taylor estimators inspired by the random effects model (Hausman and Taylor, 1981). The random effects model is an alternative to the fixed effects model presented in Table 1. The random effects model assumes the following Equation 3:

Equation 3:

$$EXP_{i,j,k,t} = \alpha + \beta_1 GDP_{i,t} + \beta_2 GDP_{j,t} + \beta_3 DIST_{i,j} + \beta_4 \frac{PATAPP_i}{PATAPP_j} + \beta_5 ENTAX_{j,t} + \beta_6 UNCER_{i,j,t} + \beta_7 z_{i,j} + u_i + u_j + F_t + \epsilon_{i,j,k,t}$$

where $u_{ij}$is the unobservable component and ($\epsilon_{i,j,k,t}$)are the idiosyncratic random effects. The random effects model assumes that all covariates are uncorrelated with the unobservable component (u_i & u_j) and ($\epsilon_{i,j,k,t}$). The Hausmann-Taylor specification corrects the random effects model in case of suspect violation of the hypothesis of uncorrelation between some of the covariates and the unobservable component (u_{ij}). The suspect endogenous variables are the GDP of the importer ($GDP_{i,t}$) and of the exporter ($GDP_{j,t}$) and the technological variable ($\frac{PATAPP_{i,t}}{PATAPP_{j,t}}$). It is plausible to deem these variables to not be truly exogenous variables (as requested by the Ordinary Least Squares basic assumptions) because the dependant variable (trade of environmental goods) may have an impact on these covariates. To mitigate this simultaneity bias for these variables, the Hausmann-Taylor approach is adopted. Other covariates are more unlikely to suffer simultaneity bias. Variables such as distance, colony, language, border or environmental taxes in the importing country are not affected by trade of environmental goods representing the dependant variable. The trade of environmental goods is also unlikely to significantly affect the bilateral exchange rate, which generally represents a small share of overall trade exchanges across countries. Table 3 shows that the results of the random effects model and of the Hausmann-Taylor estimation do not change considerably in terms of sign and magnitude compared with the results of Table 1. The only relevant exception is the relative patents variable for developed countries, which is not significant.

A third strategy to mitigate endogeneity and to test the robustness of results is to mitigate the potential simultaneity bias by lagging one period of the covariates (Cantore et al., 2016). The simultaneity bias is based on the bidirectional correlation between trade of environmental goods (dependant variable) and suspect endogenous covariates (GDP of the exporter and importer and the innovation variable in this paper). By lagging the suspect endogenous covariates one period, it is plausible to think that the trade of environmental goods at time (t) cannot affect the GDP of the importing country or the application of patents at time $(t - 1)$. The results contained in Table 4 support the hypothesis that the magnitude and signs contained in Table 1 are robust.

6 Conclusions

The 2030 Agenda calls for a strong and coordinated action of all countries to meet ambitious environmental targets. To be successful, the diffusion of environmental technologies to minimize the use of resources and to reduce pollution will be crucial.

Unfortunately, environmental goods still only represent a small market segment. This market's current size is not prepared to tackle the tremendous challenges of establishing a circular economy, economies' decarbonization and resource efficiency. It is therefore key to adopt the appropriate measures to promote the development and expansion of environmental goods.

This study is the first one to attempt to analyse the determinants of environmental goods trade and global diffusion. The results of our study show that the trade of environmental goods depends on the traditional variables that affect trade of other goods, namely GDP, transaction costs and uncertainty. What is unique about this market is the technological intensity of these goods and their link to environmental policy. Trade of environmental goods will be fostered through the strengthening of countries' innovation capabilities (related to education, infrastructure, etc. as discussed in the IDR 2016) and by opportune environmental policies. The endogenous technological change literature (e.g. Poop, 2004) shows that environmental policies can create the right incentives for producers and the necessary demands and domestic markets for cleaner technologies.

Table 2 Newey-West model with different lags

The dependent variable, export is the log of export values of environmental goods from country i to country j denominated in US dollars (UN Comtrade, 2017). The main explanatory variables, log (exporting country's GDP) is the log of GDP of country i denominated in US dollars (World Bank, 2017), log (importing country's GDP) is the log of GDP of country j denominated in US dollars (World Bank, 2017), log (environ. patents ratio) is the log of the relative environmental pattern ratio of country i to country j (OECD, 2017), log (importer environ. tax) is the log of the ratio of environmental tax revenues to GDP in country j denominated in US dollars (OECD, 2017), log(distance) is the log of the distance between the most populated cities in country i and country j denominated in kilometres (CEPII, 2017), log (bilateral exchange rate) is the log of the annual average volatility of monthly bilateral currency rates between country i and country j (IFS, 2017), contiguity is a dummy which equals 1 if country i and country j share a country border and common language (CEPII, 2017), common official language is a dummy which equals 1 if country i and country j share an official or national languages and languages spoken by at least 20 per cent of the population in the respective country (CEPII, 2017), colony is a dummy which equals 1 if country i and country j have colonial links (CEPII, 2017). Income classification is based on the World Bank (2013), GNI per capita in US$ (Atlas methodology) (see Appendix 1 for the list of countries).

