The impact of environmental policy on the waste management industry

by

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To my loving parents who have always encouraged me to pursue my dreams.

Preface

In 2014 citizens in the southern Polish city of Dąbrowa Górnicza organized a series of protests in an attempt to prevent toxic waste, originating in El Salvador, from being disposed of in a nearby incinerator (DZ, 2014). This prompted a debate in the media and among politicians as to whether Poland should accept hazardous waste from abroad. People became very emotional, to the extent that some even claimed the country was being poisoned by wealthier nations exporting their unwanted, toxic waste, to Poland.

The European Environment Agency's (EEA) data is very clear on this issue. Poland and other Central and Eastern European Countries (CEECs) neither import nor export large amounts of hazardous waste, especially when compared to Western Europe. Nevertheless, the same data shows that in the case of Poland, waste imports have been growing in the past few years.

The incident in Dąbrowa Górnicza and subsequent analysis of EEA's statistics inspired the author to investigate the following;-

1. the factors that drive firms to export their toxic waste,
2. how specific destinations are chosen, and
3. whether accepting foreign waste for treatment can promote the economic growth of transition countries such as Poland, without posing a threat to citizens' health.

A review of the existing literature revealed academic research addressing the problem of trade in waste to be relatively scarce. Moreover, the authors do not usually distinguish between waste destined for recovery and waste destined for final disposal. It should be noted that there is a separate strand of literature that focuses specifically on recycling, however, it is the view of this researcher that the answers can only be determined by including all treatment options in one research. This approach allows for the comparison of trade patterns in waste products as well as location patterns of waste management firms, depending on the treatment option.

The ideas presented here have evolved and crystallized through the process of countless discussions with professors and colleagues. The author would like to express her appreciation for the difficult questions asked during the presentation of results at two seminars held at Hitotsubashi University in Tokyo: the Environmental Economics Seminar and the International Trade Seminar.

Here, I should like to express special gratitude to my academic advisor, Prof. Hidetoshi Yamashita, who has supported me from the first day I arrived in Japan. He has always been very generous with his time and inspired me in many ways.

I am also indebted to my co-advisor Prof. Jota Ishikawa, whose critical comments and valuable insights helped me greatly to refine and strengthen my arguments.

Though it is impossible to list all the individuals I am thankful to, I must acknowledge the vast kindness and extremely useful suggestions received from Prof. Taiji Furusawa, Prof. Michikazu Kojima, Prof. Yoichi Sugita, Prof. Shunichi Teranishi, and Prof. Eiichi Tomiura.

I would like to express my deep gratitude to the Japanese Government, whose financial support through the MEXT Scholarship, has enabled me to conduct my research at Hitotsubashi University in Japan.

Finally, I would like to thank my family and friends who have been very patient, supportive, and encouraging during the process of writing this dissertation.

Contents

Chapter 1

General introduction

1.1 Research aim and motivation

Over recent decades, an increase in the general awareness of pollution-related harm has been accompanied by the pursuit of environmental conservation. Since waste generation rates around the world have been growing rapidly, some of the biggest concerns are, not surprisingly, related to waste management issues.

For a long time, the problems of waste transfer have been addressed mainly by environmentalists, Jim Puckett of Greenpeace has even coined the phrase ”toxic colonialism” as a way of describing the form of such transfers (Puckett, 2003). The attention of the media focuses, perhaps naturally, on the issue of the, often illegal, exportation of toxic waste to developing countries unable to deal with it in a safe manner. From an academic perspective, this raises the question of whether trade in waste products follows the pattern predicted by the pollution haven hypothesis (PHH), or, stated differently: Do lax environmental standards promote specialization in dirty industries such as that of waste management?

Research addressing this issue is quite limited, and it either concentrates on testing the PHH, with respect to the aggregated waste flows (Baggs, 2009; Kellenberg, 2012), or investigates the problem of recycling (van Beukering, 2001; Kojima and Michida, 2011). To the author's knowledge only one study attempts to test the Porter hypothesis (PH) with respect to the waste management industry. Cecere and Corrocher (2016) found that there is a relationship between stringent environmental policy and the number of innovations in the waste management sector. There is, as yet, no research assuming both the PHH and the PH be true, but for different treatment options.[1]

[1]The PHH predicts that when barriers to trade are reduced, the pollution-intensive industry will relocate to those countries where environmental regulations are less stringent. The PH postulates that properly designed environmental policy leads to innovations which may, in turn, enhance firms'

This research aims to fill the gap in the existing literature by integrating the main treatment options, as well as both the PHH and the PH, into one study, and further by investigating the factors crucial for the development of either, or both, the disposal and the recovery industry. Unfortunately, due to data availability, this study is limited to the EU countries and Norway.

The approach taken is threefold: firstly, in Chapter 2 the location patterns of the waste management industry are examined, allowing for the consideration of both hazardous and non-hazardous waste. Chapter 3 investigates the factors that affect trade flows in hazardous waste at the country level. Lastly Chapter 4 conducts an in-depth analysis of trade patterns in hazardous waste at the facility level.

This research is worthwhile not only for academic reasons, but also because of possible implications for real world policies. Many countries are struggling to improve their waste management systems in an effort to increase efficiency and make them more environmentally-friendly. Understanding the relative importance of factors that create a comparative advantage in either disposal or recovery services is an essential step in building a better system.

This chapter is broken into sections as a means of providing a clear introduction: Section 1.2 discusses the basic facts and findings concerning international and European trade in waste. Section 1.3 describes data sources used in this research together with their limitations. Section 1.4 introduces four measures of environmental policy stringency, which is a crucial variable, used in chapters 2-4. Section 1.5 describes the theoretical framework adopted in this study. Lastly, Section 1.6 provides a brief overview of subsequent chapters.

1.2 International trade in waste

Despite international effort aimed at reducing waste shipments and eliminating "dirty dumping" (The Basel Convention, 1989), trade in waste has been growing rapidly, including shipments from developed countries to developing nations (Kellenberg and Levinson, 2014). This is apparent even if one considers only data on legal trade flows. Obviously, there is no exact data on illegal activity, meaning a researcher can only make educated guesses as to the magnitude of the problem.

The available literature does offer some estimates, for example, Rucevska et al. (2015) claim that 60-90% of the world's electronic waste is traded illegally. According to Appelqvist (2013), illegal trade in waste is worth between 10 and 12 billion dol-

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international competitiveness. Both the PHH and the PH are explained in detail in Section 1.5 of this chapter.

lars annually. EEA (2009) revealed that reported annual illegal shipments in the EU amount, on average, to 0.2% of notified waste. Despite the agency fearing that this figure may be only a fraction of the actual number, it does not attempt to estimate it: apparently, it is too difficult a task. Even though it is certain that the number of reported cases has increased, it cannot be determined whether this is down to an increase in illegal shipments or simply due to better monitoring.

The difficulties in measuring illegal activities make it impossible to include illegal waste transfers in this study, of course, omitting these transfers may introduce a bias, but nevertheless, it is both possible and worthwhile to analyze and model transboundary movements of hazardous waste based on available data. This research does not directly address the issue of illegal shipments of waste, it is, however, essential to be aware of this problem in order to avoid misinterpretation of results based solely on official data.

In contrast to illegal trade in toxic waste, the majority of the legal shipments are directed to developed countries (Baggs, 2009). The EU Member States only very rarely export waste outside the EU.

In Figure 1.1, below, circles represent annual shipments of notified waste from the EU-27 to partner countries either within or outside the EU-27. The bigger a circle, the larger the volumes traded. It is clear that EU countries usually trade waste with fellow EU partners. Moreover, in the past few years, the intra-EU trade in waste has been constantly growing whereas volumes shipped to the rest of the world have shrunk.

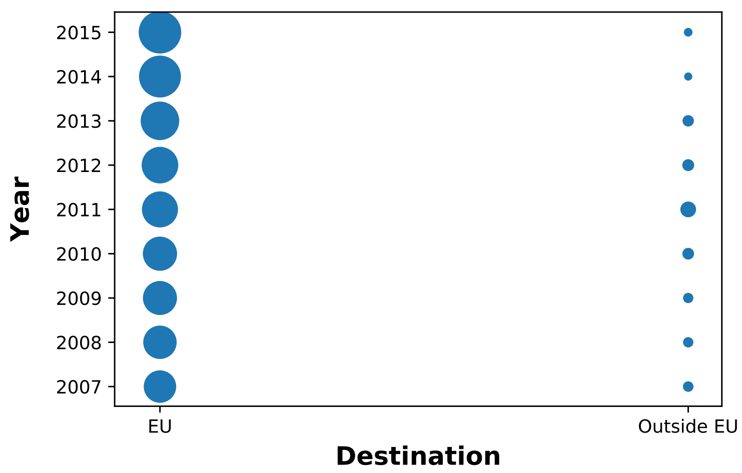

Figure 1.1 Destinations of the hazardous waste shipments originating from EU-27, 2007-2015. Source: Own elaboration based on the Eurostat

Figure 1.2 is similar to Figure 1.1, but it presents data obtained from the E-PRTR. The circles are distinctly smaller because the E-PRTR covers only the biggest exporters and fewer categories of waste than the Eurostat. Generally, the data of Figure 1.2

confirms the conclusions drawn from Figure 1.1. The structure of trade is very similar. However, the E-PRTR data shows that both the exports to other EU countries and the exports to the rest of the world have increased slightly over the years.

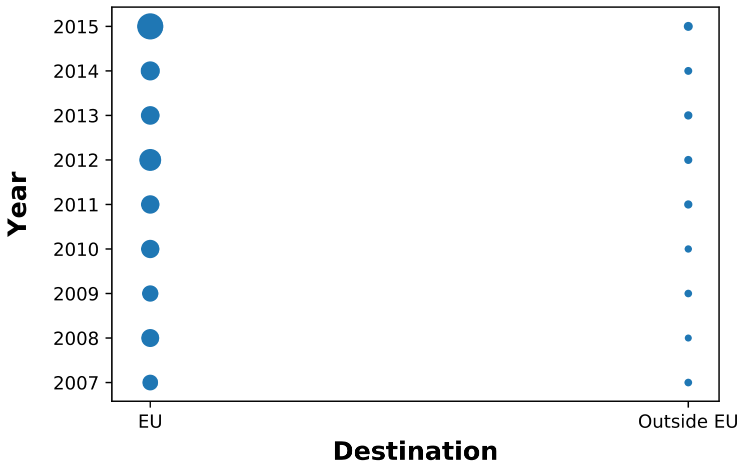

Figure 1.2 Destinations of the hazardous waste shipments originating from EU-27, 2007-2015. Source: Own elaboration based on the E-PRTR

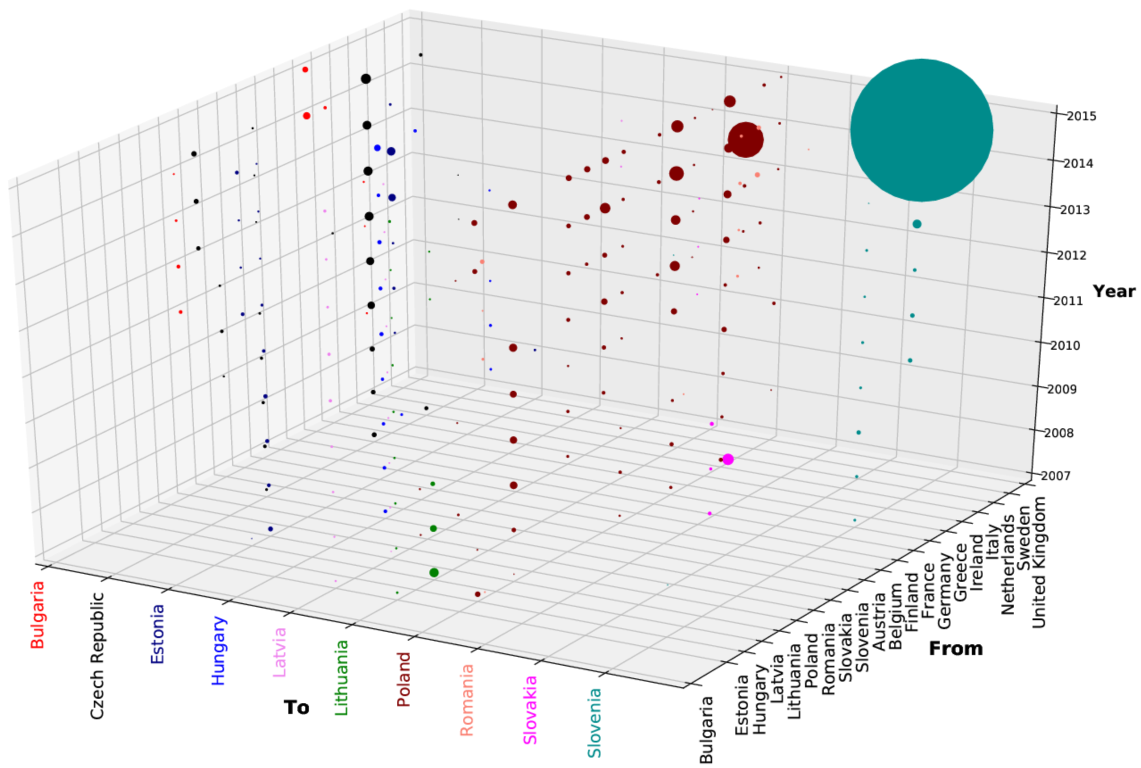

Figure 1.3 Hazardous waste shipments to CEECs, 2007-2015. Source: Own elaboration based on the E-PRTR.

Figure 1.3 considers only the shipments from the EU-27 to transition countries reported to the E-PRTR. It is evident that the CEECs region (especially Poland) has been receiving more and more waste over the years. The big dark cyan circle at the top represents the shipment from Italy to Slovenia in 2015. Italy has long been one of the largest waste exporters in the EU. Even so, the year 2015 was quite remarkable, as more than 60% of all hazardous waste (in terms of volume) reported to the E-PRTR originated in Italy.

Table 1.1 Individual countries exports of hazardous waste as a percentage share of total EU-27 exports, 2007-2015 (based on the E-PRTR)

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015	Avg
Italy	20.24	25.57	29.95	35.70	29.16	20.16	21.16	17.67	60.69	32.05
Netherlands	14.23	13.33	15.90	15.05	14.95	38.71	19.23	25.13	8.38	18.39
Belgium	13.79	8.85	10.89	10.23	11.81	7.97	11.84	9.48	6.47	9.57
France	10.74	8.25	7.09	7.20	9.27	7.70	15.04	10.23	4.74	8.46
Germany	6.62	4.89	5.53	4.63	4.33	4.08	5.95	7.74	5.15	5.34
Ireland	9.16	14.67	5.85	4.52	4.82	2.88	4.05	3.61	2.26	5.09
Austria	6.61	5.88	5.68	5.50	5.26	3.67	2.56	5.21	1.14	4.11
Sweden	3.52	3.05	4.70	3.78	3.84	2.93	4.67	4.77	2.91	3.67
UK	3.11	3.37	3.72	3.25	4.18	2.41	3.82	3.63	2.05	3.12
Denmark	4.26	2.57	2.83	1.76	2.96	2.03	1.71	1.97	0.72	2.06
Portugal	3.50	5.67	1.69	0.72	0.94	0.99	1.37	1.07	0.50	1.58
Finland	NA	NA	1.21	1.43	1.84	1.86	2.42	2.63	1.16	1.45
Slovenia	0.90	0.91	1.59	1.57	1.52	0.97	1.24	1.62	0.80	1.18
Luxembourg	0.31	1.51	1.06	1.79	1.16	1.27	1.15	1.19	0.64	1.09
Spain	1.30	0.40	0.41	0.29	0.64	0.81	1.73	1.61	0.59	0.84

Nonetheless, transition countries, at least at present, are neither among the largest importers or exporters when compared to the older EU Member States. Table 1.1, above, lists the fifteen largest exporters (according to the E-PRTR), and only one of them (Slovenia) belongs to the CEECs region. Italy is clearly the leader, followed by the Netherlands, Belgium, and France. It is worth noting that, on average, the shipments originating in Italy and the Netherlands alone make up half of the total volume reported to the E-PRTR between 2007 and 2015.[2]

[2] The Netherlands imports and exports large volumes of waste, especially given its size. An important reason is the fact that the country has long been a major distribution hub in Europe. The

The largest importers are shown in Table 1.2 below. Germany has been receiving about half of all shipments originating from EU-27 countries and directed to other EU-27 countries. It can be noticed, however, that the volume imported by Germany has decreased in recent years. Other big importers are Belgium and France. Slovenia has the second position only due to the exceptionally large imports from Italy in 2015. Table 1.2 also reveals that the problem of confidentiality claims is serious. The vast majority of companies that have claimed confidentiality are located in Belgium.

Table 1.2 Individual countries imports of hazardous waste as a percentage share of total EU-27 imports, 2007-2015 (based on the E-PRTR)

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015	Avg
Germany	52.00	60.93	57.09	52.55	54.40	50.21	50.15	44.60	19.42	45.50
Slovenia	0.02	0.02	0.07	0.07	0.07	0.02	0.32	0.02	53.36	11.24
Belgium	9.87	9.09	10.74	9.78	10.49	21.06	8.45	10.62	4.67	10.37
France	8.85	6.60	7.94	16.06	7.84	5.63	7.66	7.45	4.43	7.52
Confidential	9.06	4.95	7.86	6.28	8.42	5.17	9.23	6.77	5.32	6.70
Netherlands	4.42	3.89	3.77	3.68	4.27	6.70	6.42	5.27	3.52	4.67
Spain	4.28	5.93	2.57	2.04	2.13	2.48	4.03	3.24	1.06	2.80
Denmark	1.87	2.11	1.65	2.07	2.08	1.85	2.82	3.24	1.66	2.12
Austria	1.11	1.34	2.50	2.80	2.80	1.66	2.26	2.41	1.26	1.94
UK	2.96	1.88	1.98	1.67	1.81	1.20	1.28	1.36	1.01	1.54
Poland	0.23	0.16	0.39	0.39	0.40	0.77	0.80	8.29	1.07	1.44
Italy	1.42	0.55	0.15	0.41	1.26	1.00	3.08	2.93	1.40	1.40
Sweden	0.04	0.24	1.11	1.50	2.18	1.47	2.00	1.78	0.78	1.25
Portugal	1.70	0.99	0.54	0.01	0.08	0.07	0.15	0.18	0.16	0.34
Czech Rep.	0.18	0.10	0.14	0.24	0.28	0.24	0.37	0.37	0.27	0.25

As explained above, chapters 3 and 4 investigate the factors determining trade patterns in hazardous waste. At the most basic level, it is the waste generators, who have to decide what to do with the hazardous waste they produce. Figure 1.4 summarizes the factors that affect their decisions and are especially relevant in the case of the intra-EU trade. They are divided into five groups.

Netherlands, in actual fact, is one of the biggest exporters of goods in general in the world.

In chapters 3 and 4 some of the factors, such as market size, are explicitly included in empirical models. However, many factors can only be proxied by other variables- the regulatory stringency, for which there is no direct measure, is one example. In this research, it is proxied by four different measures, which are described in detail in Section 1.4 of this chapter. Another example is the transportation cost, proxied by the distance variable.

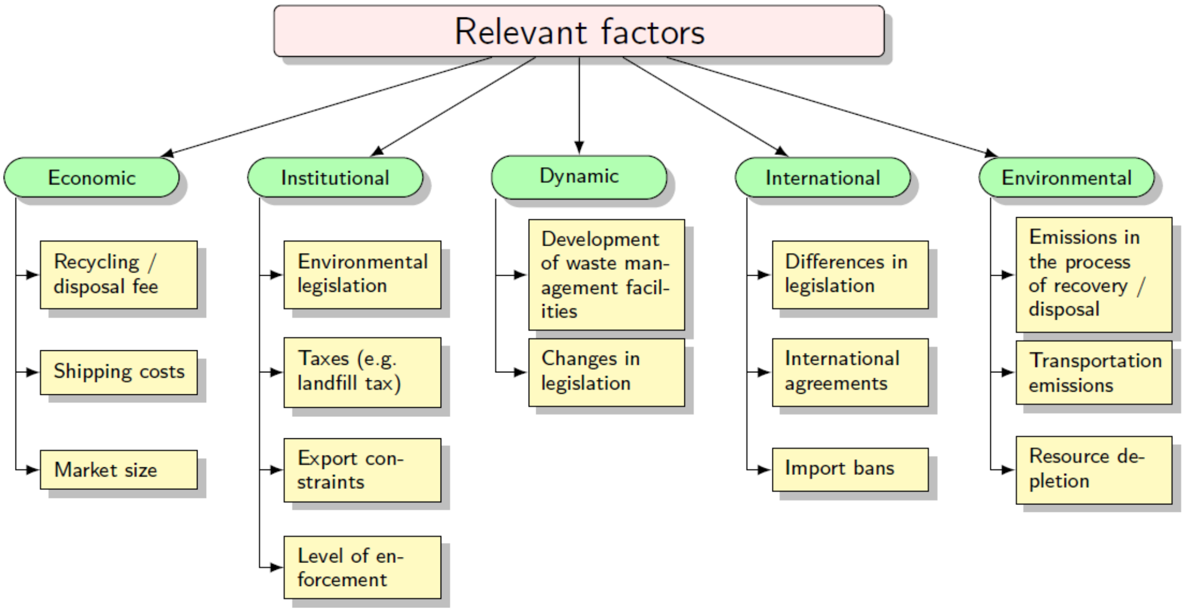

Figure 1.4 Factors affecting a waste generator's decision on whether to export hazardous waste. Source: Own elaboration

1.3 Data sources

Good quality data related to the waste industry is difficult to obtain. No existing database is sufficient, and this cannot simply be because illegal transfers of waste, as well as illegal waste treatment facilities, are not reported. Sadly, even legal activities are sometimes reported incorrectly. Although a researcher can only work with what is available, it is important that he or she understands the limitations of any given database.

The present study uses data from mainly two databases: the Eurostat and the European Pollutant Release and Transfer Register (E-PRTR).

The Eurostat database contains country-level data and is crucial for the waste management industry location patterns analysis (Chapter 2) as well as the gravity analysis of trade in hazardous waste (Chapter 3).

The E-PRTR is used for facility-level analysis (Chapter 4). It includes very valuable data on the amount of hazardous waste industrial facilities transfer to waste handlers, both domestically and abroad.

Table 1.3 Comparison of databases

Database	Who reports	What is reported
E-PRTR	Individual facilities that fall under at least one of the 65 economic activities listed in E-PRTR Regulation and at the same time exceed at least one of the E-PRTR capacity thresholds.	"Off-site transfers of hazardous waste exceeding 2 tonnes per year, or of non-hazardous waste exceeding 2000 tonnes per year, for any operations of recovery or disposal, with the exception of the disposal operations of land treatment and deep injection (…), whether the waste is destined for recovery or disposal and, for transboundary movements of hazardous waste, the name and address of the recoverer or the disposer of the waste and the actual recovery or disposal site" (EC, 2006a).
Eurostat	Statistical authorities of Member States. The same data is reported to the Basel Convention.	Countries report exports and imports of all notified wastes. They have to indicate the waste category as well as the treatment operation the waste is shipped for (recovery and/or disposal). Imports reported by one country do not always match exports reported by the partner country. Discrepancies may arise as a consequence of differences in reporting between the respective countries (for example, the use of different waste classifications or treatment codes) or the fact that the exporting Member State has included notified green-listed waste in their reporting, whereas the receiving Member State has not.
Comtrade	Statistical authorities of Member States. The data is standardized by the UN Statistics Division.	Countries report the trade in wastes without distinguishing between hazardous and non-hazardous waste. There are 60 waste categories, and most of them may contain both hazardous and non-hazardous components. Treatment operation is not reported. Similarly to Eurostat, exports do not necessarily match reported imports. Differences are due to various factors; including valuation (imports CIF, exports FOB), differences in inclusions/ exclusions of particular commodities, timing, etc.

In addition to the above mentioned databases, some studies use the UN Comtrade Database in order to investigate trade patterns in hazardous waste, or test the PHH (Kellenberg, 2012; Kellenberg 2014). Therefore, this section explores the UN Comtrade Database along with the Eurostat and the E-PRTR, and explains why the latter two are more suitable for this research.

Table 1.3, above, summarizes the most relevant characteristics of the three databases. The E-PRTR is the only facility-level database, so it was chosen for the analysis included in Chapter 4. Country-level data in the two other databases cannot be directly compared with the E-PRTR's data, but the Eurostat at least collects data using the same definitions of hazardous waste as the E-PRTR. It is impossible to identify shipments that contain only hazardous waste using the UN Comtrade Database.

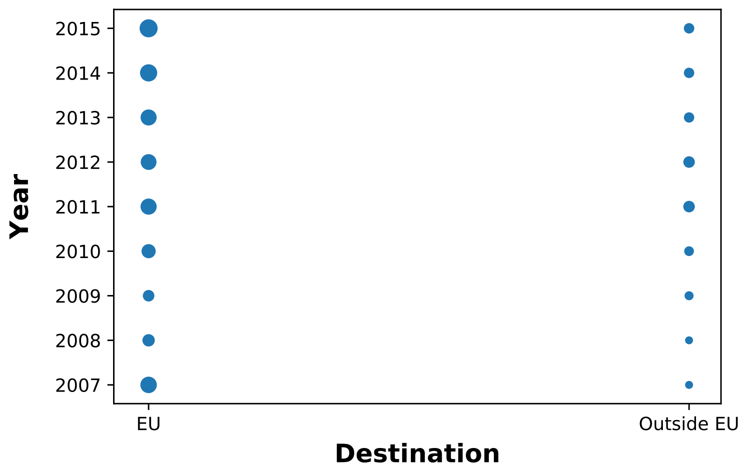

Figure 1.5 Destinations of hazardous waste shipments originating from EU-27 between 2007 and 2015. Source: Own elaboration based on UN Comtrade Database

Figure 1.5 presents hazardous waste shipments originating in the EU between 2007 and 2015. The plot is based only on those UN Comtrade HS tariff codes that are most likely to contain only hazardous waste. They are listed in Table 1.4. Compared to Figure 1.1, which reflects Eurostat data, the circles representing volumes of shipments in Figure 1.5 are much smaller. However, although it cannot be seen from the plot, the number of destination countries is in fact larger in the case of UN Comtrade data. This means that, on the one hand, the categories used in the plot include some non-hazardous waste while on the other hand, large volumes of hazardous waste must be contained in excluded categories. Apparently, the UN Comtrade Database does not allow for even the approximate identification of non-hazardous waste. Nonetheless, it should be noted that despite unavoidable differences, all databases suggest a very similar structure of trade (with most waste being traded within EU borders) and point to the same countries as being the largest exporters and importers.

The Eurostat database is plainly more suitable for making comparisons with the E-PRTR database than the UN Comtrade database. It uses the same definitions of waste and indicates whether or not the waste in question is hazardous and also what kind of treatment it has been shipped for. It is clear from figures 1.1 and 1.2 that the volumes shipped according to Eurostat have been much larger than the volumes reported to the E-PRTR. This is consistent with the fact that Eurostat covers all hazardous waste transfers and all waste generators.

