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Drivers of international shipments of hazardous waste: the role of policy and technology endowment

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Abstract

Using a gravity model for trade, this work analyzes the factors influencing the patterns of international hazardous waste flows, relying on newly available data reported in the E-PRTR (*European Pollutant Release and Transfer Registry*) for EU-OECD countries over the period 2007 to 2014. Exploiting a consolidated empirical framework (Kellenberg, 2012), we test two empirical hypotheses: firstly, we explicitly assess if, according to the *pollution heaven hypothesis* (PHH), the relative levels of environmental policies across countries are an important determinant of hazardous waste trade, and secondly, we test if technological specialization, proxied here by a technology-specific patent stock, can be considered as a *pull* factor capable to influence the patterns of international trade of hazardous waste.

Keywords: International Trade, Hazardous waste, Gravity model, Environmental policy, Factors endowment

JEL: F18, F64, O44, Q27, Q56

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1. Introduction

In the last decade the volume of waste treated across countries has increased, this is the reason why waste shipment represents an important topic becoming increasingly considerable in the literature about environment and international trade. Focusing the attention on the link between the international and environmental aspect of this phenomena, we analyze the increasing volume of hazardous international waste flows that may potentially produce serious consequences in terms of toxicity and land pollution in the receiving country. The interest about hazardous waste comes from different factors. First, it is one of the few environmental domains in which the free trade principle may seem to be undesirable. Second, the bulk of international policy in the waste realm is aimed at regulating hazardous waste transactions. In fact, according to Basel Convention trade barriers seem to be necessary in order to prevent transfer of hazardous waste while minimizing the toxicity of waste generated. The Basel Convention was adopted by 184 countries and European Union (Haiti and USA have signed but not ratified it) on 22 March 1989 and entered into force on 5 May 1992. His objective is to protect human health and the environment from the toxic effects of hazardous waste. In particular the convention pursues (1) the reduction of hazardous waste generation; (2) the restriction of transboundary movement; (3) a regulatory system for that cases where movements are permissible. The last one objective is based on the idea of prior information consent, it requires the track of every transaction. The European policy, however, seems to go in a different direction, establishing that recycling and recovery of waste occur outside the border of member states within the EU (European Commission, 2016). This idea comes from the efficiency principle: waste should be treated where the facility has the best recovery or recycling process. This underlines the role of trade in promoting specialization and efficiency.

The environmental literature that investigates the links between international trade and environment highlights two main mechanisms. The first one is linked to role played by capital abundance, that represents one of the most important drivers of trade patterns. According to Copeland and Taylor (1997) if capital endowment represents the unique difference between two countries, then the richest -with capital intensive production - becomes net exporter of bad goods. These countries moreover, generally exhibit an harder regulation leading to a decrease of total pollution. In contrast, if the income difference between countries dominates, then lower income countries have a comparative advantage in dirty production while higher income ones specialize their production in clean goods. In this way free trade moves most polluting industries to poorest countries.

The second mechanism refers to cross-country heterogeneity of environmental policies. The introduction of a specific policy represents an additional cost to domestic firms that could lead to loss international competitiveness. The regulation would induce the firms to relocate pollution-intensive productions abroad or to import pollution-intensive goods from countries with lax environmental regulation, because the compliance with environmental standards requires radical solutions (in terms of clean product and process) that increase the marginal cost of production. The literature has elaborated the concept of "*Pollution Haven Hypothesis"*, that represents the core of the debate about environment and international trade.

In this setting, the free trade of waste could produce the same polluting effect, and this is the so-called "*Waste Haven Effect"*. By exporting hazardous waste, all pollution and toxic activities that are needed to manage waste will take place abroad. In the recent years it has been developed the idea that the more direct way for countries to export pollution is *"to export pollution itself"*. Waste management is a capital intensive activity, with large fixed and sunk cost. For this reason, it is less likely that firms decide to offshore these activities (Ederington, Lenvinson and Miner 2004)[1]. Hence the central point of "waste shipment" is that for many countries the marginal cost of exporting waste is smaller than the cost of building new waste facilities at home or offshoring the production facilities that are responsible for the generation of waste.