VARIABLES	Newey-West lag (1) All countries	Newey-West lag (1) Developed countries	Newey-West lag (1) Developing countries	Newey-West lag (2) All countries	Newey-West lag (2) Developed countries	Newey-West lag (2) Developing countries	Newey-West lag (3) All countries	Newey-West lag (3) Developed countries	Newey-West lag (3) Developing countries
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
log (exporting country's GDP)	0.3831***	0.2754***	0.5416***	0.3831***	0.2754***	0.5416***	0.3831***	0.2754***	0.5416***
	(24.4416)	(13.3323)	(20.3024)	(22.7504)	(12.3422)	(19.1687)	(21.8208)	(11.8151)	(18.5456)
log (importing country's GDP)	0.6639***	0.7297***	0.4737***	0.6639***	0.7297***	0.4737***	0.6639***	0.7297***	0.4737***
	(67.8018)	(59.9847)	(26.9744)	(62.6976)	(55.1746)	(25.4812)	(59.1461)	(51.8653)	(24.4172)
log (environ. patents ratio)	0.1557***	0.1213***	0.1522***	0.1557***	0.1213***	0.1522***	0.1557***	0.1213***	0.1522***
	(29.1257)	(17.2389)	(16.4145)	(27.3096)	(16.1898)	(15.8311)	(25.9931)	(15.4233)	(15.3640)
log (importer environ. tax)	-0.1752***	-0.1703***	-0.2198***	-0.1752***	-0.1703***	-0.2198***	-0.1752***	-0.1703***	-0.2198***
	(-10.8698)	(-8.9847)	(-7.1928)	(-10.2529)	(-8.4548)	(-6.8457)	(-9.8550)	(-8.1111)	(-6.6293)
log (distance)	-0.7490***	-0.7199***	-0.8495***	-0.7490***	-0.7199***	-0.8495***	-0.7490***	-0.7199***	-0.8495***
	(-114.1186)	(-95.1971)	(-57.8828)	(-101.8416)	(-84.4311)	(-52.8426)	(-93.6600)	(-77.3248)	(-49.3574)
log (bilateral exchange rate)	-0.0217***	-0.0276***	-0.0114	-0.0217***	-0.0276***	-0.0114	-0.0217***	-0.0276***	-0.0114

	(-3.9528)	(-3.9341)	(-1.2939)	(-3.7532)	(-3.7607)	(-1.2244)	(-3.6101)	(-3.6206)	(-1.1803)
Contiguity	0.9912***	1.1374***	0.6731***	0.9912***	1.1374***	0.6731***	0.9912***	1.1374***	0.6731***
	(42.8712)	(39.9464)	(15.9524)	(38.1631)	(35.2720)	(14.4309)	(35.0357)	(32.2305)	(13.3793)
Common official language	0.4227***	0.3502***	0.3202***	0.4227***	0.3502***	0.3202***	0.4227***	0.3502***	0.3202***
	(25.0268)	(15.7273)	(10.6872)	(22.5232)	(14.0606)	(9.7656)	(20.8168)	(12.9437)	(9.1133)
Colony	0.1649***	0.1940***	-0.0471	0.1649***	0.1940***	-0.0471	0.1649***	0.1940***	-0.0471
	(7.0847)	(7.5167)	(-0.7885)	(6.3004)	(6.6467)	(-0.7159)	(5.7840)	(6.0840)	(-0.6653)
Constant	-18.4295***	-17.3500***	-16.8726***	-18.4295***	-17.3500***	-16.8726***	-18.4295***	-17.3500***	-16.8726***
	(-44.2784)	(-31.1265)	(-24.4393)	(-41.0529)	(-28.8667)	(-22.8183)	(-39.4100)	(-27.7463)	(-22.0120)
Reporter dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Partner dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	463,153	323,006	140,147	463,153	323,006	140,147	463,153	323,006	140,147

Note: *t-statistics* in parentheses
*** $p<0.01$, two-tailed. ** $p<0.05$, two-tailed. * $p<0.1$, two-tailed.