Table 1.4 UN HS tariff codes vs. Waste Shipment Directive (WSD) codes

Code	UN Name	Code	WSD Name
262019	Other Ash and Residues Containing Zinc	A1070, A1080	Leaching residues from zinc processing, etc., Waste zinc residues not included on list B
262020	Ash and Residues Containing Mainly Lead	A1080, A1020	Waste zinc residues not included on list B
262050	Ash and Residues Cont. Mainly Vanadium	AA060	Vanadium ashes and residues
262110	Ash and Residues from the Incineration of Municipal Waste	Y47	Residues arising from the incineration of household wastes
262021	Leaded Gasoline Sludges & Leaded Anti-knock Compound Sludges	A3030	Wastes that contain, consist of or are contaminated with leaded anti-knock compound sludges
262029	Ash and Residues (excl. from the mfr. of Iron/Steel) cont. Lead	A1080, A1020	Waste zinc residues not included on list B
271390	Residues of Petroleum Oils etc. n.e.s.	A3010	Waste from the production or processing of petroleum coke and bitumen
382510	Municipal Waste	Y46	Waste collected from households
382530	Clinical Waste	A4020	Clinical and related wastes
382541	Halogenated Waste Organic Solvents	A3150	Waste halogenated organic solvents
382549	Waste Organic Solvents Other Than Halogenated W.O.S.	A3140	Waste non-halogenated organic solvents, but excluding such wastes specified on list B
382550	Wastes of Metal Pickling Liquors, Hydraulic Fluids, Brake Fluids & Anti-freeze Fluids	A1060, AC060/70/80	Waste liquors from the pickling of metals, Hydraulic fluids, Antifreeze fluids, Brake fluids
382561	Wastes from Chemical/Allied Industries, Cont. Organic Constit.	A3	Wastes containing principally organic constituents
382569	Wastes from Chemical/Allied Industries, n.e.s.	A2, A4	Wastes containing principally inorganic constituents
382590	Residual Products of the Chemical/Allied Industries, n.e.s.	A2, A4	Wastes containing principally inorganic constituents
810730	Cadmium Waste & Scrap	A1010	Metal wastes & waste cons. of alloys of cadmium
811020	Antimony Waste & Scrap	A1010	Metal wastes & waste cons. of alloys of antimony
811213	Beryllium Waste & Scrap	A1010	Metal wastes & waste cons. of alloys of beryllium
780200	Lead Waste & Scrap	A1010	Metal wastes & waste consisting of alloys of lead
811252	Thallium Waste & Scrap	A1010	Metal wastes & waste consisting of alloys of thallium
854810	Waste & Scrap of Primary Cells, Primary Batteries etc.	A1160, A1170, A1180	Waste lead-acid batteries, Waste electrical and electronic assemblies or scrap
810420	Magnesium Waste or Scrap	AA190	Magnesium waste and scrap that is flammable

Source: Own elaboration based on UN Comtrade official website and Waste Shipment Directive

Generally, the E-PRTR should be treated as more reliable than other databases because it collects the data directly from waste generators. E-PRTR's biggest advantage is the fact that it contains very disaggregated data that is based on calculation or actual measurements instead of estimation. Moreover, all facilities have to report according to the same standards, which enables international comparisons.

However, the E-PRTR also has some limitations that should be taken into account when analyzing the data.

First, the register covers, on average, only 39% (EC, 2013) of all hazardous waste transfers, the level of coverage differing, depending on sector. This low figure results from the thresholds associated with the facility's size and the volumes transferred. It can be problematic in the case of smaller countries and certain sectors.

Second, some of the data is kept confidential. The most common reason given for claiming confidentiality of commercial or industrial information is to protect a legitimate economic interest. The majority of facilities that have declared confidentiality are engaged in the waste management industry, the chemical industry, as well as the production and processing of metals; most commonly not revealing information on the waste handler party's names or addresses (Fikru, 2013).[3]

Third, information on the size of reporting facilities, as well as on the level of toxicity of the waste they generate, is incomplete, and thus cannot be used in this study.

Finally, there is a risk of double-counting, although it should be noted that measures have been taken to avoid it as much as possible. For example, if waste is not sent directly to a final destination, but instead undergoes blending, bulking or mixing in a waste transfer station (WTS) first, the facility is required to report the transfer station as the next destination and the actual treatment location as the final destination. Furthermore, the recovery or disposal code should indicate that the waste has undergone blending, bulking or mixing at the waste transfer station. However, sometimes waste generators do not know the final destination, in which case they enter the WTS as both the next destination and the final destination. In this research, it could be a problem if a given waste shipment has crossed borders twice or more, but this is likely to be an issue only in the case of Belgium or the Netherlands.

Despite the two databases chosen for use in this study being incomplete and imperfectly comparable, they can still reveal valuable insights about the waste management industry if handled with sufficient care.

[3]The problem of confidentiality is very serious in the case of Belgium, which keeps most of its data confidential. The European Commission seems to be aware of this issue (EC, 2009), but has not properly addressed it yet.

1.4 Environmental policy stringency measures

One of the greatest challenges in investigating the pollution haven hypothesis and the Porter hypothesis is finding an adequate measure of environmental policy stringency. Existing research presents a variety of approaches, none of which is completely satisfying. Choosing a measure that is either too broad (e.g., GDP per capita) or too narrow (e.g., environmental tax revenues) is a common problem.

This section first discusses the challenges of constructing a quantitative measure of policy stringency and then presents four measures selected for this study. They are all meant to capture, although sometimes only indirectly, the most important elements of the regulatory stringency: environmental regulations, enforcement, and people's environmental awareness and attitudes.

Brunel and Levinson (2013) argue that an ideal measure of environmental policy stringency "would be relatively easy to calculate, using data that governments already collect or that they should collect as part of efforts to achieve other policy objectives (e.g., pollution control). Such a measure would be available annually in order to facilitate panel data models that address some sources of simultaneity. It would be cardinal, enabling assessment of magnitudes, and either available for various pollutants and media or combinable into a single overarching measure of multidimensional stringency. It would be theoretically related to the costs facilities incur when they abate pollution, but it would not be determined by industrial composition."

None of the measures that have been used by researchers to date fit this ideal perfectly. There are many reasons as to why a good measure cannot be easily calculated. First, the environmental issues and the policies that address them are very heterogeneous. Different industries may face different regulations concerning the same pollutant. Moreover, those regulations may be implemented either by a central or local governments. Second, it is difficult to assess the degree of enforcement, which is a crucial factor in evaluating whether the policies in question are truly stringent or not. Third, since new regulations usually impose stricter standards on new pollution sources, firms may be reluctant to acquire the most advanced technology, and instead keep using polluting plants as long as possible. This, of course, results in stringent regulations contributing to more rather than less pollution.

There are numerous approaches to measure environmental policy stringency. Some of the more popular proxies include environmental or energy tax revenue, legislation counts, renewable energy capacity, surveys of business executives or government officials, pollution abatement cost expenditures, composite indexes, and the like. The choice of an appropriate proxy should be based on research objectives. In the present study it was important to use a measure that solves the problems of heterogeneity and multidimensionality of environmental regulations, and captures the level of enforcement. This is because, even though the core regulations are the same for the entire EU, country-specific regulations, as well as the level of enforcement, vary a lot across countries. Since composite indexes are very general, they are deemed to be the most suitable proxies for the present research. Four were selected in order to ascertain whether the results prove consistent regardless of the measure used. However, it must be remembered that composite indexes do have some shortcomings. Brunel and Levinson (2013) mention that they are often arbitrary and that it is not easy to interpret their magnitudes in a meaningful way. The basic measure in this study has, therefore, been constructed in such a way as to alleviate, as much as possible, these shortcomings.

The baseline indicator is abbreviated as SER (Stringency of Environmental Regulations) and is used in all empirical chapters. It is based on the aggregate indicator (ER index) constructed by Kheder and Zugravu (2012), which successfully captures the differences in stringency levels of environmental policy across countries.

As already mentioned, one difficulty in comparing the regulatory stringency among EU countries results from the fact that all EU Member States are supposed to follow similar standards. However, depending on the country, the level of enforcement can vary greatly; accordingly, it is important that the indicator be as unbiased and comprehensive as possible. SER index looks at various aspects of environmental policy stringency by combining the three components outlined below.

The MEAs (Multilateral environmental agreements ratified) component is meant to capture countries' concern for the environment. This component alone is not sufficient to serve as a measure of environmental stringency because, as shown by Rose and Spigel (2010), countries joining MEAs may be motivated by factors other than a willingness to protect the environment. Gaining credibility in the international arena is sometimes an important reason for signing an MEA. Nevertheless, we can assume that countries especially interested in joining MEAs are also truly concerned about environmental issues.

The INGOs (Membership in non-governmental organizations per million of population) component measures the strength of civil society, which is known to pressure governments over environmental protection issues. This component includes all organizations because the data source does not allow for distinguishing among various types of INGOs. However, according to Gemmill and Bamidele-Izu (2002), the advocacy for environmental justice is one of the key areas in which INGO's are active. Furthermore, NGOs have been recognized by the United Nations as crucial partners in the process of creating and implementing environmental programs. In some cases INGOs have an even more direct influence on a country's environmental policies. Kheder and Zugravu

(2012) give an example of the Environmental Control Agency (Bapedal) from Jakarta, which has actively enforced industrial pollution regulations because the government apparently failed to do so. Additionally, as Pring et al. (2017) showed, civil society participation is strongly related to the quality of institutions (measured by the Corruption Perception Index) which, in turn, can be linked to the ability of governments to enforce their laws.

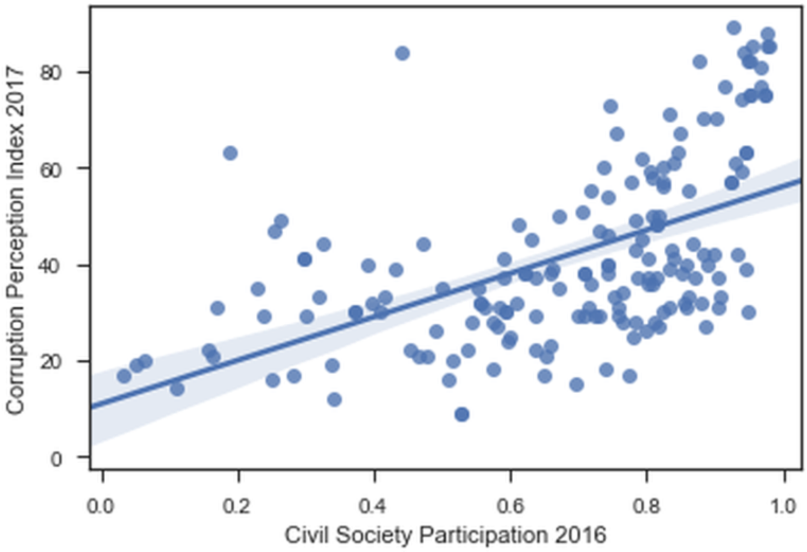

Figure 1.6 Relationship between the Corruption Perception Index and civil society participation in a sample of 175 countries

Note: Own elaboration based on data obtained from Transparency International website (https://infogram.com/01c83fbc-98f8-48a7-84cd-47b76b955656 (2018/08/13))

The INGOs component is positively correlated with income per capita and the Environmental Performance Index (EPI), which is described in the later part of this section (see Table 1.5).

Table 1.5 Correlation matrices for INGOs, Income Per Capita, and the EPI

	INGOs	Income Per Capita	EPI
INGOs	1.000		
Income Per Capita	0.471	1.000	
EPI	0.227	0.383	1.000

Finally, the energy efficiency variable (GDP/unit of energy used) looks at how effective countries are in enforcing their regulations.[4] If environmental policies are suc-

[4]Since average temperatures vary across countries, the energy use variable has been climate cor-

cessfully enforced, companies are expected to be more energy efficient. Compared to the first two components, the energy efficiency is more directly related to the costs companies face when a country implements stringent regulations (and thus justified on theoretical grounds). If, as a result of stricter environmental policies, the price of energy increases, companies look for ways to improve their energy efficiency and reduce energy consumption.

SER calculations were carried out in accordance with the procedure described by Kheder and Zugravu (2012). However, the index was computed for a different time period using different data sources. Similarly to Kheder and Zugravu (2012), the technique of Z-score was followed in order to combine all three components of the index so that they carry the same importance.[5]

PRS (Proxy for Regulatory Stringency), the second indicator of regulatory stringency calculated integrates two components: the Corruption Perception Index (CPI) and normalized income (PPS) per inhabitant using the already mentioned Z-score method.

CPI is meant to capture the quality of institutions which, among other things, determines the level of enforcement. If a country has high levels of corruption, companies can easily avoid obeying strict environmental standards by, for example, just bribing law enforcement officials.

Income per capita measures the demand for a clean environment. The empirical research which links the level of income to the demand for environmental quality was pioneered by Grossman and Krueger (1995). They argue that economic growth decreases the environmental quality only in the initial phase. Then, as income per capita increases, the environmental conditions steadily improve. It is worth noting that all EU countries are, generally, past the initial phase.

Both components of PRS can be found in existing research on the PHH. Baggs (2009) uses GDP per capita as a proxy for the environmental policy stringency. CPI and income per capita are used as instrumental variables for the policy stringency variable by Mulatu et al. (2010). PRS, similarly to SER, appears in all empirical chapters.

The third index, EAI (Environmental Awareness Index), is a measure of environmental awareness and has never been used before for testing the PHH or the PH. In this study, it was only possible to use it in the cross-sectional analysis of Chapter 2 because the EAI is available for only 2013. The EAI is relevant as a regulatory stringency

rected using Eurostat's CHDD (heating and cooling degree days).

[5]First, the values of all three variables were standardised. Second, the unweighted average of the variables' standardized values (Z-scores) was computed. Finally, the index was converted to 1-100 scale.

proxy because, ultimately, environmental policy is created, implemented, and enforced by people. Therefore, general awareness matters a great deal.

The EAI was introduced by Harju-Autti and Kokkinen (2014), and is based on a survey constructed in such a way that the results are comparable across countries. The reliability of the results is ensured by the refined methodology firmly rooted in theory. Harju-Autti and Kokkinen (2014) use sociological theories of environmental consciousness (see Van der Werff et al., 2013) as well as planned human behaviour theories, such as the values-beliefs-norms (VBN) theory (see Stern et al., 1999) to conceptualize environmental awareness. The EAI differs from other similar measures in that it does not evaluate people's opinions, but more concrete qualities, such as knowledge (concerning the environment), skills (needed to solve environmental problems), and motivation. High scores on knowledge and skills increase the chance that a country's policy is not only stringent but also well-designed. This second component is crucial for testing the PH. Unfortunately, the EAI covers only 23 of the 27 countries included in the sample in Chapter 2: additionally, it has, pre-force, some limitations imposed by the small size of the data, which was gathered and processed by just two researchers. Therefore, here, the EAI is only used for comparison.

The EAI is a very promising indicator, and hopefully, the project started by Harju-Autti and Kokkinen will be continued and extended in the future. For the time being, however, it could not be used in the panel data analysis of chapters 3-4. Instead, these chapters utilize the Environmental Performance Index, published annually by the Yale Center for Environmental Law and Policy and the Center for International Earth Science Information Network of Columbia University. The index was preceded by the ESI (Environmental Sustainability Index), which was adopted as the regulatory stringency variable in testing the PHH by Mulatu et al. (2010).

Table 1.6 Sources of environmental policy stringency measures

Name	Abbreviation	Sources
Stringency of Environmental Regulations	SER	IEA Database (MEAs component), The Yearbook of International Organizations (INGOs component), Eurostat (Energy efficiency component)
Environmental Performance Index	EPI	Yale Center for Environmental Law and Policy
Proxy for Regulatory Stringency	PRS	Transparency International (CPI component), Eurostat (Income per capita component)
Environmental Awareness Index	EAI	Harju-Autti and Kokkinen (2014)

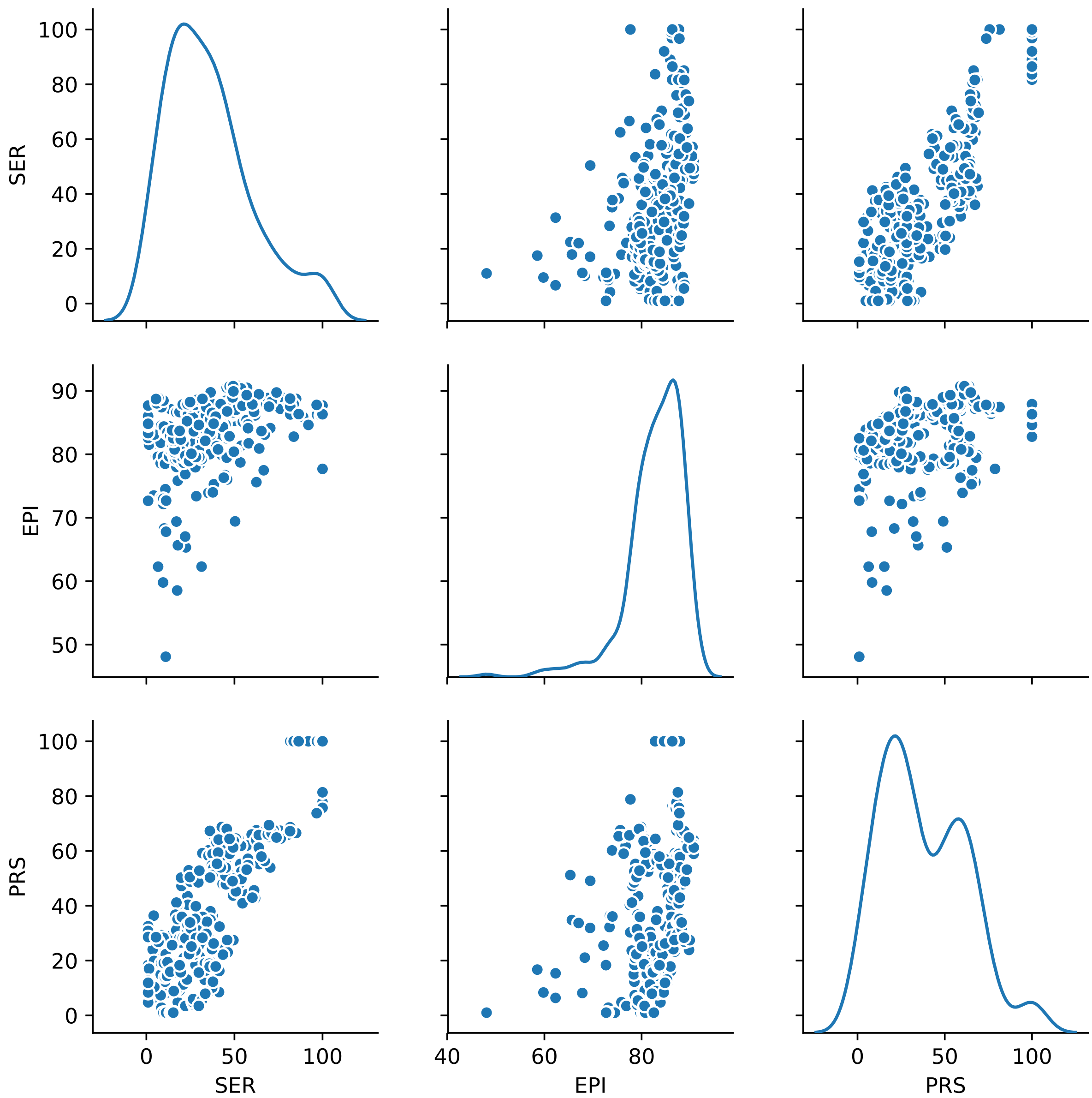

Figure 1.7 Pairwise relationships of SER, the EPI, and PRS

The EPI is a composite index, which ranks countries according to their performance in a number of areas related to environmental protection (e.g., air quality, agriculture, climate, and energy). An important shortcoming of the EPI is the fact that the methodology for computing the index has changed several times.

This thesis uses four different measures of environmental policy stringency. It is expected that they all should positively correlate with one another, as they proxy for the same variable. Figures 1.7 and 1.8 provide pairwise plots, which help to visualize the strength of the relationships. Figure 1.7 includes only SER, the EPI, and PRS because only these three indicators are available across multiple years for all the studied countries. Figure 1.8 presents pairwise relationships of all indicators, but the data for these plots is limited to 23 countries and only one year (2013).

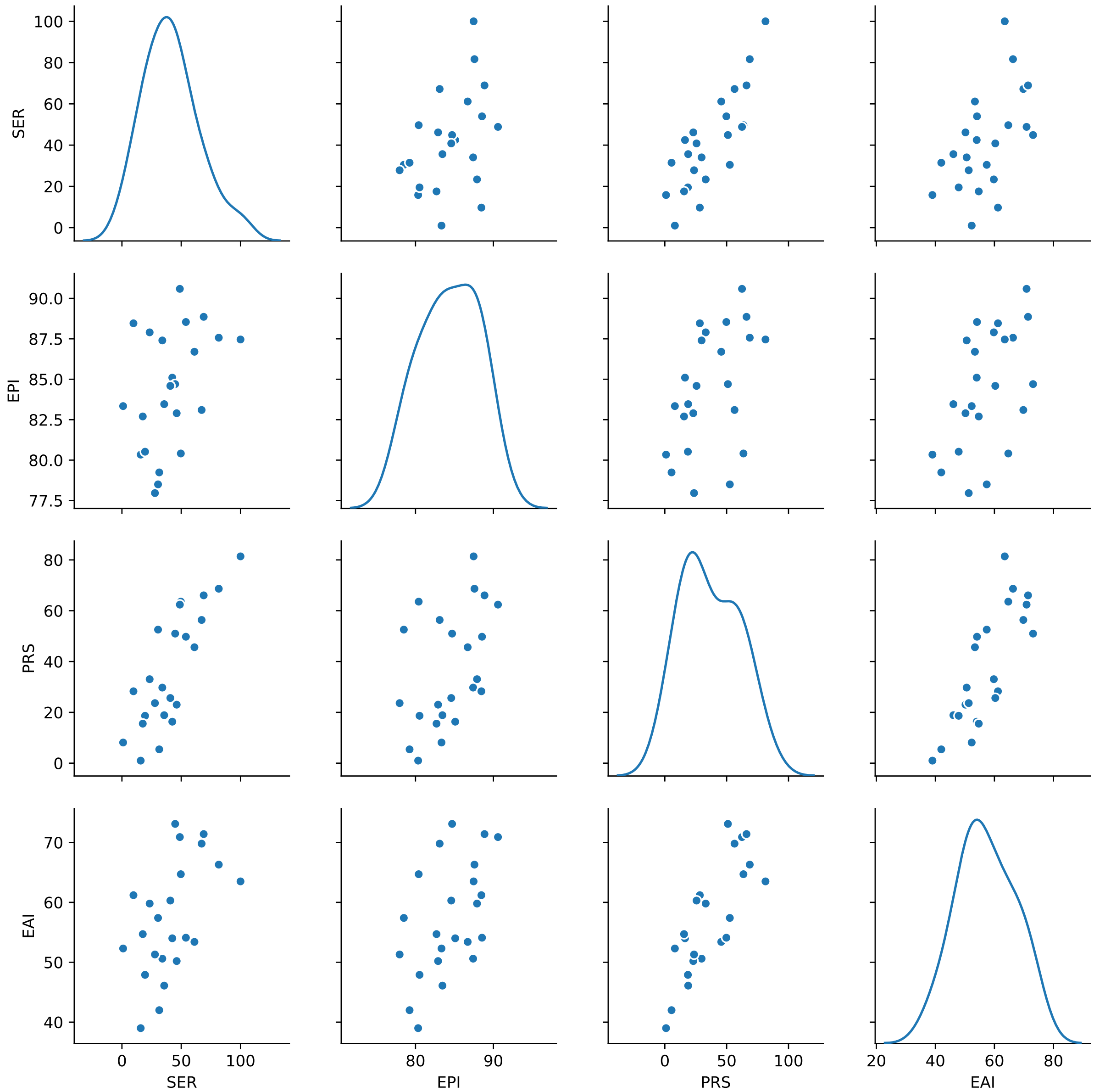

Figure 1.8 Pairwise relationships of SER, the EPI, PRS, and the EAI

Both figures show that, indeed, there is a positive relationship between all the pairs, although the strength of this relationship varies greatly depending on the pair in question. It can be seen from the plots that the most obvious and strongest relationship is observed for SER and PRS. Table 1.7, which contains correlation coefficients for all environmental policy stringency measures, confirms that SER and PRS are highly correlated, with the correlation coefficient in excess of 0.8. Table 1.7 also indicates a strong correlation between PRS and the EAI. The coefficients for the rest of the pairs suggest a rather more moderate correlation.

Table 1.7 Correlation matrices for SER, the EPI, PRS, and the EAI

	SER	EPI	PRS
SER	1.000		
EPI	0.390	1.000	
PRS	0.820	0.344	1.000

	SER	EPI	PRS	EAI
SER	1.000			
EPI	0.401	1.000		
PRS	0.814	0.464	1.000	
EAI	0.529	0.512	0.803	1.000

Note: The correlation matrix on the left covers the whole period under study and all studied countries. The correlation matrix on the right has been computed for the year 2013 and 23 countries for which the EAI index exists.

1.5 Theoretical considerations

1.5.1 The theory of comparative advantage

This section aims to provide a conceptual framework for the waste management sector analysis. Since this research focuses on understanding factors that determine location patterns of the waste management industry, and trade patterns in waste products the Heckscher-Ohlin (HO) framework has been employed as the most suitable. It has its roots in the ideas that were developed by David Ricardo in the first half of the nineteenth century.

Ricardo's theory of comparative advantage is one of the most famous theories in economics. It is nontrivial and has a great explanatory power (Costinot and Donaldson, 2012). Ricardo noticed that international trade is stimulated by the comparative differences in the costs of producing commodities among countries. His great insight was that what matters is relative production costs of goods being exchanged and not the differences in absolute costs of producing the same commodity across countries. As Cairnes put it: "When it is said that international trade depends on the difference in the comparative, not the absolute, cost of producing commodities, the costs compared, it must be carefully noted, are the costs in each country of the commodities which are the subject of exchange, not the different costs of the same commodity in the exchanging countries" (Ruffin, 2002, p. 731).

In Ricardo's theory, comparative advantage results from differences in labor productivity (WTO, 2008). Eli Heckscher and Bertil Ohlin developed a model (HO model), which is based on Ricardo's idea, but assumes that the differences in factor endowments constitute the primary source of comparative advantage (Morrow, 2010).

At its most basic the HO model considers two countries, two commodities, and capital and labor as the production factors. Production factors can move only between industries, but not between countries. The model assumes that countries have the same production function as well as identical tastes. Where they differ is factor abundance. These basic assumptions allow for deriving several propositions.

The original HO theorem states that a country specializes in the production of a product that requires large inputs of the factor in which this country is relatively abundant. Another important theorem was proposed by Wolfgang Stolper and Paul Samuelson. They showed that when the relative price of one item increases, so does the return to the factor which is used intensively in the production of that item. The return to the other factor falls. The Stolper-Samuelson theorem is related to the factor-price equalization theorem, which states that (assuming that countries have the same technology) free trade leads to the complete equalization of factor prices across countries. Finally, the Rybczynski theorem demonstrates that when a country's endowment of a factor increases, the output of the item produced mainly with this factor also increases, whereas the output of the other item decreases.(WTO, 2008).

The HO model has been a very popular tool in analyzing international trade. There are, therefore, many extensions of the standard model. From the perspective of this research, incorporating the environment, as the third production factor, is the most important extension.