There is a growing body of literature that deals with these topics. In particular we refer to Baggs (2009) and Kellemberg (2012) that have analyzed waste flows, stressing the role of two fundamental factors: the difference across countries in capital abundance and the role played by cross-country heterogeneity in environmental policy.

Following Antweiler et al. (2001), that analyzed the role played by the composition effect, Baggs (2009) considered other forces that are important in determining the direction of hazardous waste flows, first of all the capital abundance of countries. The

[1] See also Cole and Elliot (2005) and Cole and Okubo (2010)

underlying logic is that capital intensive industries are the most important producers of hazardous waste and this is a specific feature of the wealthiest countries with more stringent regulation. Therefore it happens that the high income countries have a comparative advantage in dirtiest industries (i.e. activities that generate large amounts of hazardous waste and activities aimed at disposing and recovering these hazardous waste). This capital abundance would predict that transboundary waste flows should go from lower income countries to higher income ones, so factor endowment could more than compensate the impact (opposite in sign) of environmental regulation.

More recently, Kellemberg (2012) faced this problem starting from the idea that the main driver of international waste shipment is the different level of regulation stringency. The paper evaluates total trade of waste. In order to stress the role played by environmental policy, he builds an indicator of heterogeneity in environmental regulation between pairs of countries. His analysis confirms the hypothesis about a positive role of policy as a driver of waste flows, and supports the Pollution Haven Hypothesis.

Building on their result we extend the previous literature by introducing several elements of novelty. As in Baggs (2009), we focus on hazardous international waste flows, but we use a richer dataset. In particular we use data from E-PRTR register whereby we are able to construct eight years long panel dataset that allows to include country and year fixed effect, mitigating the potential endogeneity bias in Kellemberg (2012). Secondly, exploiting an *ad hoc* patent stock we are able to account for capital abundance in a more reliable way with respect to Baggs (2009). Furthermore, we investigate the hypothesis of capital specialization. Some countries (or region) may be specialized in waste treatment and this could reduce the cost of their disposal/recovery compared with the cost of home country. For this reason, waste shipment could be the outcome of an optimal allocation of resources.

2. Context and framework

The increasing stringency of environmental regulation in developed countries seems to induce an increase in the cost of disposing and recovering hazardous waste. This could produce considerable international flows between highly regulated countries, generally belonging to the high-income group, and the poorest ones, usually characterized by lax standards[2]. In this case the interest about hazardous waste regulation appears stronger not only thanks to the Basel Convention presented above, but also because of the high level of toxicity and pollution that they release.

Compelling evidence underlines that different regulation across countries represents a considerable determinant of waste trade for different reasons. On one hand there is an important body of literature that confirms the hypothesis of pollution haven highlighting a growing trend of waste transactions to poorest countries, in which waste is recovered or disposed in unsafe ways. On the other hand, according to the literature about innovation and environmental regulation, higher stringency levels could induce a technological innovation that improves the disposal/recovery processes generating a comparative advantage in dirty industries. In this way it is possible to stress the role played by innovation and capital endowment, that can reverse the situation explained by the theory presented above about waste heaven effect.

Transboundary waste flows could be the results of a country specialization. The compliance with the standards leads to the necessity to modernize disposal/recovery processes. This could induce a technique effect which refers to change in production methods that follows the trade liberalization. In this sense free trade and specialization in waste treatment could reduce the cost of disposal/recovery and the total amount of global pollution and toxic releases from managing hazardous waste.

What is not well understood is the relative importance of all these drivers and their synergy. To this aim the purpose of this work is to combine these aspects. We use a gravity model and we propose a bilateral measure of regulation differences. Using information about patenting and installed capacity, we try to study the drivers of transboundary flows of hazardous waste.

3. Data

Panel data on transboundary hazardous waste flows are obtained from the E-PRTR database (*European Pollutant Release and Transfer Registry*) for EU countries over the period 2007 to 2014.

[2] Eliste and Frederiksson in 2002 found a positive correlation between stringency index of regulation and per capita income of 60 countries.