Table 3 Random effects model and Hausman Taylor estimation

The dependent variable *export* is the log of export values of environmental goods from country i to country j denominated in US dollars (UN Comtrade, 2017). The main explanatory variables, *log (exporter country GDP)* is the log of GDP of country i denominated in US dollars (World Bank, 2017), *log (importer country GDP)* is the log of GDP of country j denominated in US dollars (World Bank, 2017), *log (environ. patents ratio)* is the log of the relative environmental pattern ratio of country i to country j (OECD, 2017), *log (importer environ. tax)* is the log of ratio of environmental tax revenues to GDP in country j denominated in US dollars (OECD, 2017), *log(distance)* is the log of the distance between the most populated cities in country i and country j denominated in kilometres (CEPII, 2017), *log (bilateral exchange rate)* is the log of the annual average volatility of monthly bilateral currency rates between country i and country j (IFS, 2017), *contiguity* is a dummy which equals 1 if country i and country j share a country border and common language (CEPII, 2017), common official language is a dummy which equals 1 if country i and country j share an official or national languages and languages spoken by at least 20 per cent of the population in the respective country (CEPII, 2017), colony is a dummy which equals 1 if country i and country j have had colonial links (CEPII, 2017). The income classification is based on the World Bank (2013), GNI per capita in US$ (Atlas methodology) (please see Appendix 1 for the list of countries).

	Random effects	Random effects	Random effects	Hausman-Taylor Estimator	Hausman-Taylor Estimator	Hausman-Taylor Estimator
VARIABLES	All countries	Developed countries	Developing countries	All countries	Developed countries	Developing countries
	(1)	(2)	(3)	(4)	(5)	(6)
log (exporting country's GDP)	0.6773***	0.6671***	0.7314***	0.6862***	0.4889***	0.7905***
	(124.5446)	(99.8939)	(75.7860)	(68.5285)	(38.3452)	(39.6400)
log (importing country's GDP)	0.6011***	0.5604***	0.5853***	0.6422***	0.6948***	0.6735***
	(107.3856)	(82.9784)	(56.9079)	(62.6149)	(60.3563)	(28.3951)
log (environ. patents ratio)	0.1395***	0.0869***	0.1475***	0.0842***	0.0073	0.1408***
	(45.9397)	(22.2736)	(26.5717)	(22.1355)	(1.5209)	(20.7107)
log (importer environ. tax)	-0.0672***	-0.0504***	-0.1350***	-0.0543***	-0.0633***	-0.0594***
	(-7.9614)	(-5.1802)	(-8.3114)	(-5.4921)	(-5.7340)	(-2.8518)
log (distance)	-0.6300***	-0.5493***	-0.6669***	-0.8796***	-0.7691***	-1.3826***
	(-68.5525)	(-50.4107)	(-36.7144)	(-31.2043)	(-25.9005)	(-19.4684)

log (bilateral exchange rate)	-0.0119***	-0.0168***	-0.0166***	0.0031	-0.0100**	0.0205***
	(-3.5616)	(-4.1016)	(-2.8574)	(0.9300)	(-2.3899)	(3.4556)
Contiguity	0.6132***	0.8920***	0.4952***	0.9863***	1.4363***	-0.1116
	(15.7740)	(17.0370)	(8.3305)	(14.6591)	(17.4512)	(-0.8536)
Common official language	0.6064***	0.7674***	0.2942***	0.5135***	0.4135***	0.2493***
	(23.9009)	(23.6624)	(7.1127)	(11.3639)	(6.7259)	(3.2400)
Colony	0.3832***	0.3300***	0.1780*	0.2565***	0.2854***	0.1069
	(8.8134)	(6.6692)	(1.9327)	(3.9482)	(3.8273)	(0.7740)
Constant	-25.8818***	-25.0647***	-26.7591***	-25.6278***	-22.4508***	-24.4336***
	(-173.6602)	(-141.1845)	(-96.3828)	(-69.4829)	(-54.3482)	(-29.1239)
Reporter dummy	No	No	No	Yes	Yes	Yes
Partner dummy	No	No	No	Yes	Yes	Yes
Year dummy	No	No	No	Yes	Yes	Yes
Observations	463,153	323,006	140,147	463,153	323,006	140,147
Number of panelid	89,124	55,803	33,321	89,124	55,803	33,321
R-squared	0.2286	0.2343	0.1926	-	-	-