McGuire (1982) developed a model which shows the effect of environmental regulation on factor prices and allocation. He assumes that there are two sectors in a country: polluting and clean. The polluting sector is much more pollution-intensive, which means it uses large amounts of the factor environment. If the production function is linear homogeneous and has equal pairwise elasticities of substitution, stricter environmental control (e.g., an introduction of environmental taxes) will change factor prices and allocation. In particular, factors' marginal productivities in the polluting sector decrease and there is an outflow of capital and labor into the less polluting sector until the marginal productivities are equalized again. The polluting sector shrinks and the clean sector becomes larger. If we consider a range of countries with varying levels of pollution controls, then the same item is manufactured using different proportions of production factors in each country (assuming that production factors cannot move between countries). In such a case, consistent with Stolper-Samuelson theorem, if the environmental policy becomes more stringent in a large open economy, then the price of a pollution-intensive item increases worldwide and the return to the factor used intensively in its production rises in the rest of the world.(Schulze and Ursprung, 2001).

Grossman and Krueger (1991) propose another useful method of thinking about the relationship between free trade and the environment. They argue that trade liberalization affects the environment in three ways. Firstly, the pollution and resources depletion become more serious simply as a result of an increase in the scale of economic activity. Secondly, the transfer of technology can potentially lead to a reduction in pollution, at least per unit of output. Finally, there is also a composition effect which brings about greater specialization among countries, and thus can create pollution havens. It occurs when the differences in the stringency level of environmental regulations become an important source of comparative advantage.

Ultimately, comparative advantage is a concept common to all the presented approaches. It is also the key element of the pollution haven hypothesis as well as the Porter hypothesis.

The PHH can be traced back to the 1970s, when researchers first developed theoretical models showing that stringent environmental regulations could impair a country's competitiveness in world markets (Pethig, 1976; Siebert, 1977). The concept of pollution havens can be described in three main dimensions. The first dimension is related to location patterns of polluting industries. According to the PHH, differences in environmental regulations among countries influence a firm's location decisions to such an extent that the most pollution-intensive industries migrate to countries with lax environmental standards. A second way to approach the PHH is to look at trade flows. Imposing strict environmental regulations on dirty industries can reduce net exports of commodities produced by these industries. Finally, the third approach focuses on foreign direct investment (FDI). It is claimed that countries lower their environmental standards to below that considered socially optimal in order to attract FDI.

It is important to distinguish between the PHH and the pollution haven effect. The PHH predicts that when barriers to trade are reduced, pollution-intensive industry will relocate to those countries where environmental regulations are less stringent. Both the theoretical and empirical support for this hypothesis, however, is relatively weak. In contrast, the pollution haven effect has been confirmed by a number of studies (Smarzynska and Wei, 2001; Eskeland and Harrison, 2003; Cole, 2004; Kellogg, 2007; Mulatu et al., 2010). It posits that the stringency of environmental policy influences, at the margin, firms' location decisions. However, there exist other determinants of industry location, some of which are more influential than the stringency of pollution regulation.

The PH was formulated by Michael E. Porter (1991) and postulates that properly designed environmental policy leads to innovations which may, in turn, enhance firms' international competitiveness. There are three versions of the PH. The "weak" version, which links increased technological innovation to environmental regulations, but does not specify how this relationship affects the competitiveness of a country. The ”strong” version, which proposes that regulation-induced innovation can more than offset regulatory costs, consequently enhancing competitiveness. Finally, the ”narrow” version, which suggests that flexible, market-based regulations are better at fostering innovations than ”command-and-control” type regulations (Ambec et al., 2013).

Research on the PH finds a connection between strict regulations and increased innovation, but the hypothesis is usually only confirmed in its ”weak” version (Brunnermeier and Cohen, 2003; Popp, 2006; Lanoie et al., 2011; Rammer et al., 2011).

1.5.2 Comparative advantage in the context of the waste management industry

This section explains how the ideas of comparative advantage, factor endowments, pollution havens as well as the PH, can be related to research on the waste management industry.

The disposal sector and the recovery sector can be analyzed in a similar way to that of the manufacturing sector. The same logic can be applied regardless of whether a firm produces either goods or services. It is easy to imagine that one country specializes in disposal services and another one in recovery services. Use of the extended version of the HO model is an effective way to investigate factors that cause this specialization as it incorporates environment as one of the production factors.

As disposal of waste is pollution-intensive, it uses large amounts of the factor environment. Recovery is much cleaner. According to the PHH, countries with lax regulations, or poor enforcement, are expected to specialize in the production of pollution-intensive goods. Since waste management activities generate negative externalities, such countries are expected to also have a comparative advantage in waste disposal services. Recovery, as an alternative method of treating waste, should expand especially in countries with strict pollution controls. The PH explains this by postulating that strict regulations encourage companies to be more efficient and replace polluting materials with recoverable ones. Faced with similar stringent pollution controls, the waste management industry also finds it profitable to invest in recycling technology while seeking ways of dealing with waste without using too much of the factor environment, which is expensive.

Existing research, in the main, does not distinguish between recovery and disposal. The whole waste treatment sector is considered polluting, especially in empirical studies. Formal models of waste management are scarce: the most influential being that developed by Copeland (1991).

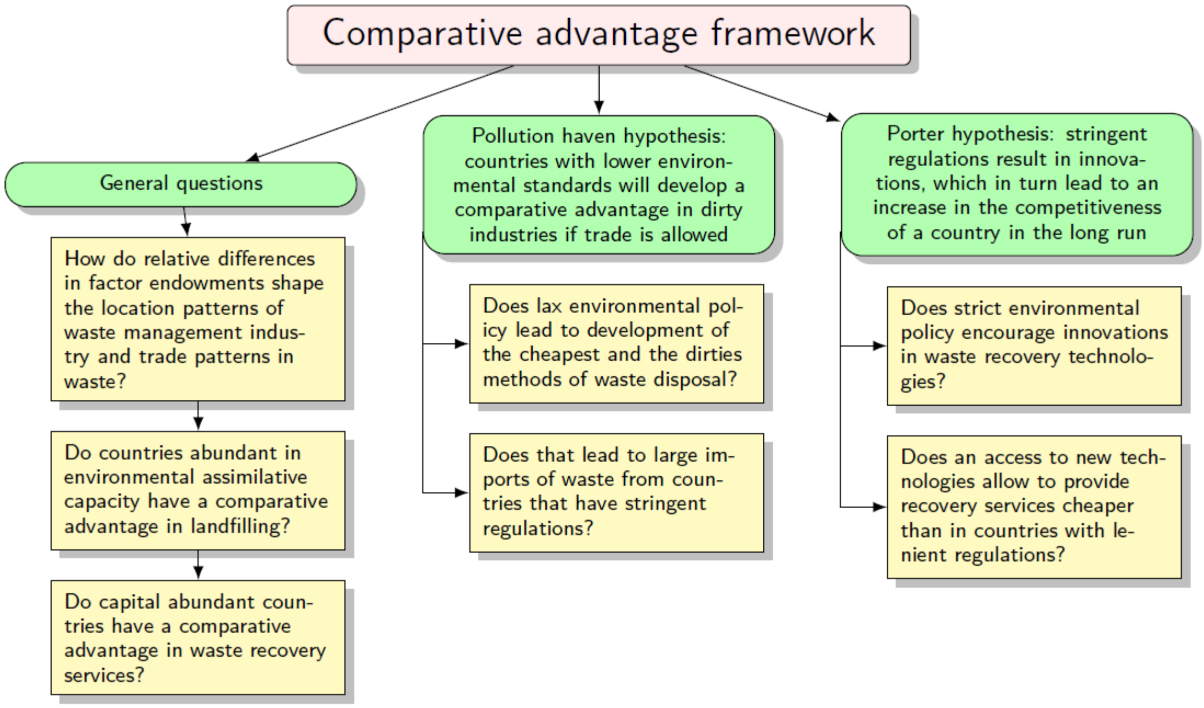

Figure 1.9 Theoretical framework. Source: Own elaboration

Copeland (1991) considers a small open economy with only two production factors, land and labor. Comparative advantage in waste disposal services is associated with land abundance. Copeland shows that if the possibility of illegal waste disposal is not a factor, then the highest level of welfare is achieved by allowing free trade in waste disposal services and reducing negative externalities through the use of domestic policy instruments such as taxes. However, if this first-best policy cannot be implemented or enforced, then trade restrictions may serve as a "second-best" policy. This kind of scenario is common in the real world as taxes set at the socially optimal level can easily be high enough to encourage firms to look for illegal ways of waste disposal. If the government in question is unable to enforce its policies effectively, it is welfare-improving to set a disposal tax below that of the socially optimal level and restrict trade in waste products.

Figure 1.9 summarizes the theoretical framework adopted for this study.[6] The PHH and the PH are viewed as not competing, but as complementary hypotheses; the former being associated with disposal services and the latter with recycling (or recovery) services.[7] This distinction is one of the most important elements that make this study

[6]The HO framework generally assumes free trade. This assumption is violated in most parts of empirical research (chapters 2-4) because trade in hazardous waste is restricted by mandatory bureaucratic procedures. However, if the differences in disposal fees among countries are large enough, it is still possible to uncover a pollution haven effect.

[7]Unfortunately, in most empirical tests it was not possible to distinguish between recycling and

different from previous research.

1.6 Thesis outline

This thesis comprises five chapters, including the general introduction. The chapters are explained in some detail below. Chapters 2, 3, and 4 employ empirical models to test the PHH and the PH. They examine location patterns of the waste management industry and trade patterns in waste products. Chapter 5 provides the general conclusions.

Chapter 2 investigates the influence environmental policy stringency has, together with other factors, such as land and capital endowments, on the location patterns of the European waste management industry. The pollution haven hypothesis and the Porter hypothesis are tested simultaneously through the employment of a model that includes interactions between country characteristics and waste treatment option intensities. Analysis of 27 countries and 3 treatment options reveals that stringent regulations increase a country's share in the recovery sector, supporting the PH. Despite the opposite effect being observed in the final disposal sector, the evidence is not strong enough to confirm the PHH in its original form. The general negative relationship between the pollution intensity and the regulatory stringency, however, indicates the presence of a pollution haven effect.

Chapter 3 tests the PHH by examining country-level data. Two different approaches are presented and contrasted. First, the standard log-linearized gravity model is applied and its results are subsequently compared with the results from the Poisson pseudo-maximum-likelihood estimator. The major advantage of the latter estimator is that it takes into account zero trade flows, allowing for the utilization of all information included in the dataset. Despite suggesting the presence of a pollution haven effect the evidence is ambiguous. In addition the limitations of the country-level data do not allow for reliable analysis of the patterns in waste trade dependent on the treatment option for which it is destined. Accordingly, the conclusion to be drawn is that it is simply not feasible to assess the validity of the PH with respect to the waste management industry by investigating trade in hazardous waste at the country level. Analysis of disaggregated data is indispensable.

Chapter 4 continues and deepens the analysis started in Chapter 3. It offers a fresh look at the pollution haven hypothesis by investigating facility-level data on trade in hazardous waste. Similarly to previous chapters, it distinguishes between waste destined for final disposal and waste destined for recovery. Chapter 4 is divided into two parts:

other recovery services. It was possible only in Chapter 2, where the study is of the location patterns of the waste management industry.

the first examines the factors affecting waste generators' decisions on whether to export waste or manage it domestically; the second investigates the factors that determine the exporting facilities' decision on where to ship waste.

The empirical analysis in the first part is based on the binomial logit model. The results show that the stringency of environmental regulations of an origin country makes facilities, located in that country, more likely to ship their waste abroad; suggesting the presence of a pollution haven effect. However, this cannot be confirmed without subsequent analysis focused on the the characteristics of the destination country.

The second part of Chapter 4 combines very disaggregated data with the highly flexible mixed logit model together with a reliable measure of environmental policy stringency. Including all these elements in one analysis allows for the uncovering of the dramatic differences in the reactions of individual waste generators to the environmental policy stringency of the destination country. Although there is no evidence confirming the PHH in its strongest form, a significant pollution haven effect has been revealed. While most facilities are deterred by the environmental policy stringency of the destination country, there are also waste generators attracted by strict regulations. Nonetheless, facility-level data provided by the E-PRTR is not detailed enough to enable precise analysis of waste streams that do not follow the pattern consistent with the presence of a pollution haven effect.

Chapter 5 summarizes the results and discusses the contribution of the present study to existing literature. It also contains recommendations for further research and indicates policy implications.

Chapter 2

Waste management industry location patterns

2.1 Introduction

This chapter aims to integrate the pollution haven hypothesis and the Porter hypothesis within one model in order to understand the determinants of waste management industry location patterns.

The PHH and the PH can be viewed either as competing or as complementary hypotheses. Both make predictions about the impact of environmental regulations on industry competitiveness, but these predictions seem to contradict each other. Ambec et al. (2013) provide a good example of this point of view: "A third approach to evaluating the PH is to examine competition among nations -which returns to the original hypothesis of Porter that environmental regulation will enhance a country's competitiveness. Much of the empirical literature turns the issue on its head -examining the 'pollution haven' hypothesis -that stringent environmental regulation will induce firms to leave the country for less strict (and hence, less expensive) regulatory regimes. The PH would suggest just the opposite". However, confirming the PHH is not necessarily equivalent to disproving the PH. It can happen, for example, when a country has a stringent, but inflexible environmental policy. Most studies choose to test just one of the two hypotheses, there is, however, also a call for an integrated approach (D' Agostino, 2015). The waste management industry (WMI) is suitable for testing both hypotheses simultaneously.

If the WMI were homogeneous, implementing stringent regulations by one country would cause that country to either lose or build its share in the global WMI, depending on which of the two hypotheses was true in this case. However, the heterogeneity of the WMI makes it conceivable that some firms will follow the PH and increase their market share, while others will go out of business unable to cope with competition from countries having lax regulations. In other words, different levels of regulatory stringency across countries may generate specialization.

Principally, waste can be either disposed of or recovered. If the trade in waste were free, countries abundant in land and characterized by lax environmental controls would probably develop a comparative advantage in landfilling, whereas capital-abundant countries with a systemic approach to environmental protection would specialize in recovery services. It is conceivable that even more waste than at present would end up in landfills, however, surely not all waste. It is feasible that at least some waste can become valuable material, but it often requires treatment using advanced technology. According to the PH, the kind of technology needed may be developed in response to a well-designed environmental policy. Long before the PH was even formulated, American inventor, architect, and philosopher R. Buckminster Fuller said "Pollution is nothing but the resources we are not harvesting. We allow them to be dispersed because we've been ignorant of their value" (Farrell, 1971, p. 51). Porter and van der Linde (1995) argue similarly that pollution can be seen in many cases as a waste of resources.[1]

There are real-world examples suggesting that some countries have developed a comparative advantage in recycling because of advanced technology they possess, whereas other countries seem to have a comparative advantage in landfilling. In Poland, for instance, no waste management firm has the technology required to recover metals from spent catalysts, used in chemical processes. Consequently, Anwil SA, one of the largest fertilizers, plastics, and chemicals producers in the CEECs region, faces the choice of either paying for the disposal of its spent catalysts in a hazardous waste landfill in Poland or to being paid for the material by a foreign-based company which has access to the technology necessary for the recovery of valuable metals. Even though the export of hazardous waste is very expensive (transportation costs, lengthy bureaucratic procedures, etc.) the firm still finds it profitable to sell the spent catalysts to a Dutch company instead of disposing of them domestically.[2]

Trade in the opposite direction usually occurs because of the differences in price for waste management services. In the 1990s there was some controversy in the media over the issue of dumping used tyres from Western Europe in Eastern European landfills.(van Beukering, 2001). The disposal fees in Eastern Europe were much lower than those in the West, as were the environmental protection standards. It is worth noting that trade

[1] Interestingly, the "ignorance" mentioned by R. Buckminster Fuller happens to be an important element of the PH too. If a profit-maximizing firm needs government regulation in order to create a profit-increasing innovation, it must be ignorant of some profitable opportunities.

[2] Relevant data can be found in the E-PRTR database.

in waste, with the purpose of disposal, is much more restricted now than it was in the past; nevertheless, these two examples serve as a source of inspiration in the formulation of the following hypotheses:

1. Countries characterized by relatively lax environmental controls tend to have a comparative advantage in waste disposal services (consistent with the PHH).
2. Countries with stringent environmental regulations tend to have a comparative advantage in waste recovery services (consistent with the PH).

It must be noted here that trade in all hazardous waste and non-hazardous waste intended for disposal is restricted and that this fact violates the assumption of free trade: a key element of the theoretical framework adopted for this study. The restrictions, in force, make it difficult for countries to specialize in waste disposal services. By investigating location patterns under these conditions it is possible to test whether the EU policies have been successful in preventing the creation of pollution havens. If there is no pollution haven effect, it may mean that either the environmental regulations are efficient, or too strict, or that they are not necessary at all. If, however, a pollution haven effect is present, despite strict regulations, the restrictions can be seen as justified.[3] In such a case it is very likely that a pollution haven effect would be stronger in the absence of restrictions. It should be emphasized that the restrictions (mostly costly bureaucratic procedures) do not prohibit trade (although there are rare exceptions), but simply make it more expensive. Therefore, the differences in disposal fees among countries have to be far greater for the trade to occur and for the pollution haven effect to be revealed.

In this study the waste management sector is treated as an industry, which is affected by environmental regulations, in such a way that it uses different technologies and approaches depending on the stringency level of said regulations. This feature of the WMI makes it possible to test both hypotheses empirically by investigating the location patterns of various treatment options. Integrating the PHH and the PH in this case is not only feasible but also desirable. Demonstrating an integrated approach in the WMI context is surely one of the most important contributions of this study to existing literature.

The major limitation of previous research is the fact that it tests the PHH without making any distinction between waste destined for recovery and that destined for final

[3]Especially because in the case of the EU, preventing poorer countries from becoming pollution havens for wealthier countries is one of the most important objectives of the restrictions.

disposal.[4] Without making this distinction, analyzing trade in waste results at most in revealing a moderate or small pollution haven effect.[5] Generally, existing studies make it clear that developed countries are net importers of hazardous waste (Baggs, 2009; Kellenberg and Levinson, 2014). Moreover, Baggs (2009) suggests that if there were no distance costs, the trade in toxic waste would more than double with the largest increase in shipments to OECD nations.[6]

Most papers investigating the impact of environmental policies on the WMI focus on the PHH. One recent piece of research, however, confirms the ”weak” version of the PH by showing that the number of innovations in the waste management sector tends to increase as a country's environmental policy becomes more stringent (Cecere and Corrocher, 2016).

In addition to the research on trade flows, there is one study on location decisions of waste management firms. Stafford (2000) analyzed location patterns of the hazardous waste management industry in the United States and confirmed a pollution haven effect. This chapter is the first attempt the author is aware of, to investigate WMI location patterns in an international setting.

The present study also contributes to the literature by comparing various measures of regulatory stringency. The first, basic index, abbreviated as SER (Stringency of Environmental Regulations), has been inspired by the available literature (Kheder and Zugravu, 2012) and consists of three components: Multilateral environmental agreements ratified (MEAs), Membership in international non-governmental organizations (INGOs) and Energy efficiency. The second measure is a proxy for regulatory stringency (PRS), constructed by combining two variables: the Corruption Perception Index (CPI) and Income (PPS) per inhabitant. Finally, this chapter uses an index that measures environmental awareness, specifically, the Environmental Awareness Index (EAI),

[4]Obviously, waste streams are not homogeneous. Waste destined for final disposal at landfills has a ”negative price”, whereas waste destined for recovery can have a positive price. If no distinction is made, the trade in waste that contain valuable materials and is going to be treated with sophisticated technology is seen as supporting the pollution haven effect, in the same way as the trade in waste intended for landfilling.

[5]It is worth noting that existing research on trade in waste is, in large part, limited to hazardous waste flows as data on hazardous waste is relatively easy to obtain from a variety of databases, but analysing the WMI location patterns, rather than those of trade, enabled the overcoming of this limitation. However, if only the PHH is to be tested then it is actually better to focus on hazardous waste. The reason being most hazardous waste has to be disposed of with much less potential for recycling than in the case of non-hazardous waste (Albers, 2015).

[6]However, there is research which proposes a theoretical model showing that, in the case of e-waste, it can be cheaper for developed countries to export it to developing countries than to dispose of it locally (Kellenberg, 2010). This is consistent with the PHH because developing countries are usually assumed to have less stringent environmental policies than developed nations.

which was introduced by Harju-Autti and Kokkinen (2014). All environmental policy stringency measures are explained, in detail, in Section 1.4 of Chapter 1.

The remainder of this chapter proceeds as follows: Section 2.2 provides background information on the waste management sector within the EU; Section 2.3 outlines the empirical model; Section 2.4 describes the dataset; Section 2.5 presents the empirical results and the last section concludes the chapter.

2.2 Background on the waste management industry in the EU

The vast majority of countries included in the sample are EU Member States.[7] Accordingly, in addition to the national legislation, they are required, in theory, to follow the European standards and rules that have been developed in order to achieve a circular economy.[8]

The legislative framework for waste management is very complex and can be analyzed at several levels. At the most general level there are global and European commitments, which are either directly incorporated into EU directives (e.g., Basel Convention, 1989) or they set the context for more detailed legislation (e.g., 7th Environment Action Programme, 2014-2020). The overall framework for the management of waste, including definitions and principles, is provided by the Waste Framework Directive (2008) and the Waste Shipment Regulation (2006).[9] The more detailed legislation includes directives on waste treatment operations (e.g., the Landfill Directive, 1999) and directives on waste streams (e.g., sewage sludge, 1986; end-of-life vehicles, 2000).

The EU legislation has been designed in such a way as to encourage Member States to treat most waste domestically and follow the waste hierarchy.[10] In principle, if the export of waste does occur, it should be destined for recovery and, if possible, directed to another EU Member State. Countries can prohibit imports destined for final disposal

[7]Norway is the only exception. However, as a member of the European Economic Area (EEA), it is tightly associated with the EU. Other EEA countries were excluded from the sample due to a lack of data.

[8]The environmental standards and the level of enforcement, however, vary markedly across countries.

[9]Basic principles, such as the precautionary principle and the polluter-pays principle, were first defined in the Treaty on the Functioning of the European Union (1958) and the Treaty on European Union (1992).

[10]According to the five-step waste hierarchy, defined in the Waste Framework Directive, prevention should be considered the most desirable option and is followed by re-use, recycling, recovery other than recycling, and disposal as the worst option.

altogether some actually having done so.[11]

The waste statistics show that the EU is getting closer to achieving its goals. Figure 2.1 illustrates how the difference between the amount of waste generated and treated in the EU has been getting smaller over the years.

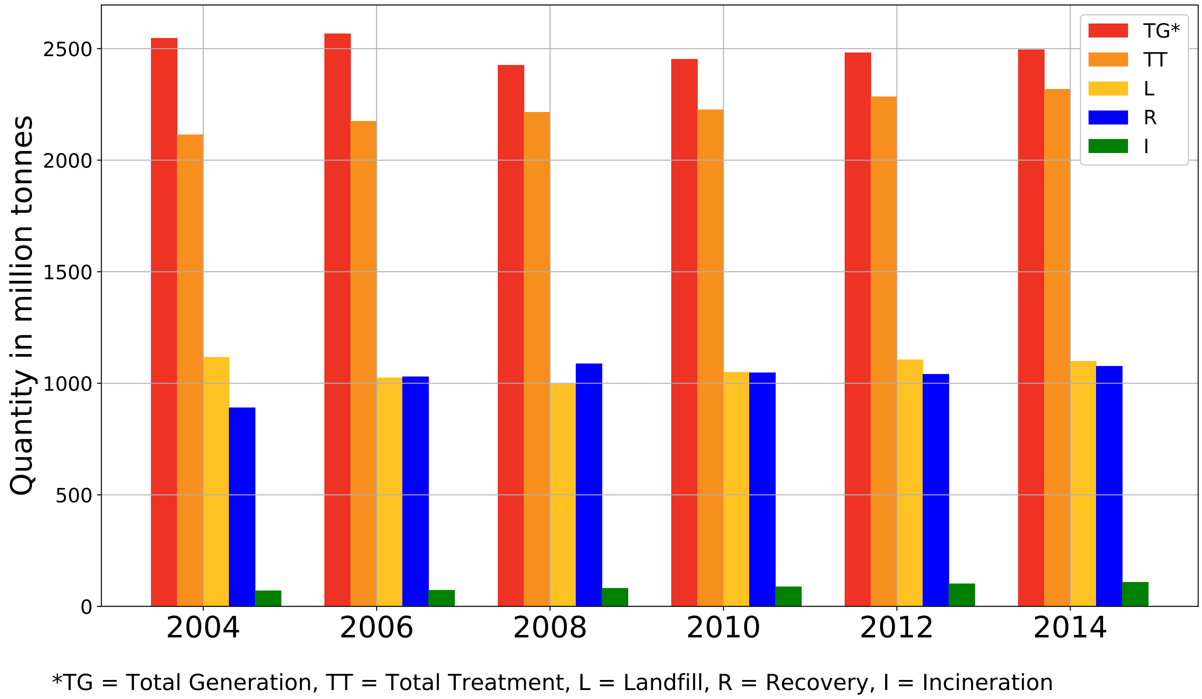

Figure 2.1 Generation and treatment of waste in EU Member States, 2004-2014. Source: Own elaboration based on the Eurostat

What is also observable is that the amount of waste generated tends to increase, year on year, with the notable exception of the period of financial crisis. There is also an increase in recovery operations and a decrease in disposal operations.[12] Figure 2.B.1 in Appendix 2.B shows even more clearly how the treatment rates and recovery rates are increasing and disposal rates are decreasing.[13]

Country-level data suggests that some countries treat a larger fraction of their waste domestically than do others and a few countries are net importers of waste. However, the question central to this research is: What is the extent of specialization across countries in the area of waste management? In order to analyze the differences in the

[11]Hungary, Poland and Slovakia prohibit imports of waste if it is destined for final disposal.

[12]"Incineration" in Figure 2.1 and Figure 2.B.1 (Appendix 2.B) refers to incineration with energy recovery. "Recovery" means recovery other than energy recovery, which is approximately equivalent to recycling.

[13]Treatment rate is the ratio of the amount of waste treated in the EU to the total amount of waste generated in the EU. Disposal (or recovery) rate is the ratio of the amount of waste slated for final disposal (or recovered) to the total amount of waste treated in the EU.

waste management market structures of countries it was decided to use the so-called Krugman Specialization Index (KSI), defined as follows:

$$KSI = \sum_{w=1}^{W} |s_w - \bar{s_w}|, \tag{2.1}$$

where s_w is the share of one treatment option in the whole waste management market in one country and $\bar{s_w}$ is the mean of all other countries. The index takes values from 0 to 2, and the higher the value, the more a country is characterized as specialized.