Introduced by Regulation (EC) 166/2006, the E-PRTR is the European-wide register that collects environmental data for about 30.000 industrial facilities and covers 65 sectors. For what concerns hazardous waste, E-PRTR includes information on international waste shipment of hazardous waste for those facilities that transfer off-site (either in the home country or abroad) 2 tonnes or more of hazardous waste per year.

Hazardous waste are defined in Annex III of Directive 2008/98/EC. The difference between hazardous and non-hazardous waste is based on the system of classification and labelling of dangerous substances and preparations. In general, waste that poses threats to the environment and public healthy, in terms of toxicity, corrosivity, ignitability and reactivity, is defined hazardous.

To measure the relative stringency of waste-related environmental policies, we build a specific policy indicator. The policy index is the result of a two-step process representing respectively: (1) the systemization and weighting of the different types of government policies to manage waste, and (2) their joint adoption per country per year. The indicator is based on the "*OECD database on Policy Instruments for the Environment*". [3] On the basis of this information, we create a series of ordinal variables ranging from 0 to 2 and representing the policies adopted in the field of waste management. Specifically, the variable takes the value of 0 when the policy has not been adopted, 1 when the policy stringency is below the yearly median level, and 2 when it is above the median. After the creation of this indicator variable, we standardize the policy index by averaging all the policies adopted per country per year (hence, we averaged all the ordinal variables adopted per country per year).

We retrieved information on patent applications at the European Patent Office in two different IPC classes that are related to the management of hazardous waste. These are:

- A62B 29/00 " Devices, e.g. installations, for rendering harmless or for keeping off harmful chemical agents";
- A62D 3/00 " Processes for making harmful chemical substances harmless, or less harmful, by effecting a chemical change in the substances".

[3] Data are available here: http://www2.oecd.org/ecoinst/queries/. As these data only refer to countries that belong to the OECD, our sample only considers EU countries that also belong to the OECD.

EPO patent applications were assigned to the country of the applicant and the stock was built by means of the perpetual inventory methods (with depreciation 0.15). Moreover, to account for the general level of technology of countries, we also compute the total stock of EPO patents (depreciation rate 0.15).

Data about gravity variables (distance, contiguity, common language between partner and reporter) are taken from *CEPII* database[4]. These variables are considered as the specific determinants of bilateral trade flows between country pairs.

Other covariates of our empirical analysis include:

- Total GDP, retrieved from the World Bank Development Indicator database;
- Population density, retrieved from the World Bank Development Indicator database;
- Installed capacity (in MW) of plants that recover energy from industrial waste, as a proxy of installed capacity of treatment plants, retrieved from Eurostat.

We began the analysis from the first year of application of the registry (2007) to 2014. The sample contains information about every region transaction outside the home country of hazardous waste in EU countries that also belong to the OECD.

4. Descriptive evidence

Figure 1 reports trends in the quantity of hazardous waste shipped as well as the trend in the number of transactions as reported in the E-PRTR. Between 2 million and 4 million of tonnes of hazardous waste were shipped every year in our selection of countries, with a fast growing trend. These shipments occur in about 2000-2500 transactions per year. As visible in Figure 2, the ten most important bilateral flows over the whole period (accounting for 66 percent of total shipments in our sample) are the export of waste from Italy to Germany and the export of waste from the Netherlands to Germany. This means that Germany represents the destination of the most important part of the whole European hazardous waste, suggesting the leadership of the Germany in this field.

In Figure 3 we show the amount of waste exported and imported (total for 2007-2014) by country. Again, Germany emerges as the largest importer of hazardous waste, followed by Belgium, while Italy and the Netherlands are the largest exporter of

[4] http://www.cepii.fr/cepii/en/bdd_modele/bdd.asp

hazardous waste. We want to stress the Italian role given the relevance of the problem in the last years Finally, in Figure 4 we report the patent stock at end of our period for selected technologies related to the management of hazardous waste, and compare it with the total patent stock. France emerges as the technological leader in terms of patents in the field of recovery and disposal of hazardous waste, followed by Germany and Italy. Interestingly, we observe that the ranking of countries when considering our selection of technologies does not overlap with the ranking for total patents, suggesting a pattern of specialization of certain countries in these technologies.