Note: *t-statistics* in parentheses

*** p<0.01, two-tailed. ** p<0.05, two-tailed. * p<0.1, two-tailed.

Table 4 OLS with lagged endogenous variables

The dependent variable *export* is the log of export values of environmental goods from country i to country j denominated in US dollars (UN Comtrade, 2017). The main explanatory variables, *lagged (t-1) log (exporting country's GDP)* is the log of GDP of country i in t-1 period denominated in US dollars (World Bank, 2017), *lagged (t-1) log (importing country's GDP)* is the log of GDP of country j in t-1 period denominated in US dollars (World Bank, 2017), *lagged (t-1) log (environ. patents ratio)* is the log of the relative environmental pattern ratio of country i to country j in t-1 period (OECD, 2017), *log (importer environ. tax)* is the log of the ratio of environmental tax revenues to GDP in country j denominated in US dollars (OECD, 2017), *log(distance)* is the log of the distance between the most populated cities in country i and country j denominated in kilometres (CEPII, 2017), *log (bilateral exchange rate)* is the log of the annual average volatility of the monthly bilateral currency rates between country i and country j (IFS, 2017), *contiguity* is a dummy which equals 1 if country i and country j share a country border and common language (CEPII, 2017), common official language is a dummy which equals 1 if country i and country j share an official or national languages and languages spoken by at least 20 per cent of the population in the respective country (CEPII, 2017), colony is a dummy which equals 1 if country i and country j have had colonial links (CEPII, 2017). The income classification is based on the World Bank (2013), GNI per capita in US$ (Atlas methodology) (see Appendix 1 for the list of countries).

	Fixed effects	Fixed effects	Fixed effects
VARIABLES	All countries	Developed countries	Developing countries
	(1)	(2)	(3)
lagged (t-1) log (exporter country GDP)	0.6677***	0.5486***	0.9500***
	(41.1623)	(26.9805)	(32.2561)
lagged (t-1) log (importer country GDP)	0.6956***	0.7885***	0.4544***
	(71.2806)	(65.3096)	(24.3969)
lagged (t-1) log (environ. patents ratio)	0.1616***	0.1529***	0.1361***
	(30.0189)	(20.9948)	(13.6516)
log (importer environ. tax)	-0.2458***	-0.2116***	-0.3368***
	(-13.8145)	(-10.1539)	(-9.7112)
log (distance)	-0.7051***	-0.6857***	-0.7943***
	(-114.8510)	(-99.5740)	(-52.3904)
log (bilateral exchange rate)	-0.0466***	-0.0518***	-0.0412***
	(-8.0086)	(-6.8885)	(-4.3143)
Contiguity	0.9723***	1.0602***	0.7205***
	(47.0246)	(42.4510)	(17.7956)
Common official language	0.3886***	0.3360***	0.2923***
	(23.7226)	(15.9172)	(9.4217)
Colony	0.1475***	0.1670***	-0.0881
	(6.7029)	(6.9750)	(-1.5105)
Constant	-27.1615***	-26.5272***	-27.6702***

	(-65.2561)	(-49.1210)	(-38.0346)
Reporter dummy	Yes	Yes	Yes
Partner dummy	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes
Observations	374,029	267,203	106,826
R-squared	0.2770	0.2742	0.2609

Note: *t-statistics* in parentheses

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

References

Andersson F. (2017), "International trade and carbon emissions: the role of institutional and policy reforms", Journal of Environmental Management, http://linkinghub.elsevier.com/retrieve/pii/S0301479717309210

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

Baltzer K., Jensen M. (2015), "Study of the Impacts of Green Trade Liberalisation on Least Developed Countries", file:///C:/Users/cantoren/Downloads/Green%20Trade%20Final%20Report%20November%202015%20(1).pdf

Blazejczak J., Braun F., Edler D. (2009), "Global Demand for Environmental Goods and Services on the Rise: Good Growth Opportunities for German Suppliers", https://www.diw.de/sixcms/detail.php?id=334081

Cantore N., Cali M., te Velde D. (2016), "Does energy efficiency improve technological change and economic growth in developing countries?", Energy Policy, 92, 279 – 285.

Costantini V., Crespi F. (2008), "Environmental regulation and the export dynamics of energy technologies", Ecological Economics, 66, 447 – 460.

Costantini V. Crespi F. (2010), "Public policies for a sustainable energy sector: regulation, diversity and fostering of innovation", Journal of Evolutionary Economics, 23, 410 – 429.

Costantini V., Mazzanti M. (2012), "On the green and innovative side of trade competitiveness? The impact of environmental policies and innovation of EU experts", Research Policy, 41, 132 – 153.