Table 2.1 Krugman Specialization Index computed for a sample of 27 European countries

Country	KSI 2004-08	KSI 2010-14	Country	KSI 2004-08	KSI 2010-14
Austria	0.53	0.12	Italy	0.40	0.62
Belgium	0.71	0.73	Latvia	0.20	0.10
Bulgaria	1.10	1.16	Lithuania	0.48	0.53
Croatia	0.67	0.34	Netherlands	0.87	0.82
Cyprus	0.42	0.21	Norway	0.37	0.61
Czech Rep.	0.44	0.50	Poland	0.65	0.50
Denmark	0.82	0.51	Portugal	0.20	0.15
Estonia	0.40	0.23	Romania	1.04	1.12
Finland	0.41	0.49	Slovakia	0.02	0.17
France	0.34	0.31	Slovenia	0.24	0.58
Germany	0.56	0.61	Spain	0.31	0.09
Greece	0.77	0.85	Sweden	0.69	0.66
Hungary	0.43	0.14	UK	0.07	0.36
Ireland	0.36	0.06			

Source: Own elaboration based on the Eurostat

The size of the waste management market is proxied by the total amount of waste treated in this market (measured in tonnes).[14] The size of a particular treatment option is defined similarly, as the amount of waste processed with that option. Table

[14]Another approach would be to use the number of facilities. This approach does not ensure comparability across countries, however, since facilities differ in size.

2.1 reports values calculated for countries from the sample: considered were the average values for two time periods: 2004-2008 and 2010-2014. The smaller value in each row is highlighted. The number of highlighted values is similar for all columns, meaning that countries neither converge nor become more specialized over time. One thing is clear, however, the majority of the countries seem to have a market structure considerably different from the sample average. In particular, two new Member States, Bulgaria and Romania, have a large index value (in excess of 1).[15]

In the case of most countries, the value of the KSI has not changed much over time. The structural differences remain sizeable, although it can be expected that the new Member States' waste management industry will eventually become more similar to that of the old Member States as a result of an effort to comply with European Community legislation.

2.3 The model

The WMI's structure within a country depends on a number of factors. This chapter concentrates specifically on the environmental policy stringency and its role in shaping waste management markets across Europe. One way of assessing how the share of each treatment option is affected by the stringency of environmental regulation is to interact the variables representing the pollution intensity of all three treatment options with the environmental policy variable. This approach allows for integrating the PHH and the PH within one model and for showing explicitly that different treatment options respond in different ways to a country's environmental regulations. Therefore, there is no such thing as an overall comparative advantage in waste management services. Ultimately, a comparative advantage, in any treatment option, depends on a complicated interplay of a country's characteristics and the corresponding treatment option's intensities.

Midelfart-Knarvik et al. (2000) introduced a model suitable for determining how endowments of countries and related attributes of industries interact to create different market structures in different countries. The model was originally developed in order to investigate European industry location patterns using two groups of variables. The first group is associated with the New Economic Geography Theory and includes, for example, market potential as a country characteristic and economies of scale as an industry characteristic.[16] The second group of variables represents the theory of comparative

[15]This means that more than 50 percent of waste would have to be treated differently in those countries to achieve the market structure of an average country from the sample.

[16]New economic geography (NEG) is one of the approaches employed to the study of spatial organization of economic activities. According to this theory, the crucial factors affecting firms' location decisions include economies of scale, the level of demand, transportation costs, etc. (see Krugman,

advantage and incorporates the variables such as abundance of labor in a country and labor intensity of an industry. Combining comparative advantage and new economic geography models results in the following reduced form equation:[17]

$$log(Share_{i,w}) = c + \alpha log(Gen_i) + \sum_j \beta^j (y_i^j - \gamma^j)(z_w^j - \kappa^j) \tag{2.2}$$

The dependent variable is defined as the share of country i in the waste treatment option w:

$$Share_{i,w} = \frac{x_{i,w}}{\sum_i x_{i,w}}, \tag{2.3}$$

where $x_{i,w}$ is the size of treatment option w in country i.

Gen_i, the first independent variable in the model, represents the effects of the size of a country. It measures the share of the amount of waste generated in a given country in the sample's total waste generation. All else being equal, larger countries are expected to have a larger share of the waste management sector. The variables in the summation term measure the jth interaction between a country i's characteristic (y_i^j) and the related treatment option w's intensity (z_w^j). α, β^j, γ^j and κ^j are coefficients. α measures the impact of the scale variable. β^j is the coefficient of particular interest to this study as it represents the effect that variations in the country characteristics have on the WMI's location decisions. Characteristics and intensities have been selected in such a way that β^j is expected to be positive for all interactions. γ^j and κ^j allow the product, which is inside the summation term, to equal zero. This occurs in two cases. The first is when a particular country characteristic level (γ^j) has no effect on the share of treatment options, regardless of their levels of associated intensity. The second is when a certain level of treatment option's intensity (κ^j) causes this option to be unaffected by the level of the corresponding country characteristic. γ^j and κ^j can be termed 'neutral' levels of a country characteristic and a waste treatment option intensity, respectively.

The set of country and treatment option characteristics takes into account special features of the WMI and therefore differs from that used by Midelfart-Knarvik et al. (2000).[18] It includes an interaction between the environmental policy of a country and the pollution intensity of a treatment option. As a matter of fact, a similar interaction has been tried already by Mulatu et al. (2010) who adopted Midelfart-Knarvik et al.'s

1991).

[17]Some modification of notation was necessary in order to customize the model to this research.

[18]Despite trying to include both NEG and HO variables only variables associated with HO seemed to work and consequently only these variables appear in the empirical part in Section 2.5. Mulatu et al. (2010), who investigated the manufacturing industry, also found NEG variables to be insignificant.

(2000) model to test the PHH with respect to the manufacturing industry in a sample of 13 European countries.

The remainder of the interactions in the present version of the model consist of the following pairs of variables: (i) Land Scarcity and Facility Size; (ii) Capital Abundance and Capital Intensity; (iii) Coldness of Climate and Heat Generation. All variables are described in detail in Section 2.4.

2.4 Data

The core empirical analysis is cross-sectional and uses a sample of 27 European countries and the 3 most common treatment options: landfilling, recovery other than energy recovery (mostly recycling), and incineration with energy recovery.[19] It is conducted separately for the two time periods: 2008-2010 and 2012-2014. Finally, a panel data analysis is used as a robustness check. Variables, as well as data sources, are described in Table 2.2, however, several issues require further explanation.

Most of the interactions are dictated by theory. The land, capital, and environmental interactions are consistent with comparative advantage models. The climate interaction has been inspired by literature (SLR Consulting Limited, 2005). It is worth noting that rather than using a measure of land abundance a measure of land scarcity was preferred and then paired with the facility size variable prefixed with a minus sign. Similarly, a measure of environmental laxity could have been paired with the pollution intensity of a treatment option, instead, the pollution intensity variable was converted to the cleanliness variable and then used to construct the policy stringency and cleanliness interaction.

Table 2.2 Variables description

	Country Characteristic	**Industry Characteristic**
Variable	Land Scr. (Land Scarcity)	Size
Definition	Population density (2009 and 2013)	Average facility size in ha (prefixed with a minus sign to indicate that the land required to construct a facility is lost for other uses)

[19]As Mulatu et al. (2010) pointed out, using a dataset that consists only of European countries reduces the risk of omitted variable bias because of the similarities across countries in many important areas such as history, culture or institutions.

Source	Eurostat	NLWA (North London Waste Authority), Eurostat[a]
Variable	Capital Abd. (Capital Abundance)	Capital Int. (Capital Intensity)
Definition	Capital stock at current PPPs per inhabitant in mil. 2011 USD (2007 and 2011)	Initial capital cost in million 2011 USD[b]
Source	Penn World Tables, Eurostat	Broome, Vaze and Hogg (2000)
Variable	(1) SER, (2) PRS, (3) EAI	Cleanliness
Definition	(1) SER (Stringency of Environmental Regulations) is an index integrating three components: MEAs ratified, Membership in INGOs, and Energy efficiency (2009 and 2013) (2) PRS (Proxy for Regulatory Stringency) combines an indicator of the corruption level and normalized income (PPS) per inhabitant (2009 and 2013) (3) EAI (Environmental Awarness Index) measures the environmental awareness of a country (2013)	Pollution intensity (USD 2011 per tonne of waste) prefixed with a minus sign.[c] I assume pollution intensity of recycling to be zero because any pollution associated with recycling activities is offset by the reduction in the pollution caused by the extraction and processing of virgin materials as well as the pollution caused by landfilling or incineration.[d]
Source	(1) IEA Database, The Yearbook of International Organizations, Eurostat (2) Transparency International, Eurostat, (3) Harju-Autti and Kokkinen (2014)	Rabl, Spadaro and Zoughaib (2008)
Variable	Coldness	Heat Generation
Definition	Mean annual heating degree-days (2009 and 2013)[e]	Heat generation from waste (GJ/t)[f]
Source	Eurostat	Jeswani and Azapagic (2016)
Size Variable	LogGen (Waste generation)	NA
Definition	Natural log of the share of a country's waste generation in the sample's total waste generation	NA
Source	Eurostat	NA
Dependent Variable	LogShare (Treatment Option Share)	NA

Definition	Natural log of the share of a country in a given waste treatment option (average for the periods: 2008-2010 and 2012-2014)	NA
Source	Eurostat	NA

[a] Average size of a landfill in countries was estimated from the sample using the data on the number and rest capacity of landfills in Europe. A cross-section shape of an isosceles trapezoid, the height of 20 meters, was assumed (Durmusoglu 2004), and the 3:1 slope (MIT, 2004). Also assumed was that, on average, a landfill is in the middle of its lifespan.

[b] The costs, in the original source, are expressed in 1997 GBP, they have, however, been converted to 2011 USD.

[c] Converted from EUR 2004.

[d] In fact, it is usually more than offset. However, it was not possible to choose any positive number here because of the difficulty in precisely calculating how much reduction in pollution occurs in the country where recycling facilities are located. Countries with a large recycling sector are not necessarily large virgin materials producers.

[e] Heating degree-days express the severity of the cold in a specific time period, taking into consideration outdoor temperature and room temperature. The Eurostat defined the following method for the calculation of heating degree days: $(18°C - Tm)d$ if Tm is lower than or equal to 15 °C (heating threshold) and are nil if Tm is greater than 15 °C, where Tm is the mean $(Tmin + Tmax/2)$ outdoor temperature over a period of d days.

[f] The estimate for a landfill is divided by 10 because only about 10 percent (Smart Ground, 2017) of landfills in Europe are sanitary landfills capable of energy recovery.

The data on waste treatment option intensities (the size of recycling and incineration facilities, capital intensity, heat generation) has been obtained, in most cases, from British sources. Obviously, some of these values may vary from country to country: however, in this research, the magnitudes of the differences in intensity levels across treatment options are much more important than the actual numbers, and it can be assumed that they should be about the same for all countries in the sample. The value of the landfill size variable and also the value of pollution intensity, are based on European averages.

A list of countries included in the sample together with descriptive statistics for all variables are presented in tables 2.A.1, 2.A.2, and 2.A.3 in Appendix 2.A.

2.5 Estimation and results

2.5.1 Cross-sectional analysis

The estimating equation is obtained by expanding (2.2):

$$log(Share_{i,w}) = c' + \alpha log(Gen_i) + \sum_j (\beta^j y_i^j z_w^j - \beta^j \gamma^j z_w^j - \beta^j \kappa^j y_i^j) + \varepsilon_{i,w}, \qquad (2.4)$$

where $c' = c + \sum_j \beta^j \gamma^j \kappa^j$.

Ordinary Least Squares estimation results of (2.4) are summarized in Table 2.3. Combining 27 countries and 3 treatment options yields a total of 81 observations.[20] Given a small sample size and a potential heteroskedasticity problem, a special effort is required to ensure the validity of results. Therefore, it was decided to use heteroskedasticity consistent covariance matrix, known as HC3, which is in line with the recommendations presented in the literature (Long and Ervin, 2000; Hausman and Palmer, 2011).[21]

Five different specifications were estimated. Models (1), (2), and (5) have been estimated for the period 2012-2014. Models (3) and (4) cover the period 2008-2010.[22] Models (1) and (3) use the SER index, models (2) and (4) the PRS index, and model (5) uses the EAI as a measure of environmental policy stringency.

The focused interest of this research is in coefficients on the interactions. In all models they resulted in having expected positive values, indicating that treatment options intensive in a given factor tend to be located in countries abundant in the related characteristic. In the case of land and climate interactions, the values of coefficients are very similar regardless of specification. They are also significant, though at different levels. Interestingly, the capital interaction is insignificant in models covering the period 2008-2010. It is possible that this interaction has become more important in recent years due to incineration plants, which are the most capital-intensive option, gaining popularity, especially in capital abundant countries. Interactions between the cleanliness variable and all three measures of regulatory stringency have coefficients suggesting that countries with stricter policies have a larger share of less polluting treatment options.[23] The coefficients are of similar magnitude and significance, but in models (2) and (5) they are significant only at the 10% level.

[20]The last specification is an exception because the EAI is available for only 23 of the 27 countries in the sample. This reduces the number of observations to 69.

[21]HC3 and HCJ are the most conservative of the HCj estimators. Estimation was attempted with HC0, HC1 as well as HC2 and in all cases the significance of the coefficients increased dramatically.

[22]Table 2.2 in Section 2.4 shows the period (or year) for which a given variable was computed. It is worth noting here that the capital abundance variable for 2007 and 2011 was calculated as it was assumed that capital-intensive projects such as an incineration plant often take several years to be completed.

[23]The EAI has been converted to 1-100 scale making the coefficients on all regulatory stringency variables comparable.

Table 2.3 Regression results (cross-sectional analysis)

		Dependent variable:				
		LogShare				
		(1)	(2)	(3)	(4)	(5)
	Constant	-0.06	0.04	-0.14	-0.14	-0.05
		(0.25)	(0.26)	(0.25)	(0.26)	(0.28)
Size Variable	LogGen	0.88***	0.87***	0.88***	0.88***	0.86***
		(0.07)	(0.07)	(0.08)	(0.08)	(0.08)
Interactions	Land Scr. x Size	0.001***	0.001***	0.001***	0.001***	0.001***
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	Capital Abd. x Capital Int.	0.15**	0.14**	0.09	0.07	0.14**
		(0.06)	(0.07)	(0.09)	(0.10)	(0.07)
	SER x Cleanliness	0.0012**		0.0012**		
		(0.00)		(0.00)		
	PRS x Cleanliness		0.0010*		0.0012**	
			(0.00)		(0.00)	
	EAI x Cleanliness					0.0011*
						(0.00)
	Coldness x Heat generation	0.0003***	0.0003***	0.0003**	0.0003**	0.0003*
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Country Char.	Land Scr.	0.01***	0.004**	0.005***	0.003*	0.004**
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	Capital Abd.	-1.98	-3.84	0.16	-0.16	-3.16
		(4.00)	(4.57)	(4.73)	(5.73)	(4.05)
	SER	0.01		0.01		
		(0.01)		(0.01)		
	PRS		0.02*		0.01	
			(0.01)		(0.01)	
	EAI					0.02**
						(0.01)
	Coldness	-0.00002	-0.00008	-0.00003	-0.00005	-0.0001
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Facility Char.	Size	0.06	-0.08	0.18	0.19	0.04
		(0.37)	(0.39)	(0.37)	(0.39)	(0.42)
	Capital Int.	−0.05***	−0.04***	−0.04***	−0.04**	−0.04***
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
	Cleanliness	-0.10	-0.04	-0.16	-0.16	-0.11
		(0.16)	(0.17)	(0.16)	(0.17)	(0.19)
	Heat Generation	0.03	-0.02	0.08	0.08	0.03
		(0.14)	(0.15)	(0.14)	(0.15)	(0.16)
Obs.		81	81	81	81	69
Adj. R^2		0.805	0.805	0.737	0.742	0.758
Note:						*p<0.1; **p<0.05; ***p<0.01

For most interactions the models predict that a higher level of treatment option intensity will, in countries abundant in the corresponding characteristic, increase the share of this option. However, in order to understand how country characteristics affect each of the three treatment options of interest, it is necessary to compute the neutral level of all intensities. In the case of capital intensity and energy generation intensity, treatment options that are above cut-off points can be considered intensive for these factors. In contrast, for a treatment option to be land intensive or pollution intensive, the value of the relevant intensity must be lower than the associated cut-off point. Table 2.4 reports the cut-off points for model (1).[24]

Table 2.4 Waste management industry characteristics and cut-off points.

Facility Characteristic	Cut-off Point	Landfill	Incineration	Recycling	Above	Below
Size	-4.25	-8.60	-3.00	-1.50	I, R	L
Capital Intensity	13.27	8.9	89.01	22.25	I, R	L
Cleanliness	-9.83	-18.6	-5.85	0.00	I, R	L
Energy Generation	0.075	0.0229	1.785	0.00	I	L, R

Notes: L, I, and R refer to ”Landfill”, ”Incineration”, and ”Recycling” respectively.

Only incineration is energy generation intensive. Thus, all other things being equal, the colder a country is, the larger its share of incineration. Consistent with intuition, landfilling, as a land-intensive option, is more common in land abundant countries. It is also pollution intensive, so its share is larger in countries with relatively lax environmental policies. Incineration and recycling are above the cut-off points for cleanliness and capital, which means that their share increases when a country becomes more capital abundant and when its environmental regulations become more stringent.

Unfortunately, neither the reported regression results, nor cut-off points, enable the assessment of the relative importance of coefficients. In order to make such comparisons possible, variables required normalizing by their standard deviations before running (2.2).[25] Coefficients reported in Table 2.5 are comparable because they show how the dependent variable is affected by the explanatory variables, in terms of standard deviation units.

Land abundance appears to be the most important factor in determining the location of a waste management facility. The climate interaction is of secondary importance and is closely followed by the capital abundance and capital intensity interaction. The environmental policy variable appears to have slightly less importance than other factors, but generally the differences in the magnitudes of coefficients are rather moderate.

The coefficients only serve to show the average influence of the studied characteristics. To obtain an even better understanding of the strength of the interactions between country and waste treatment option characteristics at different intensity levels, it is crucial to assess the marginal effects at those levels.

[24]Further analysis will concentrate on this specification as it appears to be the best fit.

[25]Running directly equation (2.2) required substituting in the cut-off points estimated from (2.4).

Table 2.5 Standardized coefficients of interactions (Model (1)).

Interactions	Coefficients
Land Scarcity x Size	0.2237***
Capital Abundance x Capital Intensity	0.1537**
Environmental Policy Stringency x Cleanliness	0.1205**
Coldness x Heat generation	0.1655***

Notes: *p<0.1; **p<0.05; ***p<0.01

As Bramber et al. (2006) point out, substantively meaningful marginal effects should be calculated whenever a model includes multiplicative interaction terms. Coefficients on interaction and constitutive terms, as reported in a typical results table, do not tell the whole story and sometimes can even be misleading.

First, it must not be forgotten that the ability of coefficients on constitutive terms to measure the marginal effects on a dependent variable are dependant on the other variables, included in the interaction term, being equal to zero. Obviously, in the case of some modifying variables, it would be meaningless to interpret such effects as they never equal zero in the real world (e.g., facility size). Second, it is important to compute marginal effects of interactions at various levels of a conditioning variable as it is possible for the effects to be significant at some levels despite the coefficient on the interaction term having little or no significance. The opposite can also happen. The significance of an interaction does not guarantee the significance of marginal effects for the actual observed values of a modifying variable.

The marginal effect of a country characteristic at various intensity levels can be easily calculated from (2.2):

$$\frac{\partial log(Share_{i,w})}{\partial y_i^j} = \beta^j(z_w^j - \kappa^j) \tag{2.5}$$

The significance of marginal effects can be computed analytically by using the variance-covariance matrix from the estimated regression and the following formula for standard error:

$$se[\beta^j(z_w^j - \kappa^j)] = \sqrt{var[\beta^j\kappa^j] + (z_w^j)^2 var[\beta^j] - 2z_w^j cov[\beta^j, \beta^j\kappa^j]} \tag{2.6}$$

Formula (2.6) allows for constructing a 95% confidence interval (CI), either for a continuous conditioning variable or at the observed levels of this variable. The marginal effects at observed intensity levels for the first specification are reported in Table 2.6.

Table 2.6 Marginal effects (ME) at different intensity levels (Model I).

	ME				Normalized ME			
	Env. Policy	Land Scr.	Capital Abd.	Coldness	Env. Policy	Land Scr.	Capital Abd.	Coldness
Landfill	−0.01*	−0.005***	-0.65	-0.00002	−0.14*	−0.31***	-0.02	-0.01
Incineration	0.005	0.002*	11.27***	0.0005***	0.06	0.1*	0.33***	0.34***
Recycling	0.011*	0.003***	1.33	-0.00002	0.15*	0.2***	0.04	-0.014

Notes: *p<0.1; **p<0.05; ***p<0.01

The marginal effect of land scarcity variable is negative for landfills and positive for other treatment options indicating that, other things being equal, the smaller endowment of land a country has, the smaller its share of landfills and the larger its share of incineration and recycling facilities (see Figure 2.B.2 in Appendix 2.B).

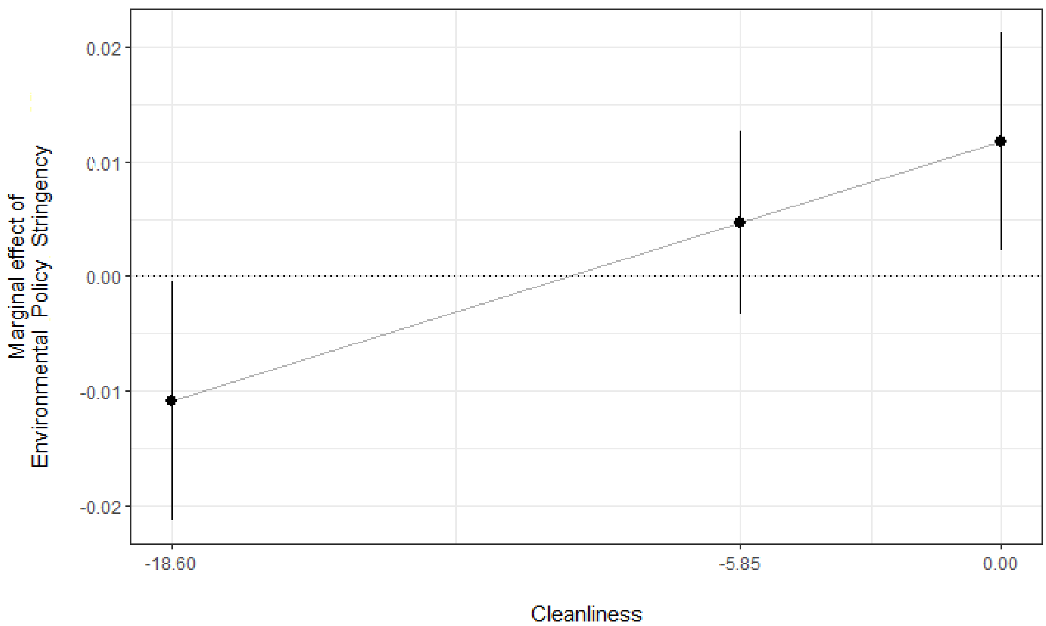

Figure 2.2 Marginal effects of regulatory stringency for the first specification. CI = 90 percent

The capital abundance variable is significant only at the highest level of capital intensity. Thus, it has a positive effect on the location of incineration facilities and no effect on the location of other treatment options. Similarly, the coldness of climate appears to influence only a country's share of incineration (see Figure 2.B.3 and Figure

2.B.4 in Appendix 2.B). Generally, colder countries rely more on this option because energy from waste can be used to supply heat to district heating networks. Standardized marginal effects indicate that the capital abundance and coldness of climate have a similar impact on the location of incineration plants.

Finally, the effects of the environmental policy variable on landfilling and on recycling go in opposite directions, as expected (see Figure 2.2 above) with almost the same magnitude. Furthermore, normalized coefficients show environmental policy stringency to be the second largest determinant of recycling facilities' share. However, since the coefficients are significant only at the 10% level, it was necessary to calculate marginal effects for two alternative measures of regulatory stringency. It transpires that in both cases the effect on recycling is significant, at the 5% level, whereas the effect on landfilling is insignificant (see Figure 2.3). The effect of the environmental policy variable on incineration is significant only for model (5), which, as can be seen, uses the EAI.

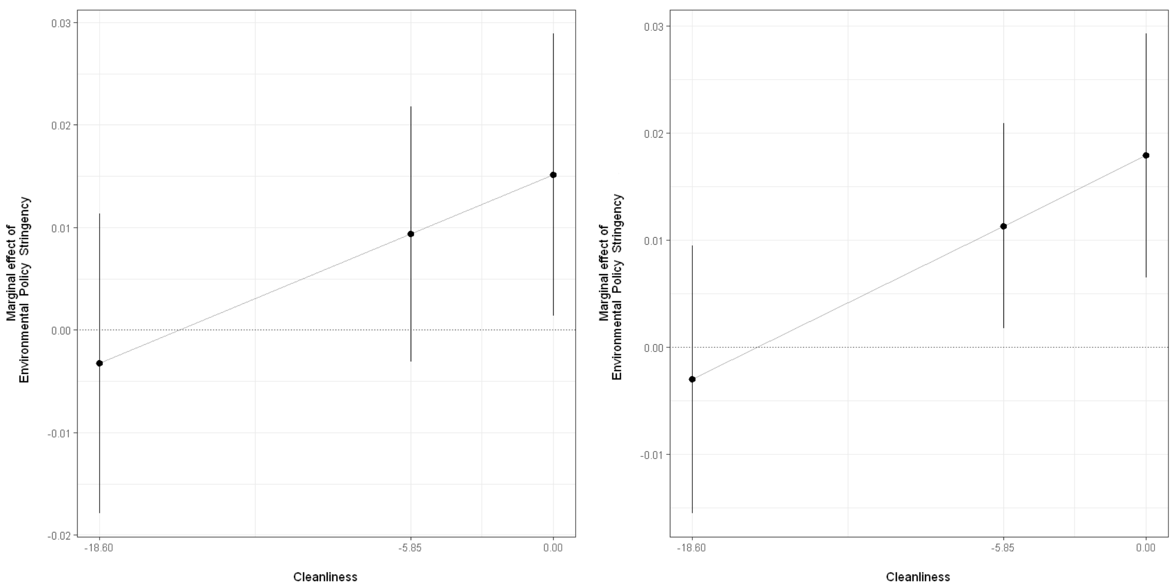

Figure 2.3 Marginal effects of regulatory stringency for models (2) (left) and (5) (right). CI = 95 percent

When all three measures of regulatory stringency are considered, the results are somewhat ambiguous. Certainly, the general negative relationship between the pollution intensity and the regulatory stringency points to the presence of a pollution haven effect. The lack of clear evidence in the case of landfilling can be explained by the fact that the waste disposal market in the EU is considerably restricted, as mentioned in the introduction to this chapter. The EU policies seem to be fairly efficient, but not completely successful in preventing a pollution haven effect. In contrast to waste intended for disposal, non-hazardous waste destined for recovery can be traded relatively freely. Therefore, it is much easier for a country to specialize in recovery services than in disposal services and, as a matter of fact, the significant and positive marginal effects in the case of recycling for all three specifications indicate that strict environmental regulations foster specialization in this area.

2.5.2 Panel data analysis

Mulatu et al. (2010), who applied the same model to test the PHH with respect to the manufacturing industry in Europe, suggested that one way to enhance their research would be to use panel data.

There are lots of advantages to panel data over cross-section data; it usually offers more variability and more efficiency. It was possible to collect time-varying data for the dependent variable, the size variable, and all country characteristics. However, since the assumption had been made that facility characteristics were the same over the whole period of 2008-2014 and since the data was available only for four different years (2008, 2010, 2012, and 2014), the decision was made not to use it for the baseline analysis. Even so, as panel data analysis is useful as a robustness check, it is worth presenting.