Figure 1 - Trend in hazardous waste shipments

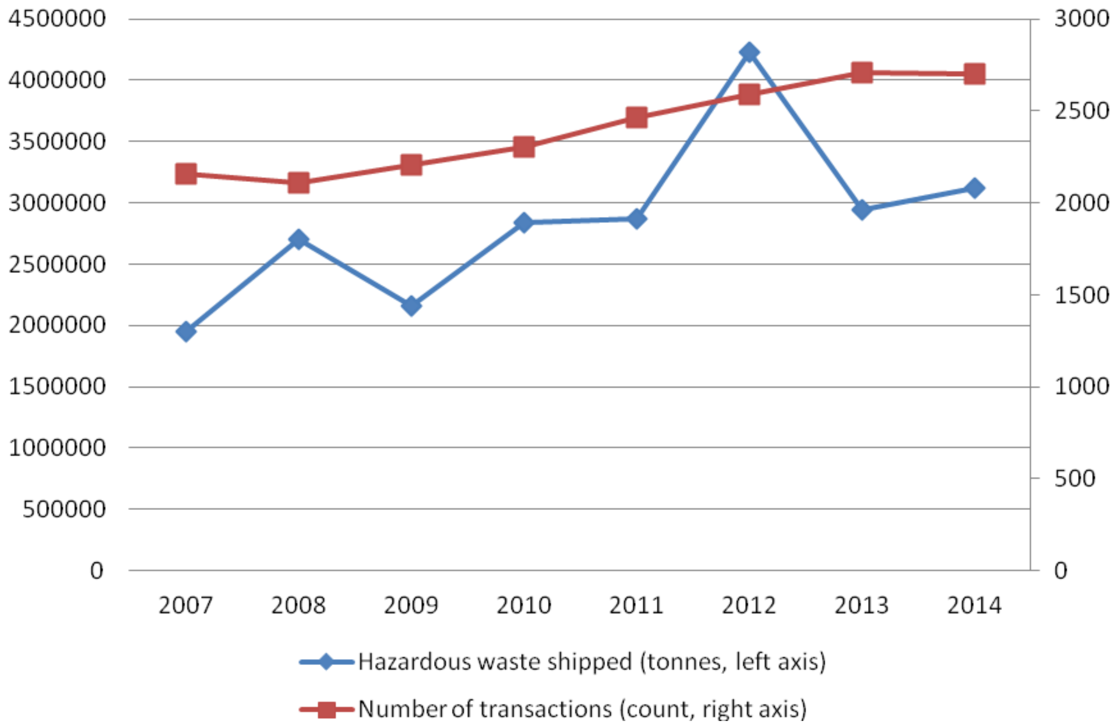


Figure 2 - Most important bilateral flows

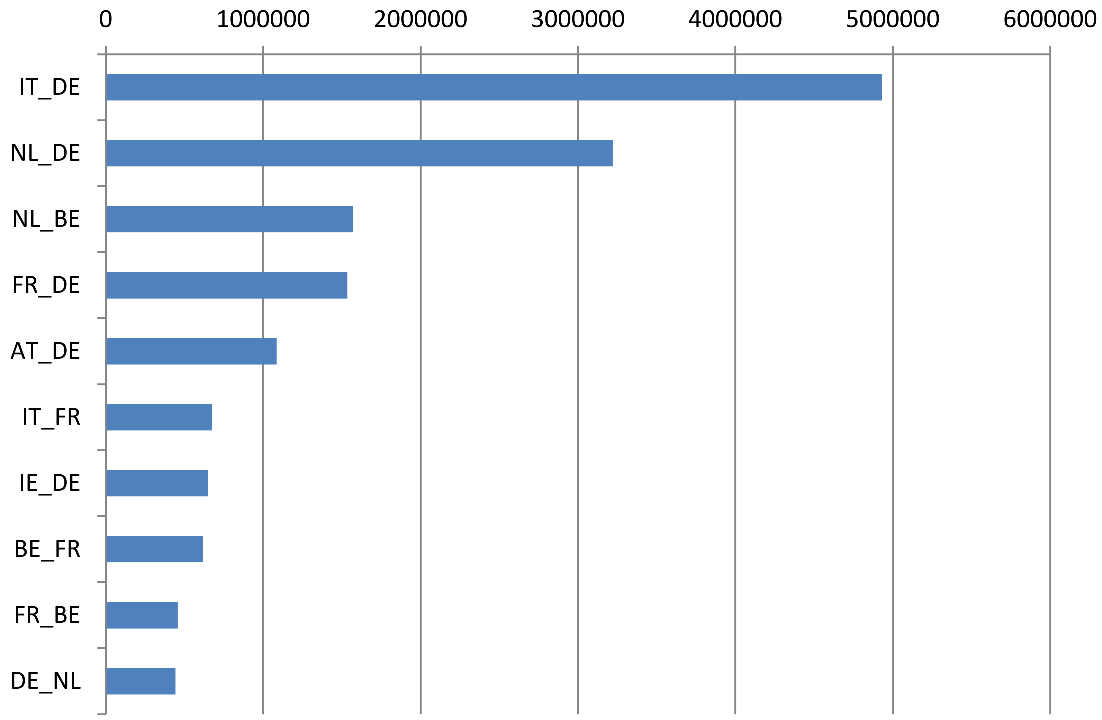