Chalioti E., Drivas K., Kalayvitis S., Katsimi M. (2016), "Innovation, Patents and Trade: A Firm-level Analysis, file:///C:/Users/cantoren/Downloads/del16-Chalioti.pdf

Dell'Ariccia, G., (1998), "Exchange Rate Fluctuations and Trade Flows: Evidence from the European Union", IMF Research Department, IMF Working Paper 1998/107, 1 – 27.

Dutz M., Sharma S. (2012), "Green growth, technology and innovation", Policy Research Working Paper 5932.

Greene (2003), "Econometric analysis", 7th Edition, Prentice-Hall.

Grosjean, P. (2011), "The weight of history on European cultural integration: A gravity approach", The American Economic Review, 101 (3), 504 - 508.

Hausman, J. A., and W. E. Taylor. 1981. Panel data and unobservable individual effects. Econometrica 49: 1377–1398.

Helpman, E., Melitz, M., and Rubinstein, Y., (2008), "Estimating Trade Flows: Trading Partners and Trading Volumes", The Quarter Journal of Economics, 123 (2), 441 – 487.

Marinova, D., and McAleer, M. (2003), "Modelling trends and volatility in ecological patents in the USA", Environmentla Modelling & Software, 18, 195 - 203.

Popp D. (2004), "Endogenous technological change in the DICE model of Global warming", journal of Environmental Economics and Management, 48, 742 – 768.

Porter, M., and C. van der Linde (1995), Toward a New Conception of the Environment Competitiveness Relationship, Journal of Economic Perspective 9(4), 97–118.

Rahman S., Serletis A. (2009), "The effects of exchange rate uncertainty on exports", Journal of Macroeconomics, 31, 500 – 507.

Rosen R., Guenther E. (2015), "The economics of mitigating climate change: What can we know?", Technological forecasting and social change, 91, 93 – 106.

Steenblick (2005), "ENVIRONMENTAL GOODS: A COMPARISON OF THE APEC AND OECD LISTS", OECD Trade and Environment Working Paper No. 2005-04

Sauvage G. (2014), "The stringency of environmental regulations and trade in environmental goods". OECD Trade and Environment Working paper 2014/03.

Sugathan M. (2013), "List of environmental goods: an overview", ICTSD information note, December 2013.

Tamini L., Sorgho Z.(2016), "Trade in environmental goods: how important are trade costs elasticities?", https://www.create.ulaval.ca/sites/create.ulaval.ca/files/Publications/taminisorgho-2016-3.pdf

Tinbergen, J. 1(962). Shaping the World Economy: Suggestions for an International Economic Policy. New York: The Twentieth Century Fund.

The World Bank, World Development Indicators (2013), World Bank GNI per capita operational guidelines & analytical classifications [Data file] Retrieved from: http://siteresources.worldbank.org/DATASTATISTICS/Resources/OGHIST.xls

United Nations Industrial Development Organization (2016), "The role of technology and innovation in inclusive and sustainable industrial development", https://www.unido.org/fileadmin/user_media_upgrade/Resources/Publications/EBOOK_IDR2016_FULLREPORT.pdf

Yoo S., Kim J. (2011), "Trade Liberalization in Environmental Goods: Major Issues and Impacts", Korea and the World Economy, 12, 579 – 610.

Wooldridge J. (2008), "Introductory econometrics: a modern approach", South Western Publisher.

Appendix 1 Country list

Countries are classified as developing countries based on World Bank Analytical Classifications (presented in the WDI), using GNI per capita in US$ (Atlas methodology) in 2013, excluding those countries which had a high income level during 1987–2013, for instance, American Samoa (1987–89) and Hungary (2008–11).

Developing countries (38)	**Developed countries (33)**
Argentina	Australia
Armenia	Canada
Bulgaria	Chile
Bosnia and Herzegovina	Croatia
Belarus	Cyprus
Brazil	Czech Republic
China	Denmark
Colombia	Estonia
Costa Rica	Greece
Algeria	Hong Kong, China
Egypt, Arab Rep.	Hungary
Georgia	Iceland
Guatemala	Israel
Indonesia	Japan
India	Korea, Rep.
Iran, Islamic Rep.	Kuwait
Jamaica	Latvia
Jordan	Lithuania
Kazakhstan	Malta
Kenya	New Zealand
Lebanon	Norway
Sri Lanka	Poland
Morocco	Russian Federation
Moldova	Saudi Arabia
Mexico	Singapore
Macedonia, FYR	Slovak Republic
Malaysia	Slovenia
Panama	Sweden

Peru	Switzerland
Philippines	United Arab Emirates
Romania	United Kingdom
Seychelles	United States
Thailand	Uruguay
Tunisia	
Turkey	
Ukraine	
South Africa	
Zimbabwe	

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