In order to avoid the so-called Moulton bias, clustered standard errors are estimated. The results of panel analysis are reported in Table 2.7. Model (6) uses SER and Model (7) uses PRS as a measure of environmental policy stringency, both include country fixed effects. EAI could not be used because it is available only for 2013.

In the panel data the values of coefficients and their significance are very similar to those obtained in cross-sectional analysis. This is especially true for the coefficients on interaction terms. The conclusions drawn from cross-section analysis have been confirmed. It is worth noting that the adjusted R^2 is slightly higher in the case of panel data specifications.

This paper complements the Cecere and Corrocher's (2016) study, which demonstrates that there is a positive relationship between the regulatory stringency and the number of innovations in the WMI, but does not discuss the effect it has on a country's competitiveness in waste management services. Combining both results suggests that the WMI responds to stricter policies by using more environmentally friendly ways of dealing with waste and that many recycling facilities acquire advanced technology and so increase their international competitiveness.[26]

[26]Landfills in countries characterized by stringent environmental policy also use more advanced and environmentally friendly technologies. However, this does not make them more competitive. From the point of view of a customer, they are just more expensive. In contrast, a recycling company can become more competitive by investing in technology, which allows it to recover resources more efficiently.

Table 2.7 Regression results (panel data)

		Dependent variable:	
		LogShare	
		(6)	(7)
	Constant	0.0845	-0.0391
		(0.2802)	(0.3411)
Size Variable	LogGen	0.3339**	0.2666*
		(0.1293)	(0.1344)
Interactions	Land Scr. x Size	0.0013***	0.0010***
		(0.0002)	(0.0002)
	Capital Abd. x Capital Int.	0.1102**	0.1050**
		(0.0424)	(0.0398)
	SER x Cleanliness	0.0012**	
		(0.0005)	
	PRS x Cleanliness		0.0011**
			(0.0005)
	Coldness x Heat generation	0.0003***	0.0003***
		(0.00009)	(0.00009)
Country Characteristics	Land Scr.	0.0158	0.0146
		(0.0095)	(0.0099)
	Capital Abd.	−5.2215**	−3.6062**
		(1.8927)	(1.7177)
	SER	0.0152**	
		(0.0058)	
	PRS		0.0166**
		(0.0064)	
	Coldness	−0.0002**	−0.0002**
		(0.0001)	(0.0001)
Facility Characteristics	Size	-0.1568	0.0324
		(0.4262)	(0.5177)
	Capital Int.	−0.0349***	−0.0376***
		(0.0078)	(0.0084)
	Cleanliness	-0.0274	-0.0929
		(0.1589)	(0.1953)
	Heat Generation	-0.0475	0.0226
		(0.1591)	(0.1937)
Obs.		324	324
Country Fixed Effects		Yes	Yes
Adj. R^2		0.815	0.816
Note:		*p<0.1; **p<0.05; ***p<0.01	

However, change in market structure towards more recovery, at least initially, comes at a cost. It may, for example, harm the competitiveness of those firms that find themselves paying more for waste disposal. The analysis presented in this study does not allow for the assessing of the overall effect of this change on a country's economy.

Even if the waste management market increases its international competitiveness, as a result of more stringent regulations, it is still possible that the costs for the whole economy are greater than the benefits.

2.6 Concluding remarks

The WMI is challenging to analyze. In addition to a variety of waste treatment methods and heterogeneity of waste streams, the sector is highly regulated both at national and international levels. This is especially true in the case of waste destined for final disposal and makes it difficult for waste disposal facilities to escape from countries with stringent pollution controls. Consequently, the evidence supporting the PHH, with respect to disposal services, is not particularly strong. From this it can be concluded that the EU regulations are rather efficient in achieving their goal of preventing a pollution haven effect. They also appear justified because a pollution haven effect, although fairly weak, is still present and it can be argued that this effect would be much stronger in the absence of restrictions.

The recycling industry, which is not constrained as much by the EU regulatory framework as is the disposal industry, could, theoretically, use cheaper and dirtier technology, and locate in countries with lax environmental policies. However, this is not what we actually observe. On the contrary, this study, as well as previous research, shows that the waste recovery sector responds to strict regulations by producing innovations and increasing its share in a country rather than escaping to pollution havens. These findings are robust under various specifications and confirm this part of the PH, which predicts that stringent regulations may increase firms' international competitiveness. Nevertheless, important questions, that would allow better evaluation of the PH with respect to recovery services, remain to be answered by future research.

Firstly, the PH assumes that time is required for an innovation to remove inefficiencies and enhance competitiveness. This may mean that countries which have had stringent regulations for years and caused firms to invest in recovery technologies, were able to reduce inefficiencies by changing pollution into resources and now can reap the fruits of this investment. Conversely, it is conceivable that much of the recovery business is not really a profitable enterprise for firms, so countries that do not actively encourage it end up with a smaller share of the waste recovery market. There is probably some truth to both considerations. In fact, it is a great challenge to examine all the social costs and benefits and so find the optimal volume of recovery activities.

Secondly, interesting questions, from the perspective of the PHH, are: What would happen if legislative barriers to trade in waste were removed? Would some countries specialize in landfilling to a much greater extent than they do now? What would be the effect on recycling rates? Obviously, here the EU legislation assumes that countries with laxer policies would become pollution havens for waste management services and that recycling rates would drop.

Finally, the present research could be enhanced by adding more countries to the sample and by using panel data that cover more than just a few years. Hopefully, in the future, cross-country time-varying data will be available for all variables studied in this chapter, thus aiding more in-depth analysis.

Appendix

2.A Tables

Table 2.A.1 List of countries

Country	SER	PRS	EAI_c*	EAI	Landf. Share	Incin. Share	Rec. Share
Norway	100.000	100.000	72.129	63.5	0.002	0.029	0.004
Denmark	74.676	82.799	80.258	66.3	0.003	0.035	0.009
Sweden	67.017	80.819	95.065	71.4	0.072	0.076	0.015
Finland	53.029	76.733	93.613	70.9	0.061	0.091	0.024
Germany	51.944	69.355	90.419	69.8	0.073	0.317	0.234
Slovenia	48.265	38.663	62.839	60.3	0.001	0.003	0.004
France	47.347	55.948	42.806	53.4	0.108	0.128	0.184
Ireland	44.775	74.392	NA	NA	0.004	0.003	0.005
Cyprus	42.497	43.155	NA	NA	0.001	0.000	0.001
Latvia	42.022	16.281	44.548	54.0	0.001	0.001	0.001
UK	40.839	63.385	44.839	54.1	0.065	0.011	0.106
Austria	40.238	70.337	100.000	73.1	0.015	0.031	0.022
Netherlands	39.869	81.348	75.613	64.7	0.004	0.065	0.058
Estonia	36.885	36.103	61.387	59.8	0.012	0.004	0.007
Lithuania	32.601	22.200	33.516	50.2	0.004	0.002	0.001
Belgium	25.209	63.792	54.419	57.4	0.003	0.051	0.024
Italy	24.183	32.040	21.613	46.1	0.027	0.025	0.089
Spain	23.328	44.103	34.677	50.6	0.056	0.030	0.061
Romania	18.492	5.250	9.710	42.0	0.193	0.017	0.007
Croatia	17.938	12.851	NA	NA	0.002	0.001	0.001
Poland	14.728	21.033	36.710	51.3	0.039	0.040	0.109
Hungary	12.911	21.296	26.839	47.9	0.008	0.010	0.005
Bulgaria	11.679	1.728	1.000	39.0	0.170	0.002	0.002
Slovakia	10.412	21.126	46.581	54.7	0.004	0.004	0.003
Czech Rep.	9.154	28.218	NA	NA	0.004	0.008	0.013
Portugal	4.685	36.520	65.452	61.2	0.005	0.014	0.005
Greece	2.383	20.224	39.613	52.3	0.062	0.001	0.008

Notes: The *EAI_c is the EAI converted to 1-100 scale. SER, PRS and treatment option shares in the sample's total capacity are average values over 2008-2014. The EAI is available only for 2013.

Table 2.A.2 Descriptive statistics (country characteristics)

	LogShare	LogGen	Land Scr.	Capital Abd.	SER	PRS	EAI	Coldness
Min	-6.265	-2.796	15.60	0.026	1.0	1.0	39.0	495.590
Mean	0.064	0.395	122.546	0.143	35.165	44.557	57.1	3078.526
Max	3.551	2.742	500.70	0.253	100.0	100.0	73.1	6206.0
SD	1.773	1.570	105.718	0.053	22.637	27.186	9.3	1243.105

Notes: Descriptive statistics have been computed for the period 2008-2014, except for the EAI which is available only for 2013.

Table 2.A.3 Descriptive statistics (treatment option intensities)

	Size	Capital Int.	Cleanliness	Heat Gen.
Min	-8.60	8.90	-18.60	0.0
Mean	-4.367	40.053	-8.150	0.603
Max	-1.50	89.010	0.0	1.785
SD	3.060	35.10	7.778	0.837

2.B Figures

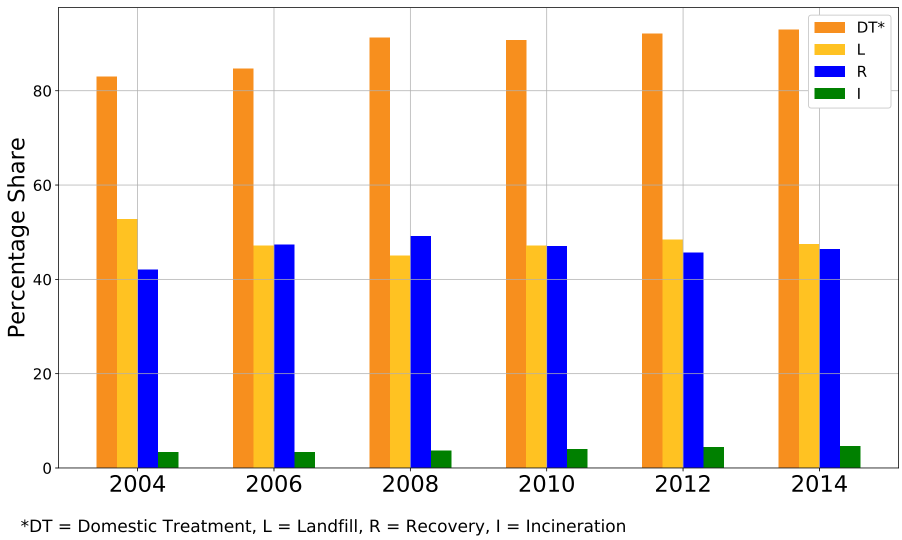

Figure 2.B.1 Percentage share of various treatment options in EU Member States, 2004-2014. Source: Own elaboration based on the Eurostat

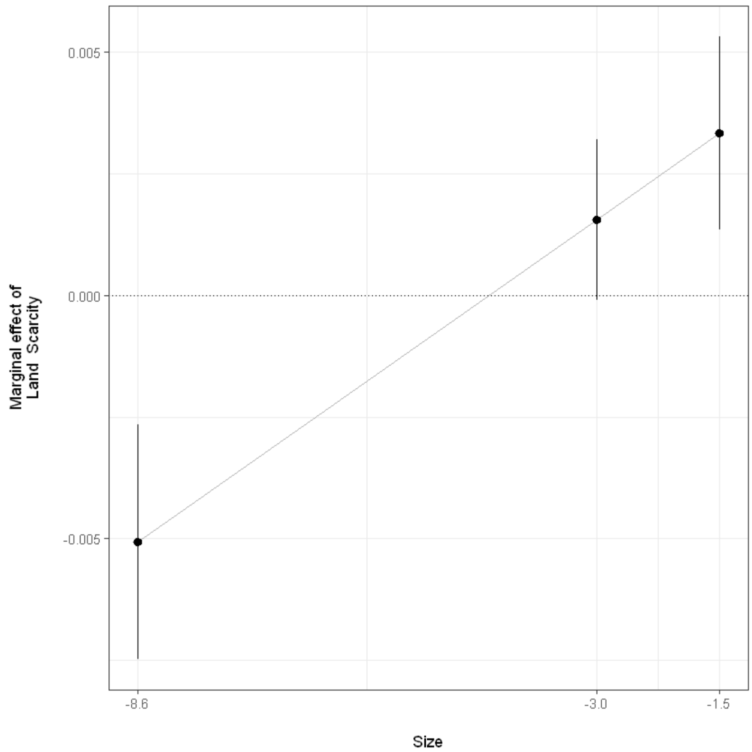

Figure 2.B.2 Marginal effects of land scarcity. CI = 95 percent

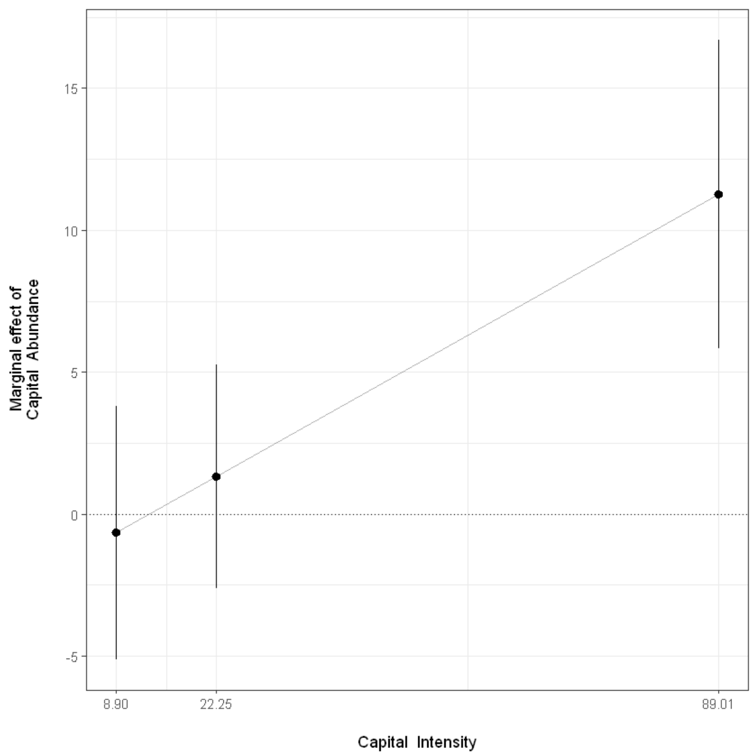

Figure 2.B.3 Marginal effects of capital abundance. CI = 95 percent

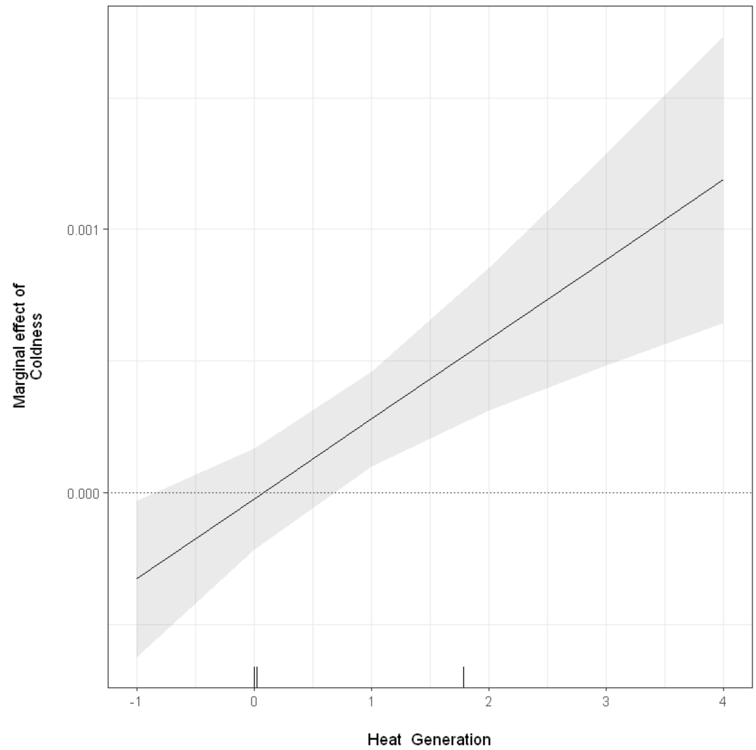

Figure 2.B.4 Marginal effects of coldness. CI = 95 percent

Chapter 3

Country-level analysis of trade in hazardous waste

3.1 Introduction

Research on trade in waste is surprisingly scarce, given the importance of waste-related problems. Most authors analyze waste transfers at a highly aggregated country level, the likely reason being the lack of firm-level data on international waste flows for the entire world. Therefore, if a researcher wants to investigate trade patterns in waste products between poor developing countries and rich developed nations, he or she has no choice but to use very aggregated data.

Generally, it is better to use more detailed disaggregated data, when available, and since this thesis is concerned with just Europe, and not the entire world, the facility-level E-PRTR dataset can be used. E-PRTR's disaggregated data is explored in Chapter 4, but it is still beneficial to conduct a country-level study first: by comparing these two approaches it is possible to show the limitations of highly aggregated data analysis; secondly, by using a different dataset for country-level analysis, which includes all notified waste transfers and not just transfers reported by the largest facilities, it is possible to gain some unique insight into this particular data; finally, as research, it is always worthwhile to look at a problem from many perspectives.

Two existing studies are especially relevant to the content presented in this chapter: Baggs (2009) and Kellenberg (2012) tested the PHH with respect to international trade in waste. Both report some evidence confirming the presence of a pollution haven effect, but their approaches are very different.

Baggs (2009) considers international transfers of hazardous waste for the period 1994-1997 and uses data reported by countries to the Basel Convention Secretariat. She concludes that a pollution haven effect, although present, is less important than other determinants of trade in waste, especially capital abundance.

Kellenberg (2012) argues that Baggs' (2009) results, while interesting, are also problematic in that she uses only GDP per capita as a measure of regulatory stringency. Even though GDP per capita is, in fact, related to the stringency of environmental policy of a country, it also includes many other factors that may be important determinants of trade in waste (e.g., wage costs). Therefore, he proposes a more direct measure of regulatory stringency, the Environmental Regulation Gradient which he defines as "the average percentage change in environmental regulation between the importing and exporting country" Kellenberg (2012). He uses Global Competitiveness Report survey results to evaluate the stringency of environmental policy of individual countries.[1] In order to include more countries in the sample, he estimates his gravity model with data obtained from the UN Comtrade database. He also finds a significant pollution haven effect, as the model predicts a country whose environmental policy becomes laxer than that of its trading partner will experience an increase in waste imports.

The present study investigates a much smaller sample of countries (EU-28 and Norway) than either Baggs (2009) or Kellenberg (2012). They may all be considered developed, but there are large differences in regulatory stringency levels and income levels, especially between the old and new Member States. Choosing a set of countries that are relatively similar culturally allows for the avoidance of part of the omitted variable bias. More importantly, the rich and reliable data offered by the Eurostat makes it possible to include variables that are vital factors of trade in waste (e.g., waste treatment capacities), but that could not be included in the models of Baggs (2009) or Kellenberg (2012).

This study also differs from previous research in that it compares several different measures of regulatory stringency. This is very important because no perfect measure exists; for example, GDP per capita used by Baggs (2009) is too broad, and the Environmental Regulation Gradient used by Kellenberg (2012) is based on subjective opinions of a sample of business leaders from each country. The primary measure in this study, SER, is more comprehensive, but the research still uses two other proxies (PRS and the EPI) in order to ensure robust results. The environmental policy stringency measures are described in Section 1.4 of Chapter 1.

The primary goal of the country-level analysis is to test the PHH with respect to trade in hazardous waste. Since the data includes information on whether waste is shipped for final disposal or recovery, it is possible to investigate differences that may

[1]The World Economic Forum publishes the Global Competitiveness Report annually. It includes the Executive Opinion Survey, which contains several questions related to the environmental policy stringency and the level of enforcement.

occur in trade patterns of waste destined for these two treatment options.

The rest of the chapter is laid out as follows. Section 3.2 introduces the gravity model, which is the baseline model in this chapter; Section 3.3 provides an overview of the data and presents the descriptive analysis; Section 3.4 reports and discusses the results of the gravity analysis, while concluding remarks are given in Section 3.5.

3.2 The model

Trade flow between counties is often investigated using the gravity model. Since it has been successfully applied in examining trade in waste products before (Baggs, 2009; Kellenberg, 2012; Kellenberg and Levinson, 2014), it was decided to employ it for the country-level analysis.

The gravity model was first conceptualized by Isard (1954) and then advanced by Tinbergen (1962), Linnemann (1966), and Anderson (1979) among many others.[2] The model assumes that bilateral trade flows are positively related to countries' economic sizes and negatively related to the distance between them. The term "distance" can be understood to refer to many measures, including cultural differences, language similarities, colonial ties, differences in technological developments, etc. This flexibility, as well as empirical success, in explaining and predicting bilateral trade flows has made the gravity model one of the most popular and extensively used tools in applied international economics. The most basic form of the gravity equation includes only trading partners' sizes measured by GDP and the distance between them:

$$T_{ij} = \frac{GDP_i^{\alpha} GDP_j^{\beta}}{D_{ij}^{\theta}} \tag{3.1}$$

T_{ij} is bilateral trade between countries i and j, GDP_i and GDP_j are economic sizes of countries i and j respectively, and D_{ij} indicates the distance between them. Finally, α, β, and θ are the parameters to estimate.

The gravity equation has been so successful in empirical studies that for a long time it has been used despite the lack of a solid theoretical foundation. Tinbergen (1962) justified it on the grounds of common sense, explaining that the economic size of a country is crucial in determining its supply potential, as well as its demand potential. Apart from economic sizes of trading partners, the geographical distance between them is also important, as it measures not only transportation costs or transaction costs, but it can also serve as a proxy for communication costs and cultural differences.

[2] Isard (1954) developed several ideas, which are now important elements of the gravity model. However, the first mathematical formulation of the model was presented by Tinbergen (1962).

The micro-foundation of the gravity model was finally provided by Anderson (1979). He assumes that each region produces both tradable and non-tradable goods. The goods of the same type from different origins are close but imperfect substitutes. Because regions have an identical Cobb-Douglas utility function, the share country j spends on tradable goods from i, denoted as s_i, is the same for all countries. The imports of country j from country i are:

$$T_{ij} = s_i a_j GDP_j, \tag{3.2}$$

where a_j is a share of income country j spends on traded goods. Because the tradable goods market is in equilibrium:

$$a_i GDP_i = s_i \sum_j a_j GDP_j, \tag{3.3}$$

If we solve for s_i and substitute in (3.2), we get:

$$T_{ij} = \frac{a_i GDP_i a_j GDP_j}{\sum_i \sum_j T_{ij}}, \tag{3.4}$$

which is the simplest form of the gravity equation. In this model the trade flows are determined only by the economic sizes of trading partners. It can, of course, be extended to include other variables, such as population variables and trade barriers.

The paper of Anderson and Wincoop (2003) includes the full derivation of the gravity equation. The simplified version of it is presented below (see also Baldwin and Taglioni, 2006; van Bergeijk and Brakman, 2010).

If country i exports tradable goods to country j, then the value of this trade flow is equal to the share country i has in the expenditure of country j.

$$p_{ij} x_{ij} = s_{ij} E_j, \tag{3.5}$$

where x_{ij} is the quantity of exports of a single item of goods from country i to country j, p_{ij} is the price of this goods item in country j (measured in terms of the numeraire), and E_j is country j's expenditure on tradable goods.

The share of goods imported from country i in the expenditure of country j, s_{ij}, depends on relative prices.[3] Assuming constant elasticity of substitution (CES) and that all goods are traded, s_{ij} can be computed as:

$$s_{ij} = (\frac{p_{ij}}{P_j})^{1-\sigma} \tag{3.6}$$

[3] For now the income elasticity is ignored.

P_j is country j's CES price index and σ is the elasticity of substitution ($\sigma > 1$). If we denote the number of nations as N and the number of varieties exported from nation i as n_i, then P_j can be expressed as:

$$P_j = (\sum_{i=1...N} n_i(p_{ij})^{1-\sigma})^{\frac{1}{(1-\sigma)}} \tag{3.7}$$

The variety index is not included here, since varieties are assumed to be symmetric.

At this point the bilateral trade costs, t_{ij}, are added:

$$p_{ij} = p_i t_{ij}, \tag{3.8}$$

where p_i is the price charged by the producer from country i.

In order to derive the gravity equation, it is necessary to obtain the total trade between countries, which requires aggregating across varieties:

$$T_{ij} = n_i s_{ij} E_j \tag{3.9}$$

Substituting (3.6) and (3.8) in (3.9) gives:

$$T_{ij} = n_i(p_i t_{ij})^{1-\sigma} \frac{E_j}{P_j^{1-\sigma}} \tag{3.10}$$

Since all goods are traded, country i sells all of its output, Y_i, to destination countries j (note that country i itself is among the destination countries).

$$Y_i = \sum_j T_{ij} \tag{3.11}$$

Substituting (3.10) in (3.11) yields:

$$Y_i = n_i {p_i}^{1-\sigma} \sum_j ({t_{ij}}^{1-\sigma} \frac{E_j}{P_j^{1-\sigma}}) \tag{3.12}$$

If we define Ω_i as:

$$\Omega_i = (\sum_j ({t_{ij}}^{1-\sigma} \frac{E_j}{P_j^{1-\sigma}}))^{\frac{1}{(1-\sigma)}}, \tag{3.13}$$

we can simplify (3.12):

$$n_i {p_i}^{1-\sigma} = \frac{Y_i}{\Omega_i^{1-\sigma}} \tag{3.14}$$

Finally, substituting (3.14) into (3.10) gives the gravity equation:

$$T_{ij} = Y_i E_j (\frac{t_{ij}}{\Omega_i P_j})^{1-\sigma} \tag{3.15}$$

Ω can be understood to be a measure of the openness of a country to exports from other countries (Baldwin and Taglioni, 2006). Ω and the price index P are two elements that make equation (3.15) different from the basic formulation (3.1). Actually, they are very important, as they point to the presence of multilateral resistance terms.

The problem of multilateral resistance terms becomes serious when analysis is undertaken of trade flows between countries from many different regions of the world. Two countries may be very similar in almost all respects except for the fact that one of them is located close to many other countries (e.g., in the EU) and the other one is a remote or peripheral country. It is obvious that because of the fierce competition, two trading partners located in Europe should have smaller trade flows than similar trading partners from some remote region of the world. This is why ignoring the multilateral resistance terms while estimating the gravity equation results in the omitted variable bias. There are several ways to deal with the issue of multilateral resistance terms. In cross-section studies exporter fixed effects and importer fixed effect can be incorporated into the model (Rose and van Wincoop, 2001; Redding and Venables, 2004). In a panel analysis, time invariant pair dummies can be used (Baldwin and Taglioni, 2006). This research includes country-pair fixed effects in one of the specifications.

3.3 Data

Most variables used in this country-level study are variables that typically appear in the gravity equation.

The dependent variable, $logShipment_{ijt}$, is the natural logarithm of waste shipments expressed in tonnes between country i and country j in year t. The data on trade in waste among the European countries from 2006 to 2015 has been collected from the Eurostat. The database includes only information on international waste transfers that have to be reported according to the Regulation on shipments of waste (EC, 2006). They are, in most cases, hazardous waste transfers. The set of origin countries consists of 29 European countries, and the destination countries are 28 European countries.[4]

The explanatory variables include, not only variables that measure economic sizes and the distance between trading partners, but also three proxies for the environmental policy stringency, which is a core variable in this study.