Figure 3 - Total import and export of waste by country

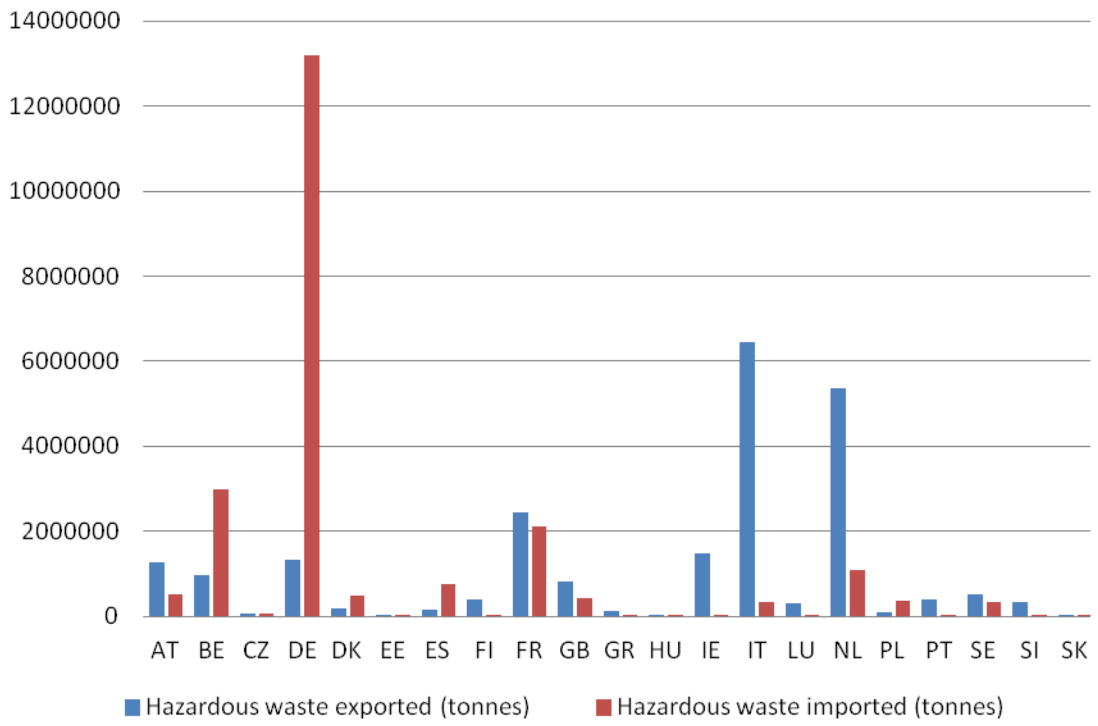
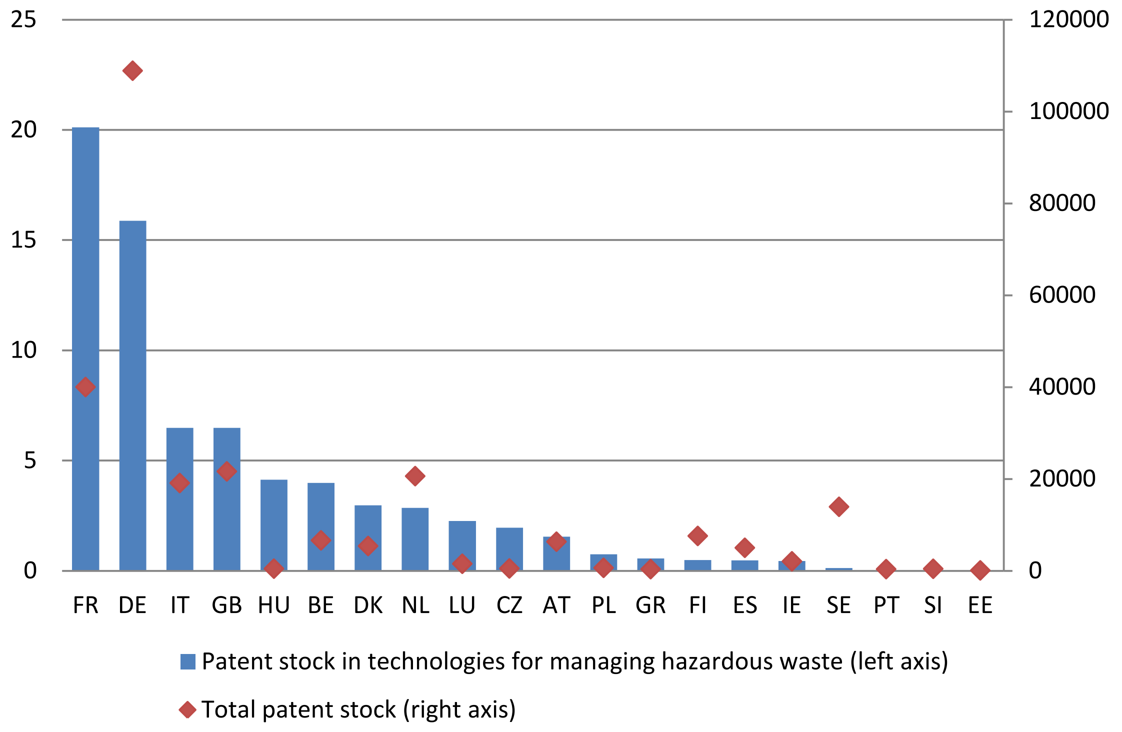