The economic sizes of countries are captured by GDP in million euros. Coefficients on GDP variables are expected to be positive. The geographical distance between capital cities (in kilometers) is measured by the Distance variable. There is also a cultural distance, proxied by the Language variable, which takes value 1 if trading

[4]Malta has been excluded because it received no waste shipments during the study period.

partners have a common language and 0 otherwise. Closely related is the variable Border, which is also binary and equals 1 if two countries share a border and 0 if they do not. The relationship between the distance and volumes of waste shipped is expected to be negative. In the case of the Border and Language variables the coefficients should be positive.

The variables unique to the study on trade in waste are Total Cap. (total capacity) and Waste Gen. (waste generation).[5] The former is the share of a country's waste treatment capacity in the sample's total capacity, and the latter is the share of a country's waste generation in the sample's total waste generation. The capacity of a destination country is expected to be positively related to the volume of waste transfers. In contrast, the capacity of an origin country should be negatively related to the volume of transfers. As for the Waste Gen. variable, the coefficient is expected to be positive.[6]

Table 3.1 Description of the variables

Variable	Name	Unit of measurement	Sources
Distance	$logDistance$	Euclidean distance in kilometers	CEPII Gravity Dataset
Border	$Border$	1 if countries share a border and 0 otherwise	CEPII Gravity Dataset
Language	$Language$	1 if countries have a common language and 0 otherwise	CEPII Gravity Dataset
GDP	$logGDP$	Million euro	Eurostat
Waste Generation	$logWasteGen.$	Share in countries' total waste generation	Eurostat
Total Capacity	$logTotalCap.$	Share in countries' total capacity	Eurostat
Stringency of Environmental Regulations	$logSER$	Score on a 1-100 scale	IEA Database, Eurostat, The Yearbook of International Organizations
Environmental Performance Index	$logEPI$	Score on a 1-100 scale	Yale Center for Environmental Law and Policy
Proxy for Regulatory Stringency	$logPRS$	Score on a 1-100 scale	Transparency International, Eurostat
Volume of waste shipment	$logShipment$	Tonne	Eurostat

[5]The data on waste generation and waste treatment capacity is only available for every second year, therefore, the missing values were replaced with values from the subsequent year.

[6]Countries that generate more waste can be expected to export more waste in absolute terms. However, such countries have usually large waste management markets, so the volume exported, relative to the volume generated, is likely to be smaller than in the case of countries that do not generate large amounts of waste.

Finally, there are three variables that are intended to capture the stringency of environmental regulations: SER, the EPI, and PRS. These variables are interacted with the dummy variable Recovery, which is equal to 1 if waste is destined for recovery and 0 if it is not. If the PHH is valid, the coefficient on the regulatory stringency variable should be positive in the case of an origin country and negative in the case of a destination country. If the trade in waste destined for recovery follows a different pattern than the trade in waste destined for disposal (for example if it is consistent with the PH), then the coefficient on the interaction between the destination country's environmental policy variable and the Recovery dummy is expected to be positive. Additionally, some specifications include a dummy variable (Policy Diff.), which equals 1 if the environmental policy of an origin country is more stringent than the environmental policy of a destination country and 0 otherwise. The coefficient on this variable should be positive to support the PHH.

The list of variables along with sources is provided in Table 3.1. Descriptive statistics, the list of countries from the sample, and the correlation matrix are presented in Appendix 3.A in tables 3.A.1, 3.A.2, and 3.A.3 respectively. Since the correlation matrix, with many variables, may be difficult to analyze, Figure 3.B.1 in Appendix 3.B shows the correlation map of the said variables.

Figure 3.1 presents the distribution of country pairs, according to the presence or absence of trade between them. Even though it can be seen that over the years more and more countries have become actively involved in the trade in waste, there is a large number of country pairs with zero trade.

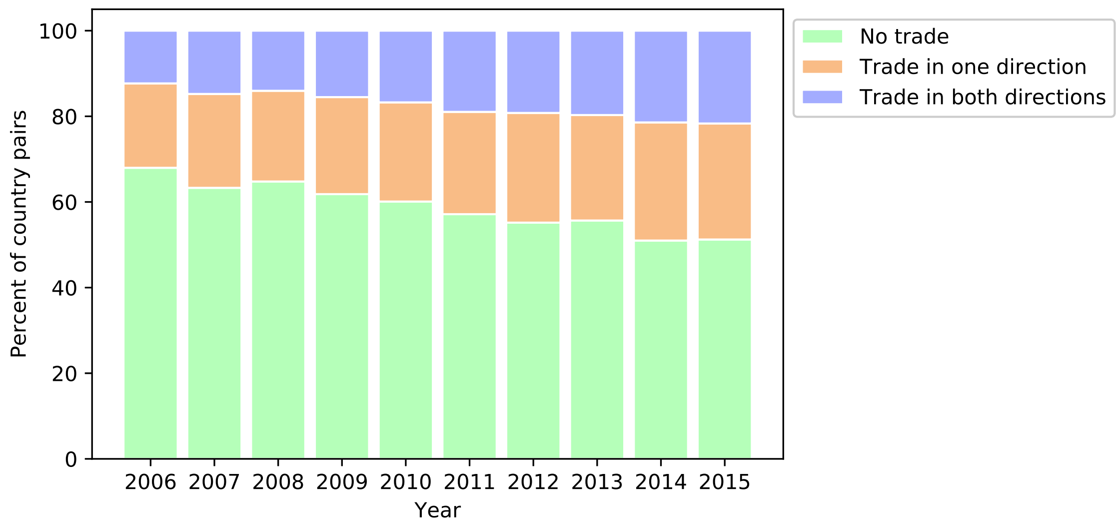

Figure 3.1 Distribution of country pairs with trade in both directions, one direction, and with zero trade. Source: Own elaboration

Zero trade is a problem that should always be carefully considered in a gravity analysis. Many researchers simply ignore observations with zero flows or add a small constant to all observations because otherwise a log-linear equation cannot be estimated (Maurel and Afman, 2007; Rose and Spiegel, 2010). However, this approach is problematic because usually zero trade flows are not randomly distributed and they carry important information: therefore, discarding them causes a selection bias. This danger has been recognized by Flowerdew and Aitkin, (1982); Eichengreen and Irwin, (1998) and Linders and De Groot (2006) and the result has been several measures to tackle the problem of zero trade flows being proposed.

A method devised by Helpman et al. (2008) has become particularly popular. It involves estimating two equations, namely the selection and outcome equations. The selection equation predicts the selection of trade partners while the outcome equation estimates trade flows. As a point of interest, the Helpman's method was applied by Baggs (2009) to study trade in hazardous waste between OECD and non-OECD countries. The greatest challenge in using this two-stage procedure comes down to identifying an appropriate variable that influences the probability of trade in the selection equation. Additionally, even though it deals with zero trade flows, the Helpman's approach does not address the issues of inefficiency and biased estimates in the presence of heteroskedasticity. Some authors suggest that the problems with zero trade and heteroskedasticity can be solved by estimating the gravity model in its multiplicative form (Wooldridge, 2002; Silva and Tenreyro, 2006; Westerlund and Wilhelmsson, 2011). It is possible with the Poisson pseudo-maximum-likelihood estimator (PPML). The PPML estimator was used in the context of international trade in waste products by Kellenberg (2012). In Section 3.4 of this chapter the traditional OLS estimates are compared with the PPML estimates.

If the PHH is valid, we might expect that the origin countries have, on average, more stringent environmental regulations than the destination countries. Figures 3.2 and 3.3 plot separately the volumes of waste traded in the case an origin country having more stringent regulations than the destination country and in the case the destination country having more stringent or equally stringent regulations.

Turning to Figure 3.2 first. It compares two measures of regulatory stringency, SER and PRS. Country pairs with an origin country having less stringent regulations than a destination country generally trade the largest volumes of waste. According to SER, in the recent years, both kinds of country pairs ("stringent to non-stringent" and "non-stringent to stringent") have traded almost the same volumes of waste. However, the gap between them used to be very large. According to PRS, up to 2011, the "stringent to non-stringent" kind of trade prevailed, then the situation changed quite dramatically.

So, there are some differences in what both measures show.

Figure 3.3 compares SER with the EPI. The picture painted by the EPI differs a great deal from that painted by SER in most years, although at the beginning of the study period they agreed almost perfectly. Around 2012 and 2013 both measures showed alike patterns again. Similarly to PRS, the EPI suggests that, depending on the year, different kinds of trade were more common, but both measures sometimes disagree on which kind of trade prevailed in a given year.

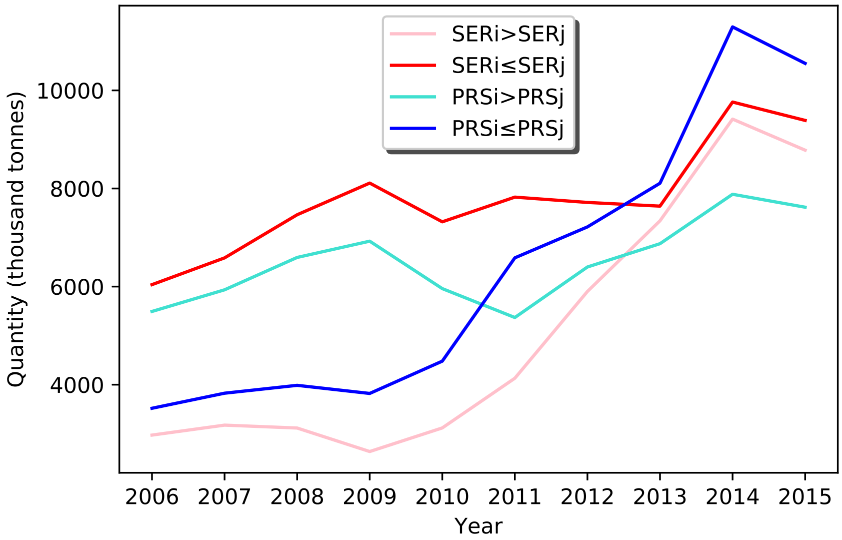

Figure 3.2 Volumes shipped, depending on the differences in the stringency of environmental policy of trading partners. Comparison between SER and PRS. Source: Own elaboration

In addition to the volumes traded, it is interesting to analyze the number of ”stringent to non-stringent” and ”non-stringent to stringent” country pairs. Figures 3.B.2 and 3.B.3 in Appendix 3.B paint a much more unambiguous picture. SER and PRS match almost ideally and indicate that the ”non-stringent to stringent” country pairs have been the more common during the whole period under study. The EPI shows the opposite. Differences between the figures presenting volumes traded and those presenting the number of country pairs suggest that ”stringent to non-stringent” pairs, although smaller in number, tend to trade larger volumes. Figures 3.B.4 and 3.B.5 in Appendix 3.B show only country pairs that traded more than the mean value of all shipments. Indeed, in those figures, the lines cross each other, and the gaps between them are much smaller. However, the EPI remains the only measure that consequently gives a degree of support to the PHH.

The descriptive statistics do not allow for the drawing of any definite conclusions. They are not clear-cut, and some of the conclusions differ depending on the environmental policy stringency variable used. More importantly, the descriptive statistics do not control for any country characteristics other than the regulatory stringency. This is why the econometric analysis is indispensable.

One thing is clear, however, over the years more countries have been trading waste and the volumes traded have also increased.

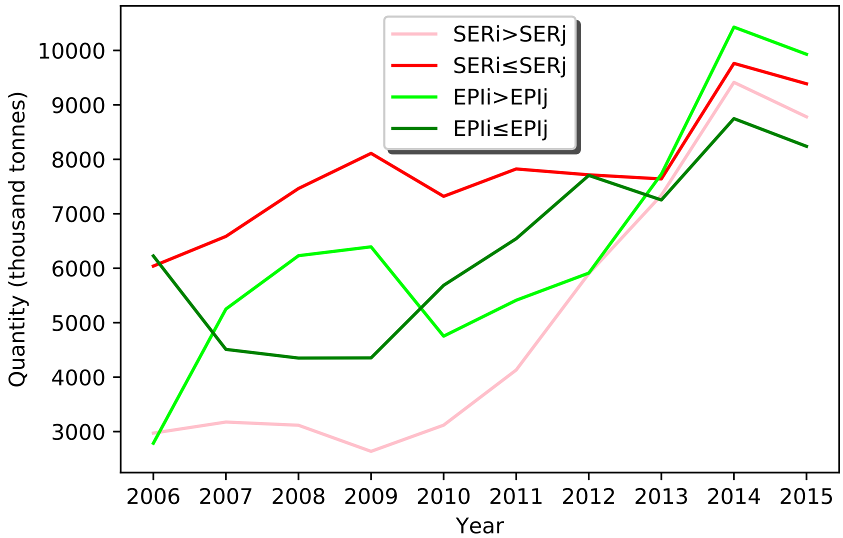

Figure 3.3 Volumes shipped, depending on the differences in the stringency of environmental policy of trading partners. Comparison between SER and the EPI. Source: Own elaboration

3.4 Results and discussion

This section presents and compares the results obtained by applying two different estimation methods: OLS and PPML.

OLS is the most common technique used to estimate the gravity equation. It requires that the original model, which has a multiplicative form, is first log-linearized. The resulting equation is:[7]

$$logShipment_{ijt} = \lambda_t + \beta_0 + \beta_1 logDistance_{ij} + \beta_2 Border_{ij} + \beta_3 Language_{ij} + \beta_4 logGDP_{it} + \beta_5 logGDP_{jt} + \beta_6 logTotalCap._{it} + \beta_7 logTotalCap._{jt} + \beta_8 logWasteGen._{it} + \beta_9 logSER_{it} + \beta_{10} logSER_{jt} + \beta_{11} logSER_{jt} * Recovery_{ijt} + \beta_{12} Recovery_{ijt} + \varepsilon_{ijt}$$

Tables 3.2 and 3.3 present the results of the OLS estimations. The latter contains models with interaction terms between the regulatory stringency variables and the

[7]Note that λ_t denotes year fixed effects.

Recovery dummy. Note that in all models the subscript i refers to the origin country, whereas the subscript j refers to the destination country.

Specifications (1), (2), and (3) of Table 3.2 use respectively SER, the EPI, and PRS as the environmental policy stringency variable. Most of the coefficients are highly significant and have the expected positive and negative values. The coefficients, except for the environmental policy stringency variable, are similar across specifications.

Table 3.2 OLS estimation results

	Dependent variable:		
	$logShipment_{ijt}$		
	(1)	(2)	(3)
logDistance	−0.96*** (0.07)	−1.07*** (0.07)	−1.01*** (0.07)
Border	1.09*** (0.12)	1.04*** (0.12)	1.07*** (0.12)
Language	0.37** (0.15)	0.45*** (0.15)	0.31** (0.15)
logGDPi	0.80*** (0.06)	0.86*** (0.06)	0.73*** (0.07)
logGDPj	0.27*** (0.05)	0.29*** (0.05)	0.34*** (0.07)
logTotalCap.i	−0.98*** (0.19)	−1.10*** (0.20)	−0.87*** (0.19)
logTotalCap.j	0.11** (0.05)	0.10** (0.05)	0.06 (0.06)
logWasteGen.i	0.73*** (0.21)	0.84*** (0.22)	0.70*** (0.21)
logSERi	0.31*** (0.05)		
logSERj	0.01 (0.07)		
logEPIi		4.53*** (0.92)	
logEPIj		−2.73*** (0.90)	
logPRSi			0.35*** (0.07)
logPRSj			−0.13* (0.07)
Constant	−1.16 (1.00)	−7.98 (5.21)	−0.55 (1.03)
Year fixed effects	Yes	Yes	Yes
Obs	3,113	3,113	3,113
Adj. R^2	0.34	0.34	0.34
Note:			*p<0.1; **p<0.05; ***p<0.01

As expected, the further apart countries are, the smaller the bilateral trade flows. In contrast, sharing a border and language increases trade. Also consistent with the gravity model, the economic sizes of trading partners have a positive influence on the size of trade between them. Interestingly, it appears that the economic size of the origin country is more important in the case of trade in waste.

The coefficients on variables related to waste treatment capacity and waste generation are also consistent with predictions. The larger the treatment capacity of an origin country the smaller the trade: obviously, waste generators do not need to export waste very often if there is a well-developed waste management industry in their own country. Consistent with common sense, the positive coefficient on the waste treatment capacity of the destination country indicates that having a large waste management industry increases waste imports. The amount of waste generated in an origin country has a positive impact on the volumes traded. So, all else being equal, the countries that generate more waste export more waste.

Coefficients on the environmental policy stringency variable differ across specifications in their magnitudes, significance and values (positive or negative).

Consider the regulatory stringency of an origin country. If waste moves from countries with strict regulations to countries with lax regulations the coefficient should be positive. Indeed, it is positive and significant in all three specifications. However, the magnitude in the case of the EPI differs markedly from SER and PRS.

The coefficient on the environmental policy stringency of a destination country has the expected negative value in specifications (2) and (3). The coefficient on SER is positive but insignificant.

The first three specifications provided some evidence for the presence of a pollution haven effect. In the subsequent models (4), (5), and (6) of Table 3.3 an interaction term was added with the Recovery dummy in order to see whether waste products destined for recovery follow a different pattern in trade than the pattern predicted by the PHH.

The coefficient on the interaction of the Recovery dummy and the variable representing the stringency of an origin country should be negative if countries with lax regulations export waste for recovery to countries with strict regulations. Conversely, the coefficient on the interaction term with the stringency variable of a destination country is expected to be positive if countries with stricter regulations tend to have a comparative advantage in recovery services. However, the coefficients on interactions in all three specifications have the opposite signs from those predicted. Moreover, all but one are significant. It seems that the pollution haven effect is indeed true, especially for waste destined for recovery. This result can actually be explained by the fact that the data includes only notified waste (mostly hazardous waste) and is very aggregated. EU legislation makes it difficult to export hazardous waste, especially if it is destined for disposal, which is why, more than 60% of waste transfers in the dataset are intended for recovery. However, it is impossible to know what kind of recovery. It is surely true that many shipments are slated for incineration, whereas it is recycling not incineration that can be expected to follow a pattern predicted by the PH.

Table 3.3 OLS estimation results with interactions

	Dependent variable:		
	$logShipment_{ijt}$		
	(4)	(5)	(6)
logDistance	−0.97*** (0.07)	−1.04*** (0.07)	−1.01*** (0.07)
Border	1.20*** (0.12)	1.13*** (0.12)	1.24*** (0.12)
Language	0.46*** (0.14)	0.53*** (0.14)	0.36** (0.15)
logGDPi	0.81*** (0.06)	0.86*** (0.06)	0.78*** (0.07)
logGDPj	0.32*** (0.05)	0.35*** (0.05)	0.36*** (0.06)
logTotalCap.i	−0.96*** (0.19)	−1.09*** (0.19)	−0.87*** (0.19)
logTotalCap.j	0.10** (0.05)	0.09* (0.05)	0.09 (0.06)
logWasteGen.i	0.67*** (0.21)	0.81*** (0.21)	0.63*** (0.21)
logSERi	−0.03 (0.07)		
logEPIi		2.35 (1.48)	
logPRSi			−0.09 (0.10)
Recovery	0.65 (0.67)	−10.75 (7.60)	2.37*** (0.91)
logSERj	0.41*** (0.15)		
logEPIj		−2.02 (1.56)	
logPRSj			0.80*** (0.22)
logSERi x *Recovery*	0.49*** (0.09)		
logSERj x *Recovery*	−0.38** (0.17)		
logEPIi x *Recovery*		3.07* (1.63)	
logEPIj x *Recovery*		−0.45 (1.74)	
logPRSi x *Recovery*			0.57*** (0.11)
logPRSj x *Recovery*			−0.90*** (0.22)
Constant	−2.81** (1.17)	−3.02 (7.51)	−4.21*** (1.38)
Year fixed effects	Yes	Yes	Yes
Obs	3,113	3,113	3,113
Adj. R^2	0.37	0.36	0.36
Note:			*p<0.1; **p<0.05; ***p<0.01

The evidence from the log-linearized specifications suggests the presence of a pollution haven effect, although it is somewhat mixed. Nonetheless, these results might be biased because no measures have been taken to eliminate the problems of zero bilateral trade flows or multilateral resistance terms. Literature suggests that a solution to the first problem is the use of PPML estimator and estimating the gravity model in its original multiplicative form. Multilateral resistance terms can be accounted for by bilateral fixed effects.

As many authors argue (Silva and Tenreyro, 2006; Westerlund and Wilhelmsson, 2011; Yotov et al., 2016) the PPML estimator not only allows taking advantage of the information included in zero trade flows, but it also addresses the problems of heteroscedasticity and country specific heterogeneity. Following the lead of Westerlund and Wilhelmsson (2011) the decision was made to include country-pair fixed effects and time fixed-effects. The estimating equation, with time fixed effects denoted as λ_t and bilateral fixed effects denoted as α_{ij}, is:

$$Shipment_{ijt} = exp[\alpha_{ij} + \lambda_t + \beta_0 + \beta_1 logDistance_{ij} + \beta_2 Border_{ij} + \beta_3 Language_{ij} + \beta_4 logGDP_{it} + \beta_5 logGDP_{jt} + \beta_6 logTotalCap._{it} + \beta_7 logTotalCap._{jt} + \beta_8 logWasteGen._{it} + \beta_9 logSER_{it} + \beta_{10} logSER_{jt}] * \varepsilon_{ijt}$$

In order to estimate time-invariant country-pair specific variables (Distance, Language and Border), specifications similar to those in Table 3.2 (without bilateral fixed effects) are considered first.

Specifications (7), (8), and (9) in Table 3.4 use SER, the EPI, and PRS respectively. Signs on the coefficients are almost the same as in the previously discussed models estimated by OLS, the only exception being the coefficient on the Language variable, which has an unintuitive negative sign. But it is significant only in the specification (9). The rest of the coefficients are significant. It is worth noting that PPML-estimated coefficients are very different from those obtained by OLS. They are much larger, for most variables, and smaller in the case of the EPI of an origin country variable as well as the Border variable. The fact that the PPML estimates are usually larger than OLS estimates was also noted by Westerlund and Wilhelmsson (2011).

Table 3.5 presents the results of the PPML estimation with bilateral fixed effects. Signs of the coefficients are almost unchanged. The estimated GDP elasticities in specifications (10)-(12) are considerably larger than in specifications (1)-(9). In fact, predicted elasticities generally differ a lot across specifications. For example model (8) predicts that a 1% increase in regulatory stringency of an origin country will result in a 3.38% increase in waste transfers from that country. According to model (11) the predicted impact is as large as 8.46%. Substantial differences in magnitudes can be observed, not only for the same policy measure in different specifications, but especially for different policy measures. The magnitude of the coefficient on the EPI is much larger than the magnitudes of the coefficients on the rest of policy stringency variables, in both OLS and PPML models. This, of course, results from the fact that these measures, although positively correlated, are far from being identical. SER and PRS focus on the quality of institutions and people's attitudes, whereas the EPI is based on environmental quality indicators.

Coefficients on the regulatory stringency of an origin country have the expected positive signs for the SER and EPI variables. PRS predicts, all other things being equal, smaller exports from countries with stricter policies (but only in specification (12)). The coefficient on the regulatory stringency of a destination country is insignificant in the case of SER. The coefficients on the EPI and PRS are, however, significant and have the predicted negative values. The evidence, therefore, is somewhat ambiguous.

Table 3.4 PPML estimation results

	Dependent variable:		
	$Shipment_{ijt}$		
	(7)	(8)	(9)
$logDistance$	-1.08^{***} (0.05)	-1.12^{***} (0.04)	-0.97^{***} (0.05)
$Border$	0.91^{***} (0.07)	0.96^{***} (0.07)	0.96^{***} (0.07)
$Language$	-0.05 (0.07)	-0.06 (0.07)	-0.16^{**} (0.07)
$logGDPi$	1.08^{***} (0.07)	1.17^{***} (0.07)	1.11^{***} (0.07)
$logGDPj$	0.40^{***} (0.05)	0.53^{***} (0.05)	0.32^{***} (0.06)
$logTotalCap.i$	-1.78^{***} (0.13)	-1.81^{***} (0.13)	-1.61^{***} (0.13)
$logTotalCap.j$	0.22^{***} (0.05)	0.19^{***} (0.05)	0.33^{***} (0.06)
$logWasteGen.i$	1.34^{***} (0.14)	1.32^{***} (0.14)	1.17^{***} (0.13)
$logSERi$	0.37^{***} (0.06)		
$logSERj$	0.31^{***} (0.06)		
$logEPIi$		3.38^{***} (0.71)	
$logEPIj$		-3.58^{***} (0.61)	
$logPRSi$			0.41^{***} (0.07)
$logPRSj$			0.46^{***} (0.07)
$Constant$	-5.45^{***} (1.06)	-4.74 (3.83)	-6.41^{***} (1.11)
Year fixed effects	Yes	Yes	Yes
Obs	8,857	8,857	8,857
Note:			*p<0.1; **p<0.05; ***p<0.01

Silva and Tenreyro (2006) argue that if PPML estimates are different from OLS estimates, the former should be preferred. Coefficients on the regulatory stringency variables for an origin country are significant and have the expected sign in all PPML specifications but specification (12). In the case of a destination country, specifications (8), (11), and (12) have estimates that are significant and consistent with predictions. In specifications (7) and (9) coefficients on the regulatory stringency variable are significant, but have an unexpected positive sign. Finally, in specification (10) the coefficient is insignificant. The EPI is the only variable that maintains both the significance and expected signs for both exporting and importing country, regardless of the specification.