Figure 4 - Stock of patent (2014) in relevant hazardous waste management technologies and total patent stock



5. Empirical model and results

We employ a gravity model to evaluate the drivers of shipment of hazardous waste across EU countries. The first theoretical explanation of a gravity model is given by Anderson (1979) and, ten years later, by Bergstrand (1989). They demonstrated that a gravity equation can be derived as a reduced form of many models of international trade. The gravity equation is a specification relating to nominal bilateral trade flows from exporter *i* to importer *j*. It is derived theoretically as a reduced form from a general equilibrium model of international trade in final goods. Exporter and importer GDPs can be interpreted in these models as the production and absorption capacities of the exporting and importing countries, respectively. Bilateral distance between the two countries is generally associated with transportation costs. We enrich this basic specification by accounting for the importance of drivers that are specific to the trade in hazardous waste. These variables relate to differences in regulatory stringency in the waste realm and differences in the technological endowment in the field of managing hazardous waste.

Following Kellenberg (2012), we express our variables in gradients using the midpoint formula. Specifically these gradients follow this structure:

$$E_{ij}=(E_i-E_j)/((E_i+E_j)/2) \qquad (1)$$

where *i* and j represent the origin and destination country, respectively. Values larger than zero indicate that the origin country has a relatively larger value of the destination country. We estimate the following model:

$$WF_{ijt}=\beta_1 GDP_{ijt}+\beta_2 PS_{ijt}+\beta_3 WPS_{ijt}+\beta_4 ES_{ijt}+\beta_5 D_{ij}+\beta_6 L_{ij}+\beta_7 C_{ij}+\delta_{it}+\mu_{jt}+\varepsilon_{ijt} \quad (2)$$

where:

- $\mathbf{WF}_{ijt}$ is the export of hazardous waste between country pairs (in tonnes);
- $\mathbf{GDP}_{ijt}$ is the gradient of the GDP between country pairs;
- $\mathbf{PS}_{ijt}$ is the gradient of the total patent stock;
- $\mathbf{WPS}_{ijt}$ is the gradient of the waste-specific patent stock;
- $\mathbf{ES}_{ijt}$ is the gradient of our indicator of environmental policy stringency;
- $\mathbf{D}_{ij}$ is the distance (in logarithm) between centroids of countries;
- $\mathbf{L}_{ij}$ is a dummy that is equal to one if both countries share a common language;
- $\mathbf{C}_{ij}$ is a dummy for common border between the two countries;
- δ_{it} and μ_{jt} are year-specific dummies for, respectively, reporter and partner countries.[5]

In line with the recent literature, the model is estimated by means of the Pseudo Poisson Maximum Likelihood estimator (PPML) proposed by Santos Silva and Tenreyro (2006) to accommodate for the large share of zeros in gravity models.

[5] Alternatively, we also estimate a less demanding specification in which we include, separately, dummies for reporter country, dummies for partner country and year dummies. The full set of results, in line with the ones presented in the paper, is available upon request.

Table 1- Baseline results

	(1)	(2)	(3)	(4)	(5)	(6)
	Export of hazardous waste	Export of hazardous waste	Count of transactions	Export of hazardous waste	Total export (value)	Total export (weight)
Contiguity	0.178	0.191	0.534*	0.324	0.473***	1.044***
	(0.280)	(0.298)	(0.275)	(0.298)	(0.0765)	(0.122)
log(distance)	-1.463***	-1.483***	-1.610***	-1.444***	-0.503***	-0.778***
	(0.286)	(0.278)	(0.248)	(0.265)	(0.0552)	(0.0752)
Common language	1.356***	1.298***	0.833***	1.143***	0.755***	0.581***
	(0.245)	(0.228)	(0.224)	(0.235)	(0.108)	(0.146)
Gradient GDP	-0.326	-0.354	0.0692	-0.347	0.122	-0.0666
	(0.377)	(0.357)	(0.291)	(0.360)	(0.201)	(0.168)
Gradient Population density	-0.928	-0.636	1.409*	-0.610	0.214	0.832**
	(0.842)	(0.846)	(0.821)	(0.857)	(0.269)	(0.352)
Gradient Total patent stock (t-1)	-0.644***	-0.580**	0.168	-0.596**	0.0528	0.00736
	(0.217)	(0.234)	(0.202)	(0.234)	(0.0718)	(0.0811)
Gradient Patent stock in technologies for treatment of hazardous waste (t-1)	-0.353**	-0.503**	-0.540***	-0.500**	0.00315	0.0302
	(0.166)	(0.236)	(0.170)	(0.226)	(0.0531)	(0.0692)
Gradient policy stringency	0.672**	0.794*	0.770**	0.580	0.143	-0.0133
	(0.334)	(0.449)	(0.381)	(0.456)	(0.245)	(0.212)
Gradient MW capacity of energy recovery from hazardous waste				-0.280*		
				(0.147)		
Model	PPML	PPML	PPML	PPML	PPML	PPML
Year dummies	Yes	No	No	No	No	No
Origin country dummies	Yes	No	No	No	No	No
Destination country dummies	Yes	No	No	No	No	No
Year-specific origin country dummies	No	Yes	Yes	Yes	Yes	Yes
Year-specific destination country dummies	No	Yes	Yes	Yes	Yes	Yes
N	3360	2867	2867	2867	3360	3360

Standard errors clustered by reporter-partner pair in parenthesis. * p<0.1, ** p<0.05, *** p<0.01. Sample: AT, BE, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, NL, PL, PT, SE, SI and SK for 2007-2014.

Results reported in Table 1 provide confirmation to our hypothesis. In columns 1, 2 and 4 we evaluate the amount of shipments of hazardous waste (in weight) of bilateral shipments of hazardous waste while in columns 3 we consider the count of bilateral transactions between two countries. As a robustness check, we also evaluate total trade in value and weight (column 5 and 6, respectively) as a benchmark. Our expectation is that our waste-specific variables (mainly the waste-specific patent stock and the policy stringency indicator) have no influence on overall trade but only on trade of hazardous waste (Kellenberg, 2012).