Table 3.5 PPML estimation results with bilateral fixed effects

	Dependent variable:		
	$Shipment_{ijt}$		
	(10)	(11)	(12)
logGDPi	2.33^{***} (0.22)	2.53^{***} (0.21)	2.84^{***} (0.24)
logGDPj	1.48^{***} (0.22)	1.69^{***} (0.21)	1.99^{***} (0.24)
logTotalCap.i	-1.32^{***} (0.11)	-1.65^{***} (0.11)	-1.31^{***} (0.10)
logTotalCap.j	0.34^{***} (0.10)	0.50^{***} (0.09)	0.30^{***} (0.09)
logWasteGen.i	0.77^{***} (0.10)	1.19^{***} (0.10)	0.72^{***} (0.09)
logSERi	0.16^{*} (0.09)		
logSERj	0.06 (0.08)		
logEPIi		8.46^{***} (0.70)	
logEPIj		-2.23^{***} (0.63)	
logPRSi			-0.33^{***} (0.12)
logPRSj			-0.60^{***} (0.11)
Constant	-41.40^{***} (5.36)	-72.71^{***} (7.56)	-49.71^{***} (5.63)
Year fixed effects	Yes	Yes	Yes
Bilateral fixed effects	Yes	Yes	Yes
Obs	8,857	8,857	8,857

Note: *p<0.1; **p<0.05; ***p<0.01

Table 3.6 Estimation results with the Policy Diff. variable

	Dependent variable:					
	$logShipment_{ijt}$			$Shipment_{ijt}$		
	OLS			*PPML*		
	(13)	(14)	(15)	(16)	(17)	(18)
logDistance	−0.96***	−1.06***	−1.01***	−1.09***	−1.12***	−0.97***
	(0.07)	(0.07)	(0.07)	(0.04)	(0.04)	(0.05)
Border	1.07***	1.04***	1.08***	0.90***	0.94***	0.97***
	(0.12)	(0.12)	(0.13)	(0.07)	(0.07)	(0.07)
Language	0.39***	0.45***	0.31**	−0.03	−0.05	−0.18***
	(0.15)	(0.15)	(0.15)	(0.07)	(0.07)	(0.07)
logGDPi	0.82***	0.86***	0.74***	1.12***	1.17***	1.10***
	(0.06)	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)
logGDPj	0.26***	0.28***	0.33***	0.40***	0.54***	0.32***
	(0.05)	(0.05)	(0.07)	(0.05)	(0.05)	(0.06)
logTotalCap.i	−0.91***	−1.08***	−0.87***	−1.63***	−1.79***	−1.64***
	(0.20)	(0.20)	(0.19)	(0.13)	(0.13)	(0.13)
logTotalCap.j	0.12**	0.10**	0.06	0.22***	0.18***	0.33***
	(0.05)	(0.05)	(0.06)	(0.05)	(0.05)	(0.06)
logWasteGen.i	0.65***	0.81***	0.69***	1.15***	1.30***	1.19***
	(0.22)	(0.22)	(0.21)	(0.15)	(0.14)	(0.13)
PolicyDiff.	−0.28**	0.26**	0.04	−0.33***	−0.20**	−0.15**
	(0.12)	(0.13)	(0.12)	(0.08)	(0.08)	(0.07)
logSERi	0.38***			0.53***		
	(0.06)			(0.07)		
logSERj	−0.10			0.14**		
	(0.08)			(0.07)		
logEPIi		2.96**			4.84***	
		(1.21)			(0.92)	
logEPIj		−1.11			−4.71***	
		(1.21)			(0.74)	
logPRSi			0.33***			0.52***
			(0.08)			(0.09)
logPRSj			−0.11			0.38***
			(0.08)			(0.08)
Constant	−0.97	−8.38	−0.59	−5.60***	−6.11	−6.43***
	(1.00)	(5.21)	(1.04)	(1.03)	(3.81)	(1.11)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Obs	3,113	3,113	3,113	8,857	8,857	8,857
Adj. R^2	0.34	0.34	0.34			
Note:				*p<0.1; **p<0.05; ***p<0.01		

Baggs (2009) concluded the presence of a pollution haven effect based on the coefficients on GDP per capita of waste importer and waste exporter. Specifications (1)-(12) of this chapter adopt a similar approach, although policy stringency measures as well as other variables differ from those used by Baggs (2009). However, even though the fact that countries with higher environmental standards tend to export more waste and at the same time accept less waste is consistent with a pollution haven effect, it does not necessarily follow that countries with strict policies export waste to countries with lax policies. Therefore, it is important to also analyze the relationship between volumes traded and the difference in regulatory stringency of trading partners. Kellenberg (2012) demonstrated this kind of approach.

Specifications in Table 3.6 include the Policy Diff. dummy, indicating that the origin country's policies are more stringent than those of the destination country. Specifications (13)-(15) are OLS models and specifications (16)-(18) are PPML models. It can be observed that most variables have the same signs as variables included in corresponding specifications without the Policy Diff. dummy (specifications (1)-(3) and (7)-(9)). Coefficients on the Policy Diff. dummy need to be positive in order to confirm a pollution haven effect. However, in most specifications they are negative, suggesting that countries with lax regulations tend to ship wastes to countries with stringent regulations. As it happens, this result is somewhat in line with the PH. It can be reasonably assumed that at least some waste shipments travel from poorer countries with relatively lenient policies to technologically advanced countries with stringent policies. Both recovery and disposal of hazardous waste often require very expensive technology. Nonetheless, at this point the results do not clearly support either the PHH or the PH.

3.5 Concluding remarks

The findings presented in this chapter are consistent with the results of Baggs (2009) and Kellenberg (2012). Clearly, there is some evidence supporting a pollution haven effect, but it is not as obvious as other determinants of trade in waste. Apart from the traditional factors that affect trade flows, such as economic sizes of trading partners or the distance between them, factors specific to trade in waste (waste treatment capacities and waste generation) turned out to be equally as important. A country having a large waste treatment capacity decreases its exports and increases imports. High levels of waste generation promote exports.

Both large waste treatment capacity and high levels of waste generation are characteristics of well-developed countries. After controlling for these factors most of the specifications employed in this research show that laxity in environmental policy is one of the sources of comparative advantage in waste management services. However, since it is only one of many determinants, we do not see an obvious pattern of waste flowing from rich to poor nations. Instead, most waste appears to be traded among high-income countries.

Surprisingly, the results suggest that the pollution haven effect is relevant, especially in the case of waste destined for recovery, which is the opposite of what was expected by this researcher. Limitations of the dataset provide some explanation to this unexpected result. It comprises only a small fraction of all traded waste, namely notified (mostly hazardous) waste. What is true for hazardous waste may not be true for other kinds of waste, as it is very different. Hazardous waste itself is, of course, hardly homogeneous, it is generally much more difficult to recycle than non-hazardous materials, but some hazardous substances, for example, lead, can be efficiently recycled. The main problem is that the dataset distinguishes only between disposal and recovery operations. Since it is also highly aggregated at the country level, a large part of waste marked as ”destined for recovery” may represent waste intended for incineration with energy recovery instead of recycling. Additionally, since only a small fraction of facilities export waste, a few that export especially large volumes may have a substantial, biasing, impact on the overall result.

Very aggregated data, as used in this chapter, cannot explain why trade in hazardous waste (in terms of volume) tends to be directed from countries with laxer regulations to countries with stricter regulations. Only by analyzing disaggregated data, it is possible to learn exactly how many firms value the stringent regulations of the destination country.

The conclusion, at this point, is that the dataset used in this study does not carry enough detail to allow for a comprehensive and robust analysis of patterns in waste trade depending on the type of intended treatment. It is therefore proposed that valuable insights can be revealed from an analysis at a disaggregated level. Still deeper understanding might be gained if it were possible to distinguish between different types of recovery operations.

Appendix

3.A Tables

Table 3.A.1 Descriptive statistics

Variable	Min	Mean	Max	SD
Quantity	0.002	41178.3	1873980	149324
GDP (Origin)	5386.1	718125	3043650	859031
GDP (Destination)	13521.7	957711	3043650	965101
Distance	59.617	974.044	3288.07	613.266
Waste Generation	0.048	4.536	15.46	4.662
Total Capacity (Origin)	0.036	4.478	17.034	5.005
Total Capacity (Destination)	0.048	6.341	17.034	5.878
SER (Origin)	1	39.574	100	22.293
SER (Destination)	1	44.27	100	22.002
PRS (Origin)	1	42.637	100	21.994
PRS (Destination)	1	46.299	100	20.477
EPI (Origin)	48.1	83.666	90.86	4.845
EPI (Destination)	48.1	83.216	90.86	4.777

Table 3.A.2 List of countries

Country	SER	PRS	EPI
Norway	99.67	77.29	86.24
Luxembourg	89.38	100.00	85.87
Denmark	72.76	67.04	86.99
Sweden	69.51	65.33	87.90
Germany	60.55	55.31	82.69
France	55.00	44.51	84.72
Finland	49.43	62.71	89.18
United Kingdom	48.41	51.13	86.59
Netherlands	43.21	64.87	80.12
Ireland	41.45	57.67	86.26
Austria	40.79	55.35	83.58
Latvia	37.84	13.49	82.38
Slovenia	37.80	31.15	84.02
Lithuania	31.21	18.12	80.29
Italy	30.28	23.06	82.16
Spain	28.91	34.93	86.50
Malta	28.69	26.91	85.37
Belgium	24.80	50.47	77.30
Romania	23.63	4.18	75.52
Estonia	21.43	30.36	85.67
Poland	20.14	17.52	77.66
Cyprus	19.94	34.22	77.55
Croatia	16.23	10.14	79.88
Hungary	13.84	17.40	79.56
Bulgaria	12.76	1.72	76.61
Czech Republic	10.13	21.58	83.06
Slovakia	10.01	16.29	81.71
Portugal	4.47	29.79	85.95
Greece	2.99	14.45	81.91

Notes: SER, PRS and the EPI are average values over 2006-2015.

Table 3.A.3 Correlation matrix

	Qty	Border	Lang.	GDPi	GDPj	Dist.	SERi	SERj	PRSi	PRSj	EPIi	EPIj	Total Cap.i	Total Cap.j	Waste Gen.i
Qty	1.00														
Border	0.23	1.00													
Lang.	0.13	0.47	1.00												
GDPi	0.15	0.09	0.02	1.00											
GDPj	0.16	-0.02	0.00	-0.14	1.00										
Dist.	-0.20	-0.57	-0.35	-0.05	0.14	1.00									
SERi	0.09	0.10	0.16	0.31	-0.05	-0.27	1.00								
SERj	0.09	0.01	0.09	0.00	0.34	0.01	0.16	1.00							
PRSi	0.13	0.09	0.29	0.14	-0.02	-0.25	0.80	0.14	1.00						
PRSj	0.09	0.02	0.22	0.02	0.15	-0.02	0.12	0.76	0.16	1.00					
EPIi	-0.02	-0.06	-0.06	0.06	-0.00	0.04	0.38	0.09	0.24	0.01	1.00				
EPIj	-0.02	-0.01	-0.02	0.04	0.11	0.06	0.12	0.43	0.03	0.24	0.46	1.00			
Total Cap.i	0.10	0.12	0.04	0.89	-0.10	-0.05	0.28	0.02	0.08	0.05	-0.02	0.00	1.00		
Total Cap.j	0.15	-0.02	-0.01	-0.14	0.90	0.14	-0.09	0.26	-0.06	0.00	-0.05	0.01	-0.10	1.00	
Waste Gen.i	0.12	0.10	0.04	0.91	-0.11	-0.05	0.30	0.03	0.11	0.05	-0.00	0.03	0.98	-0.12	1.00

Notes: The subscripts *i* and *j* refer to the origin and destination country respectively. *Qty* means quantity, *Lang.* means language, and *Dist.* means distance.

3.B Figures

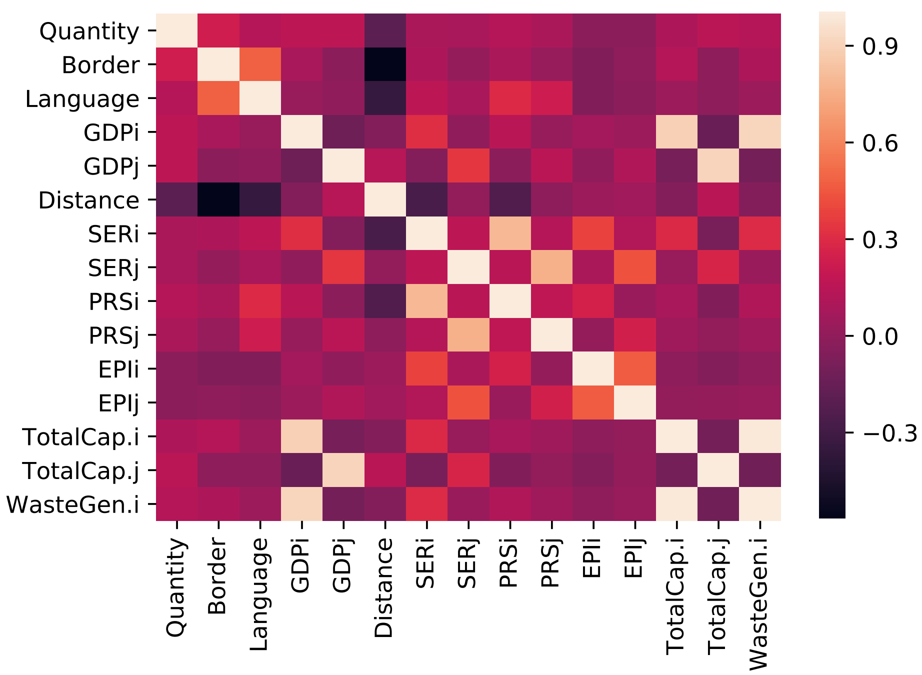

Figure 3.B.1 Correlation map of the variables. Source: Own elaboration

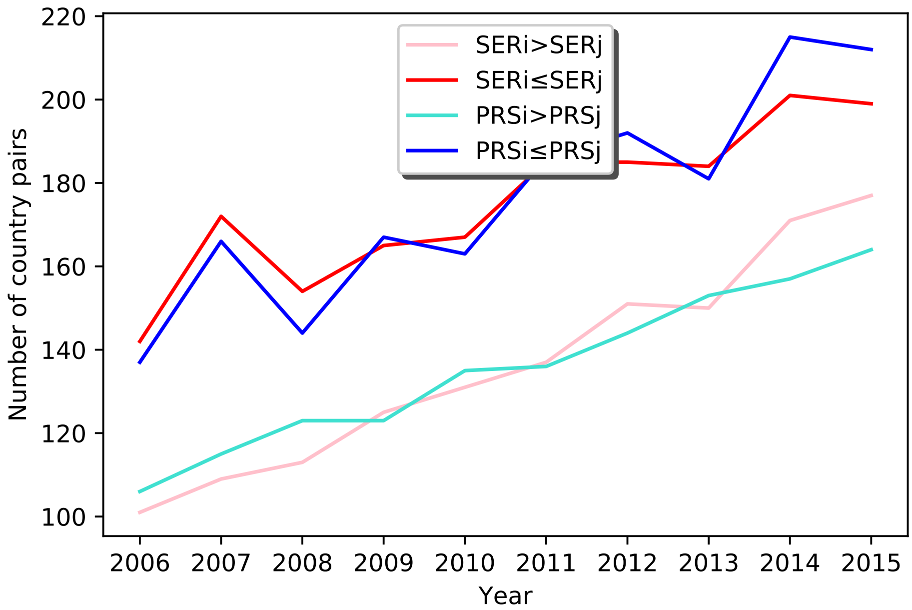

Figure 3.B.2 Number of country pairs with the origin country having either more or less stringent regulations than the destination country. Comparison between SER and PRS. Source: Own elaboration

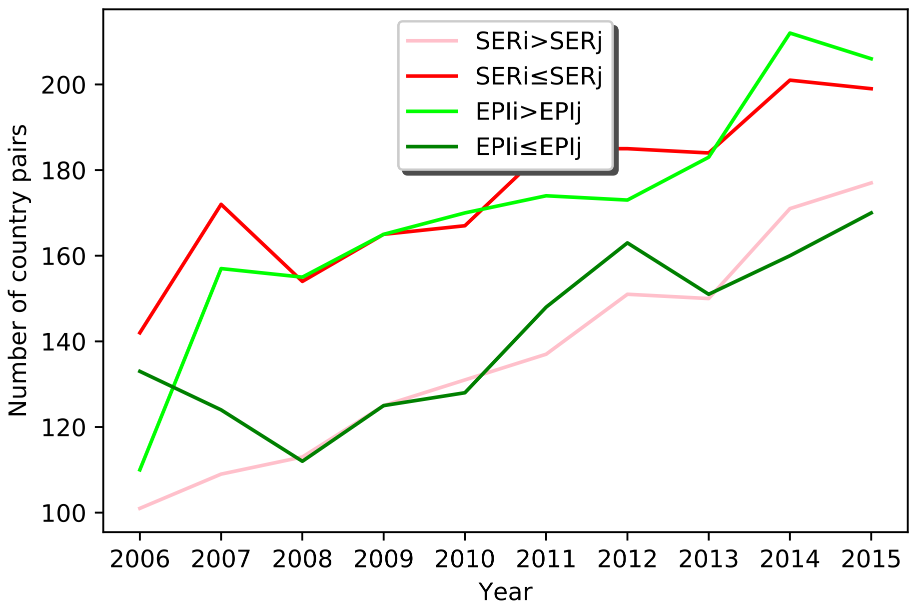

Figure 3.B.3 Number of country pairs with the origin country having either more or less stringent regulations than the destination country. Comparison between SER and the EPI. Source: Own elaboration

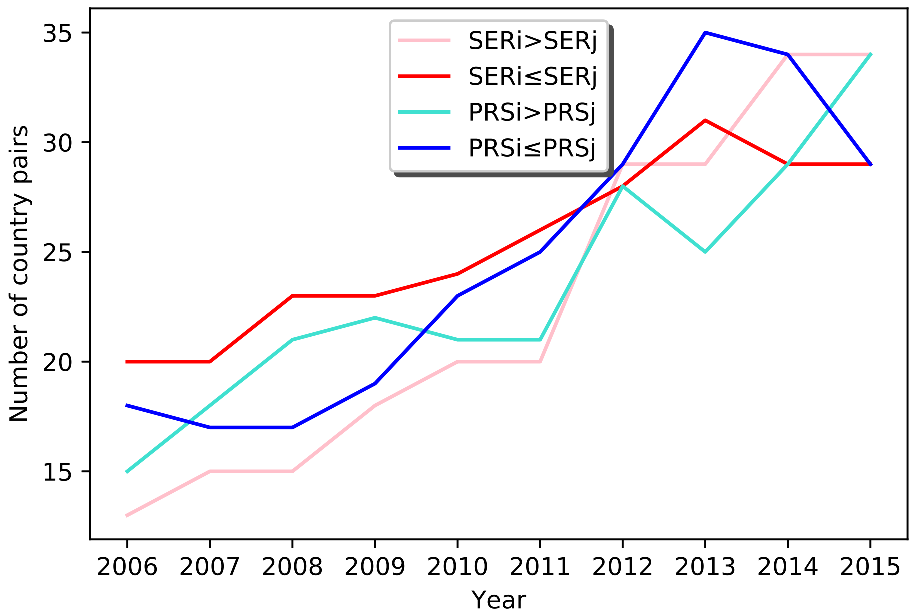

Figure 3.B.4 Number of country pairs with the origin country having either more or less stringent regulations than the destination country (only country pairs that traded more than the mean value of all shipments). Comparison between SER and PRS. Source: Own elaboration

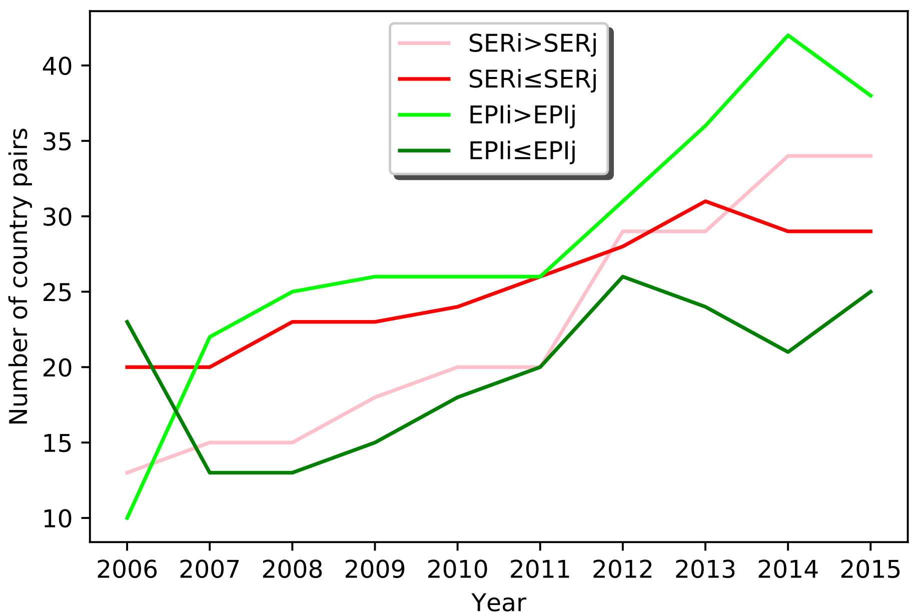

Figure 3.B.5 Number of country pairs with the origin country having either more or less stringent regulations than the destination country (only country pairs that traded more than the mean value of all shipments). Comparison between SER and the EPI. Source: Own elaboration

Chapter 4

Facility-level analysis of trade in hazardous waste

4.1 Introduction

This chapter explores data on trade in hazardous waste at the facility-level in order to test the PHH; it also looks at the waste trade destined for recovery to establish whether it follows different patterns than that of the waste trade destined for final disposal.

The elusiveness of the idea of pollution havens continues to attract researchers, who challenge it in many ways. Most studies focus on manufacturing industries and investigate location decisions of polluting firms (Smarzynska and Wei, 2001; Eskeland and Harrison, 2003; Cole, 2004; Mulatu et al., 2010) in addition to the trade patterns of pollution-intensive goods (Tobey, 1990; Grossman and Kruger, 1991; Kellogg, 2007). Regardless of which approach, at best, they find a degree of support for a pollution haven effect without actually confirming the PHH. Moreover, as some researchers point out, the openness of a country to FDI (Foreign Direct Investment) can bring about good results, in terms of environmental protection. Birdsall and Wheeler (1993) analyzed extensive data from Latin America and discovered that countries with protected economies are more likely to develop dirty industries, whereas countries with open economies usually favor cleaner industries and tend to import higher environmental standards from more developed nations.

Inconclusive results of studies on the PHH, with respect to manufacturing industries, gave rise to the idea that a possible confirmation would be to focus on the ”dirtiest” industry of all. As Baggs (2009) put it: ”Since hazardous waste is one of the most regulated and dirty goods imaginable, we might expect that, should any industry follow a pollution haven-like trade pattern, it would be hazardous waste disposal”. However, several subsequent studies produced either mixed evidence or did not confirm the PHH in its strongest form (Baggs, 2009; Kellenberg, 2012; Kellenberg and Levinson, 2014). What all authors agree on is that, despite the presence of a pollution haven effect, developed countries are usually net importers of hazardous waste. Chapters 2 and 3 of this research which use country-level data, similarly to existing papers, corroborate these findings.

It is believed that the present study is the first to explicitly test data on trade in hazardous waste within Europe for the pollution haven effect. However, Fikru (2012) uses EU's facility-level data on industrial waste flows to determine factors that influence firms' decisions on whether to export their waste or dispose of it locally. According to the study, strict environmental policies do, indeed, encourage facilities to export their toxic waste: yet, in the case of countries that are large and well endowed with capital, this effect can be more than offset by the large number of competing recycling centers driving down the price of waste management and discouraging firms from exporting waste.

Facility-level data for this research has been collected from the European Pollutant Release and Transfer Register (E-PRTR). Fikru (2012) used the same database. However, the present study covers a much longer time period and adopts a completely different empirical approach.

Fikru (2012) investigated which characteristics of an origin country may play a role in determining the export intensity of firms. She did not consider the characteristics of a destination country. The first part of this present chapter also focuses on the origin country's characteristics, although the model and regressors differ substantially from those used by Fikru (2012). The first part of the chapter can be considered as an introduction to the second, main part of the chapter, where conditional logit and mixed logit models are fitted in order to examine the variables affecting the decision of an individual facility on where to export its hazardous waste.

Special attention must be paid to the role of a destination country's environmental policy and its relation to the origin country's policy. Even though regulatory stringency is a crucial variable in testing the PHH, finding an adequate measure for it poses a great challenge to researchers. The lack of a direct measure sometimes leads to choices that are too broad to be of adequate use (e.g., GDP per capita) or, conversely, focused only on one aspect of environmental policy (e.g., environmental taxes). Needless to say, the wrong choice of environmental policy variable makes subsequent conclusions inaccurate. This chapter, therefore, utilizes and compares three different measures: SER, PRS, and the EPI. Their detailed description can be found in Section 1.4 of Chapter 1.

This research contributes to existing literature by combining very disaggregated data with the most flexible and reliable of the discrete choice models together with a comprehensive measure of environmental policy stringency. Moreover, unlike existing literature, the present study assumes that environmental regulations may affect a facility's decision on where to export its waste in different ways, depending on whether it is destined for recovery or final disposal.

The remainder of this chapter proceeds as follows. Section 4.2 analyzes the decision of an individual facility on whether to export its waste or dispose of it locally. It first describes the model and the data, it then presents the results of empirical analysis. Section 4.3, the key section of this chapter, is structured similarly to Section 4.2. It investigates, in detail, the factors determining the facility's choice of destination country for its waste shipments. The chapter then concludes with the last section.

4.2 Factors driving trade in waste products

4.2.1 The binomial model

At the most basic level, a waste generating facility faces two options when deciding on where to dispose of waste: either disposing of it domestically or exporting to another country (see Figure 4.1). Since it can be assumed that facilities are profit maximizing (and cost minimizing), the further assumption is that they will choose the cheaper option.

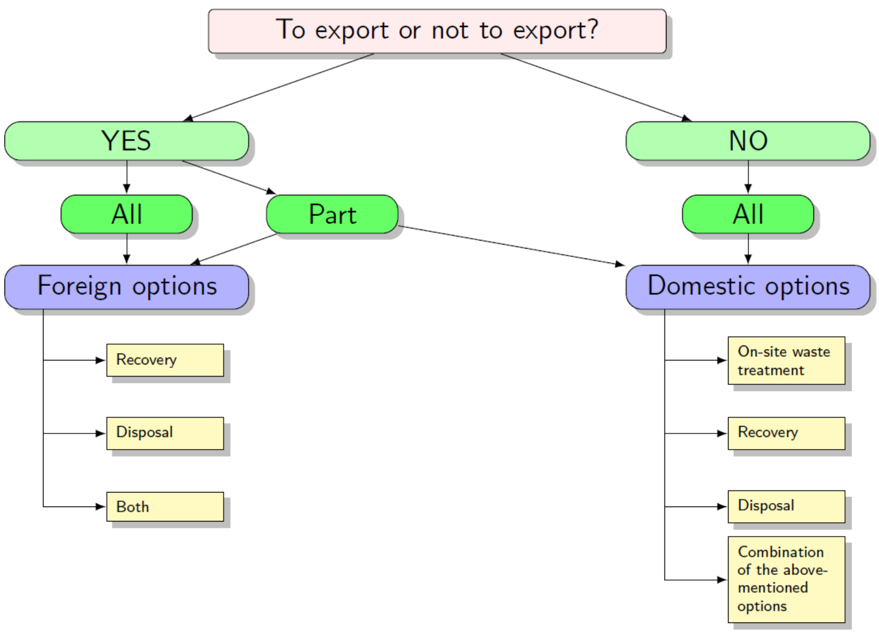

Figure 4.1 Waste generators' decision on whether to export waste or manage it locally. Source: Own elaboration

The amount of money a facility spends on waste disposal depends on the transportation cost and the disposal or recovery fee.

$$C = t * d * q + f * q, \tag{4.1}$$

where t denotes transportation cost per tonne of waste per 1 kilometer, d is the distance to the waste handler in kilometers, q is the amount of waste in tonnes, and finally f is the disposal or recovery fee.