With the only exception of column 1, where only origin, destination and year dummies are included, we include origin-year and destination-year dummies in all other regressions. Our first variable of interest, that is the (gradient of) proxy of stringency of waste-related regulation, features a generally positive and significant impact (columns 1, 2 and 3) on the quantity of hazardous waste that is shipped abroad. An increase of 10 percent in the relative stringency of waste-related environmental regulation in the origin country with respect to a potential destination country results in an increase in the export of hazardous waste (from origin to destination) of about 6.7-7.9 percent.

The gradient of the patent stock in technologies related to the management of hazardous waste has a negative impact on export of hazardous waste. If the origin country is particularly well endowed of appropriate technologies to deal with hazardous waste relative to a potential destination country, a lower amount of hazardous waste will be shipped to that destination country. A country's technological specialization is a factor influencing the patterns of international waste trade (see Baggs, 2009). It should be noted that this result is conditional on the overall differences in technologies across countries, that is accounted for by including the gradient of the total patent stock. This variable also has a negative impact on the export of waste. This suggests that the variable indicates the role of technological level between countries in general, and not only for the technologies about hazardous waste.

In columns 4 we also include another proxy variable for the domestic availability of specific facilities to manage hazardous waste, that is gradient of installed capacity (in MW) of facilities for energy recovery of hazardous waste. This variable gives us information about the actual level of facilities in terms of efficiency in disposal/recycling waste. This variable turns out to be negatively related to the export of hazardous waste: if the destination country is relatively well endowed with of energy recovery facilities for hazardous waste (i.e. high gradient), producers in the country of origin will export hazardous waste to be used in these facilities abroad.

Results for total export (columns 5 and 6) suggest no influence of either policy stringency or waste-specific patent stock on trade patterns. This means that these variables do not pick up other unobserved factors that drive trade in general, but are specific to trade in waste.

Looking at our control variables, geography-related variables influence trade in the expected way, with distance being negatively related to waste shipments and presence of a common language showing a positive impact on trade. What is interesting here is that the elasticity of hazardous waste export with respect to distance is -1.5, much larger than the one estimated in gravity equations that look at total trade of standard commodities, that is estimated to be for the same sample of countries and period about -0.5 for the value of trade and -0.78 for the weight of trade (see columns 5 and 6 of Table 1). This result is not a surprise since the waste transport is very expensive compared to other standard commodities. Contiguity only matters for the extensive margin, that is the count of transaction and the probability of observing at least one transaction.

Relative differences in the size of the economy (total GDP) and in population density do not play any significant role in explaining the export of hazardous waste. Countries with relatively larger production of non-hazardous waste tend to export less hazardous waste while countries with larger production and domestic management of hazardous waste tend to export more.

An important concern regards the issue of endogeneity. Environmental policies can be influenced by firms. The biggest firms, playing an important role in their sector or even in the economy as a whole, could encourage policy makers to undertake particular environmental choices (Downing and White, 1986). Furthermore, if the environmental stringency (or absence thereof) is considered as a form of protection for industry, the import flows may be an important factor in environmental policy strategies. Similarly, the endogenous problem comes when we consider the technological variable. Successful technologies at time *t-1*, associated with positive import performances, could be a driver for future investments in research and development at time *t* in the same technologies. In this way the current patent stock could be influenced by the one of the past period. The use of year-specific origin and destination country dummies is a way to reduce these endogeneity concerns.

6. Conclusions

The aim of this paper is to consider the different drivers of international hazardous waste flows, in particular the relative levels of environmental policies, capital endowment and technological specialization across countries. In contrast with previous literature which indicates the different regulation like *pull* factor capable to influence the pattern of international trade, we find some evidences about the role played by technological factors, suggesting that countries with greater (innovative) capital abundance have a significant greater ability to dispose and recover foreign hazardous waste. These results underline the importance of considering not only environmental policies differences across countries, but also technological factors in the analysis of the direction of international waste flows.

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