It is a fact that the majority of hazardous waste generators never ship waste outside their own country as it is usually cheaper to treat waste domestically. So, what might be the reasons for exporting waste? Firstly, sometimes the technology required to treat particular types of waste is only available abroad. Secondly, in some cases, it is simply less expensive. Let superscripts D and F refer to *domestic* and $foreign$ respectively. A facility exports waste when:

$$C^F < C^D \tag{4.2}$$

After substituting in (4.1) and some simple manipulations we obtain:

$$f^F < t^D * d^D - t^F * d^F + f^D \tag{4.3}$$

It is naturally assumed that the transportation fee is greater when a facility chooses a foreign waste handler as opposed to a domestic one. So the difference $t^D * d^D - t^F * d^F$ in (4.3) is some negative number which, here, is defined as $-P$. Equation (4.3) can be now simplified to:

$$f^F < f^D - P \tag{4.4}$$

It is clear that a facility exports waste if the fee charged by a foreign waste handler is lower than that of a domestic waste handler minus the difference in foreign and domestic transportation costs. Since transportation and bureaucratic costs, in the case of exporting waste products, are very large this rarely happens. It is worth noting that sometimes a foreign waste handler possessing technology unavailable in the country where a facility is located pays for recoverable waste, which otherwise would have to be disposed of domestically and for a fee. In this case, f^F becomes negative because money paid by a foreign waste management firm to a facility can be subtracted from the overall cost of waste disposal.

In order to answer the question as to why facilities export waste it is necessary to fit a binomial logit model. It is suitable for application in this case as the dependent variable, EXPORT, is categorical (binary) and takes only two values: (1) exported (if a facility exported waste), and (2) not exported (if a facility disposed of waste domestically). Therefore, the underlying distribution is binomial and the mean of the distribution is the probability of exporting waste:

$$P_i = \frac{e^{\boldsymbol{x_i'\beta}}}{1 + e^{\boldsymbol{x_i'\beta}}}, \tag{4.5}$$

where $\boldsymbol{x_i'}$ includes explanatory variables. This function is not linear because, theoretically, the predictions can take any value from $-\infty$ to ∞, whereas probabilities are bounded by 0 and 1. Central to the logit model is the transformation of P_i, which results in so called *logit* (Hosmer Jr et al., 2013). The logit, in the case of this study, is the log of the odds ratio in favour of exporting waste. The odds ratio is:

$$\frac{P_i}{1 - P_i} = e^{\boldsymbol{x_i'\beta}} \tag{4.6}$$

If we take the natural log of (4.6) we get:

$$L_i = ln(\frac{P_i}{1 - P_i}) = \boldsymbol{x_i'\beta} \tag{4.7}$$

L_i, the logit, has many desirable properties from the viewpoint of estimation. It is linear in parameters, can be continuous and can range from $-\infty$ to ∞. The parameters $\boldsymbol{\beta}$ are estimated by the maximum-likelihood (ML) method.

4.2.2 Data

The dependent variable, EXPORT, is equal to 1 if a facility shipped waste abroad and is equal to 0 if it did not; the relevant data on hazardous waste shipments was provided by the E-PRTR database. The 29295 facilities from 29 European countries, included in this study, reported waste shipments in excess of 2 tonnes. Only about 10% exported waste between 2007 and 2015. The number of observations, 256471, is as large as it is because some facilities submitted multiple reports during the period under study.

The explanatory variables include the determinants of domestic disposal and recovery fees.[1]

The most important factors are, unsurprisingly, related to the cost of building and running a waste treatment facility, which in turn depend on the cost of labor and the price of land.[2] The labor component is captured by the labor cost levels (Lab. Cost).

[1]The transportation component of the disposal cost is ignored here because of the assumption that transportation and bureaucratic costs are always higher when shipping abroad. Accordingly, incorporating transportation costs would not help to explain why some facilities choose to export waste.

[2]Labor cost is more important in the case of a recovery facility. The price of land is crucial in the case of a landfill.

Labor cost levels refer to the total average hourly labor costs, in Euro, within industry, construction, and services (excluding public administration, defense and compulsory social security). The cost of land is proxied by the population density variable (Pop. Dens.). It is assumed that the more densely populated a country is, the higher the cost of acquiring land. It is expected that the coefficients for the Pop. Dens. and Lab. Cost variables will be positive.

The disposal fee is determined not only by the cost of running a waste treatment facility, but also by the size of the market together with the level of competition. These factors are represented by the total landfilling and recovery capacity (Total Cap.).[3] Since a large disposal and recovery market is assumed to decrease the cost of waste treatment, the coefficient on the Total Cap. variable is expected to be be negative.

In addition to the above, disposal and recovery fees are also affected by the general stringency of environmental regulations, proxied, here, by the SER, the EPI, and PRS variables. Positive coefficients on these variables suggest the possibility that facilities direct their waste shipments away from countries with stringent environmental regulations.

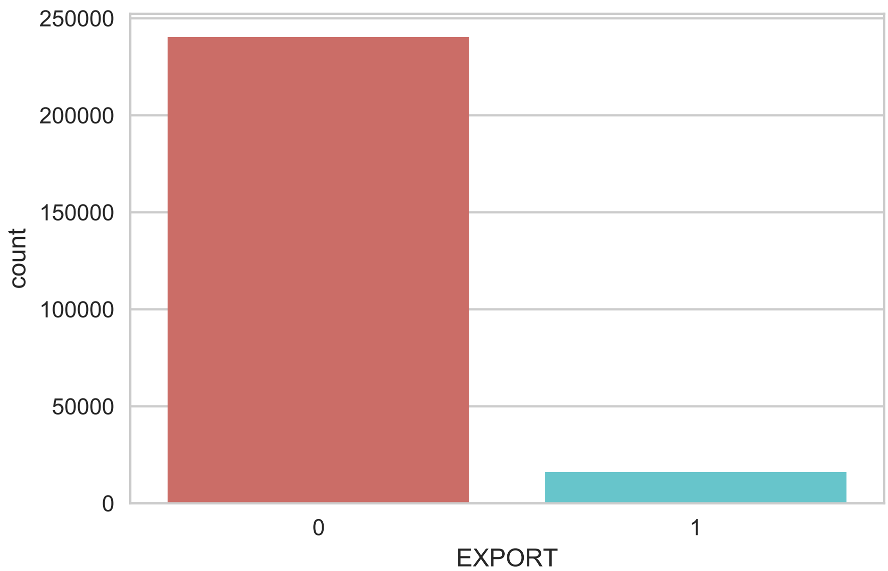

Figure 4.2 Count plot of the dependent variable. Source: Own elaboration

Finally, the Quantity variable was added, in order to find out whether the volume of a shipment is important in determining its destination (foreign or local waste handler); also included is the Recovery dummy, which equals 1 if a shipment is intended for recovery and 0 otherwise. The Quantity variable and the Recovery dummy are the only

[3]The data on waste treatment capacity is available only for every second year necessitating the replacement of missing values with values from the subsequent year.

facility-level independent variables in the model, the rest being available solely at the aggregate country level.

It is clear from Figure 4.2 that the vast majority of reported shipments were sent to a domestic waste handler.

There were more exporting facilities among those that shipped waste for recovery than among those that shipped waste for disposal (see Figure 4.3).

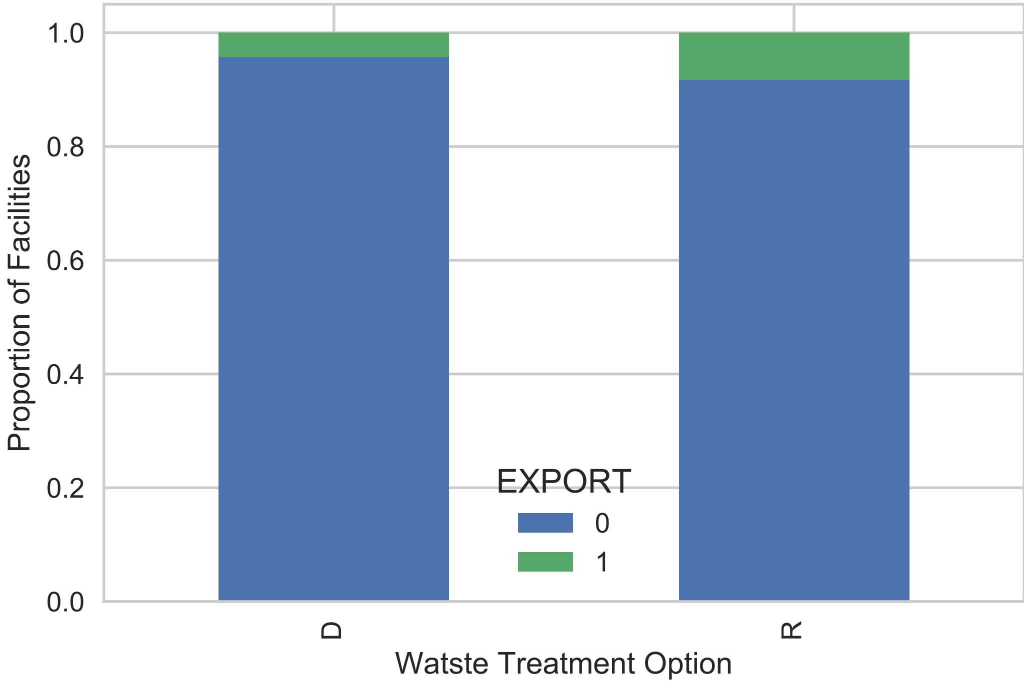

Figure 4.3 Stacked Bar Chart of Treatment Option vs. EXPORT. Note: *D* stands for disposal and *R* for recovery. Source: Own elaboration

Table 4.1 shows the average values of explanatory variables for facilities that exported waste (EXPORT = 1) and facilities that treated waste domestically (EXPORT = 0).

Table 4.1 Average values of explanatory variables depending on the value of the EXPORT variable

EXPORT	Total Cap.	Quantity	Lab. Cost	Pop. Dens.	SER	EPI	PRS
0	1.86	1.45	26.20	1.76	43.20	84.69	42.30
1	1.31	1.66	28.68	1.68	44.42	85.23	46.99

The average total capacity is larger in the case of facilities that treated waste domestically, as was expected. Table 4.1 suggests that the volume of a shipment tends to be bigger when waste is sent to a foreign waste handler. Furthermore, it is clear that most international waste shipments originate from countries with relatively high labor costs and stringent environmental regulations. Finally, exporting facilities tend to be located in countries that are less densely populated.

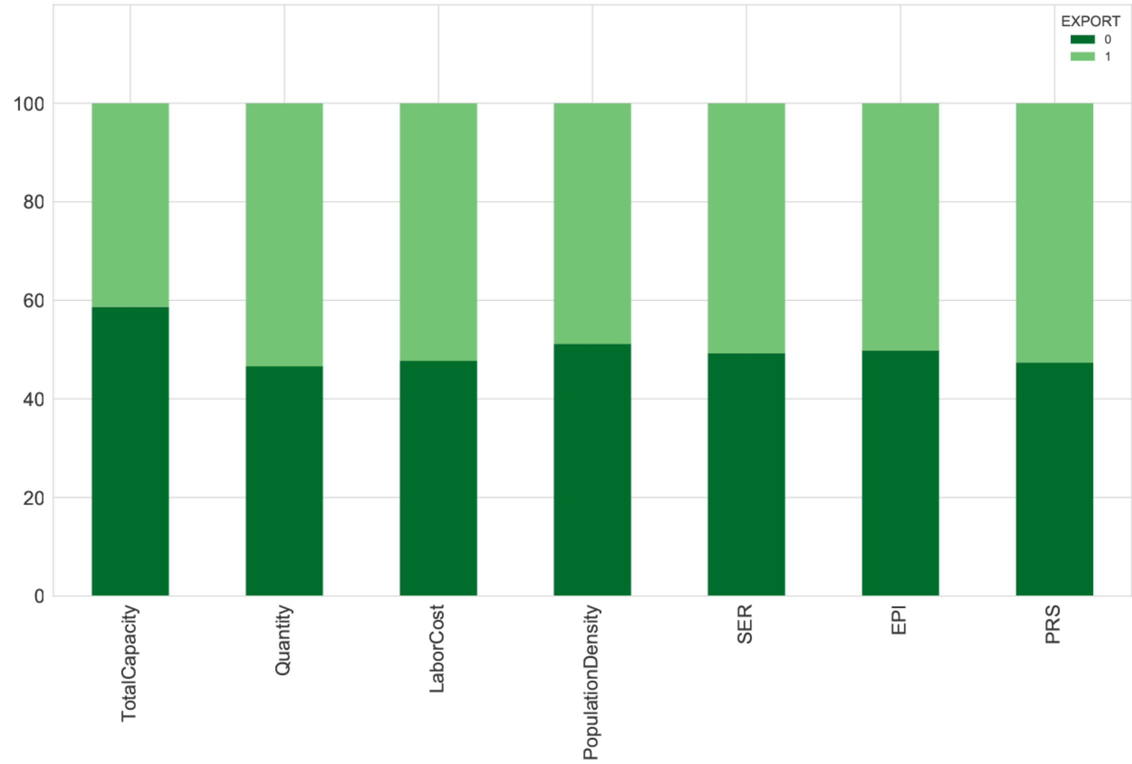

Figure 4.4 Differences in the average values of explanatory variables depending on the value of the EXPORT variable. Source: Own elaboration

Figure 4.4 presents the same information in percentage terms to allow for the comparison of differences in the magnitude of explanatory variables' average values, depending on the value of the EXPORT variable. The largest difference can be seen for the Total Cap. variable. In the case of other variables, the differences are moderate or small.

The description of explanatory variables along with sources, the descriptive statistics, and a list of countries ranked by the values of SER are provided in Appendix 4.A in tables 4.A.1, 4.A.2, and 4.A.4 respectively.

4.2.3 Estimation results

Table 4.2 presents the estimation results for three different specifications. Specification (1) uses SER, specification (2) uses the EPI, and specification (3) uses PRS as the environmental policy stringency variable.

Except for the Quantity variable, the coefficients are highly significant. Furthermore, the magnitude of coefficients is similar regardless of specification.

Table 4.2 Estimation results

	Dependent variable:		
	EXPORT		
	(1)	(2)	(3)
Total Cap.	-0.45^{***}	-0.45^{***}	-0.44^{***}
	(0.01)	(0.01)	(0.01)
Quantity	0.0003	0.0003	0.0003
	(0.0003)	(0.0003)	(0.0003)
Lab. Cost	0.04^{***}	0.04^{***}	0.03^{***}
	(0.001)	(0.001)	(0.001)
SER	0.002^{**}		
	(0.001)		
EPI		0.03^{***}	
		(0.003)	
PRS			0.01^{***}
			(0.001)
Recovery	0.73^{***}	0.74^{***}	0.73^{***}
	(0.02)	(0.02)	(0.02)
Pop Dens.	-0.10^{***}	-0.05^{***}	-0.11^{***}
	(0.01)	(0.01)	(0.01)
Constant	-3.39^{***}	-5.83^{***}	-3.49^{***}
	(0.03)	(0.28)	(0.03)
Observations	256,471	256,471	256,471
Log Likelihood	-56,680	-56,645	-56,546
Note:			*p<0.1; **p<0.05; ***p<0.01

The negative coefficient on the Total Cap. variable suggests that facilities from countries with larger waste management markets are less likely to export waste.

Exporting facilities tend to be located in countries that have higher labor cost, which is consistent with predictions. However, the coefficient on the Pop. Dens. variable has an unexpected negative value, indicating that facilities from less densely populated countries are more likely to export waste. One possible reason for this result might be that population density is not a very precise measure of land prices, another possible reason is that population density is closely related to the Total Cap. variable, which also has a negative coefficient.[4]

The policy stringency variable has positive coefficients in all specifications, meaning that, all other things being equal, waste exporters tend to be located in countries with more stringent pollution controls, which is in line with predictions concerning the presence of a pollution haven effect. These results are consistent with Fikru (2012). However, no definite conclusions should be drawn at this point because this initial analysis reveals nothing about the characteristics of a destination country. In the subsequent section, the model includes the regulatory stringency variables, of both an origin and a destination country, in an effort to deepen the level of understanding.

4.2.4 Discussion

In order to get an idea about the magnitude of the impact explanatory variables can have on the dependent variable, it is useful to analyze the odds ratios and marginal effects.

The odds ratios for specification (1) are presented in Table 4.3. Odds ratios are obtained by exponentiating estimated coefficients from Table 4.2: they are the ratio expressing the probability that a facility will export waste to the probability that it will not. Unlike predicted probabilities, whose values depend on the value of an explanatory variable, odds ratios represent the constant effect of a predictor on the likelihood that the studied outcome will occur. They are often interpreted in terms of a percentage change in the odds in favour of the event occurring for a unit increase in the value of a predictor variable.

For a unit increase in total capacity, the odds in favour of exporting waste decrease by 36.4%. The quantity shipped appears to have no influence on the odds of exporting waste, however, the method of treatment (either disposal or recovery) is important. The odds of exporting waste when it is destined for recovery (Recovery = 1) over the odds of exporting waste when it is destined for disposal (Recovery = 0) is 2.084. In terms of percent change, the odds for shipments destined for recovery are 108.4% higher than the odds for shipments destined for final disposal. A unit increase in labor costs increases the odds of exporting waste by 4.0%. In the case of population density, a

[4]More densely populated countries usually have a higher level of general economic activity, which increases the demand for waste disposal services and perforce the size of waste management markets.

unit increase results in a decrease in the odds by 9.3%. Finally, a unit increase in the environmental policy stringency variable, SER, increases the odds of exporting waste by 0.2%.

Table 4.3 Odds ratios with profile likelihood intervals for specification (1)

Variable	Odds Ratio	2.5 %	97.5 %
Total Cap.	0.636	0.627	0.646
Quantity	1.000	1.000	1.001
Lab. Cost	1.040	1.038	1.043
SER	1.002	1.000	1.003
Recovery	2.084	2.014	2.157
Pop. Dens.	0.907	0.894	0.921

Analyzing marginal effects is another way of obtaining a sense of logistic regression results. However, in a non-linear model, a marginal effect changes with the value of the variable itself. Table 4.4 shows average marginal effects representing the change in probability of exporting waste associated with one unit change in a predictor variable.

Table 4.4 Average marginal effects for specification (1)

Factor	AME	SE	z	p	lower	upper
Lab. Cost	0.002	0.0001	28.810	0	0.002	0.002
Pop. Dens.	-0.006	0.0004	-12.739	0	-0.006	-0.005
Quantity	0.00002	0.00002	1.216	0.224	-0.00001	0.00005
Recovery	0.042	0.001	40.954	0	0.040	0.044
SER	0.0001	0.00004	2.375	0.018	0.00002	0.0002
Total Cap.	-0.026	0.0005	-55.950	0	-0.027	-0.025

Except for the Quantity variable, the average marginal effects are highly significant. One unit increase in SER increases the probability of exporting waste by 0.01 of a percentage point.

Finally, the predicted probabilities for different values of SER, the EPI, and PRS, holding other variables at their means are plotted.

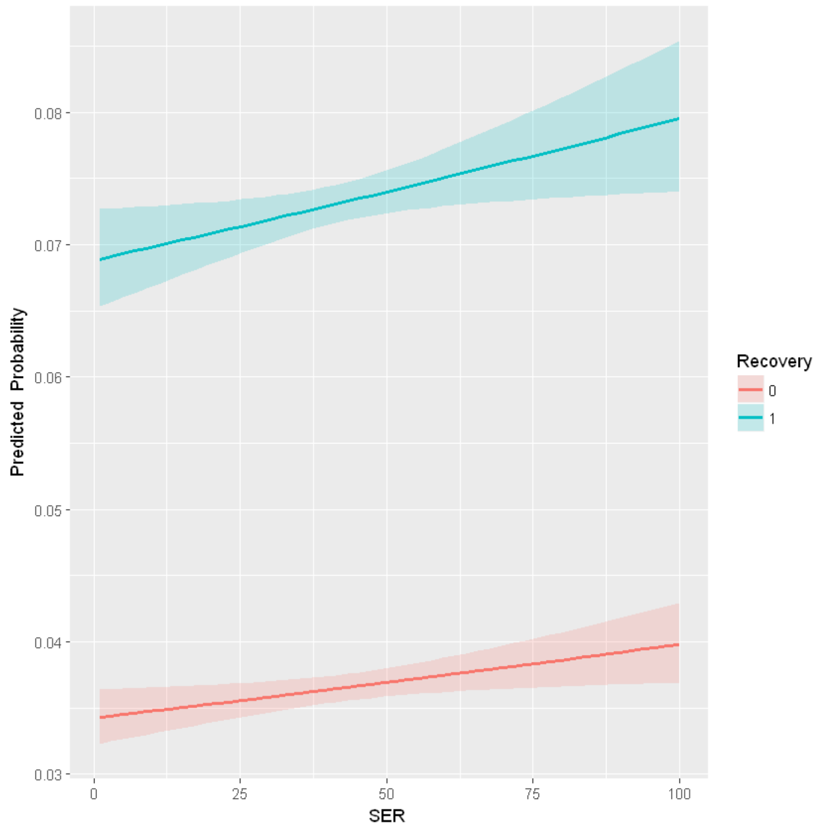

Figure 4.5 Predicted probabilities at different levels of SER

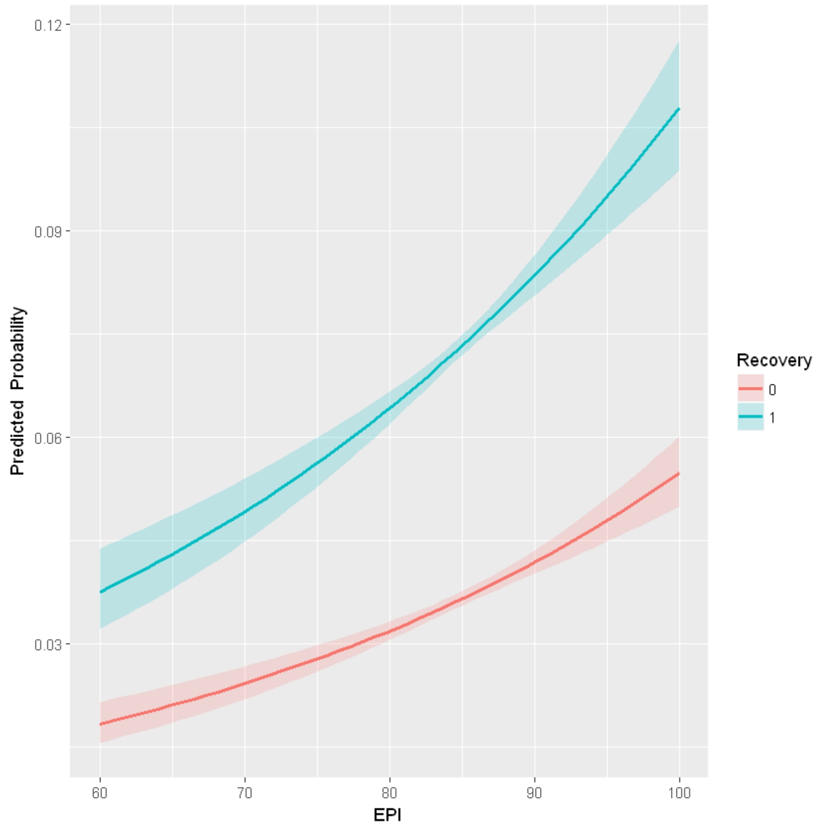

Figure 4.6 Predicted probabilities at different levels of the EPI

Potted separately are the shipments destined for recovery (Recovery=1) and the shipments destined for final disposal (Recovery = 0). It is clear from figures 4.5, 4.6, and 4.7 that tightening of environmental policy, measured by SER, the EPI, and PRS, causes an increase in the predicted probability of exporting waste.

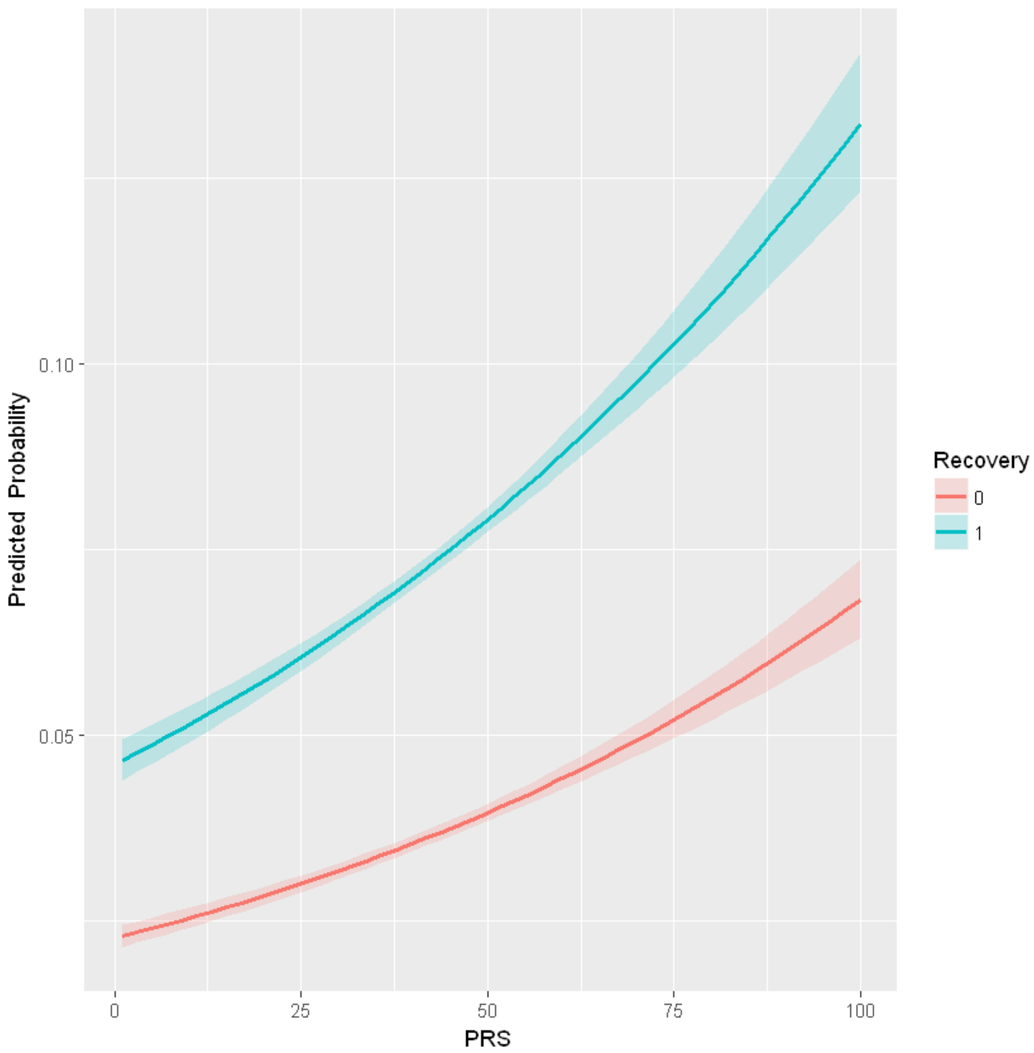

Figure 4.7 Predicted probabilities at different levels of PRS

All three plots show that probabilities are smaller when waste is destined for final disposal. Generally, SER appears to be less reliable than the EPI and PRS because the confidence intervals around it are much wider than those around the EPI and PRS. The plots in the case of SER are also considerably flatter. Nevertheless, all three regulatory stringency variables are significant and provide a degree of evidence for a pollution haven effect. However, definite conclusions cannot and should not be drawn until a more detailed analysis has been conducted. In order to unmask a pollution haven effect, it is necessary to investigate closely the factors affecting facilities' decisions on where to export their waste.

4.3 Factors determining waste shipments' destination country

4.3.1 The model

The E-PRTR database allows identification of not only a facility that produces waste, but also the waste handler that receives it. However, in the model each of the 2869 exporting facilities, from 29 European countries, is choosing only from among 28 possible destinations, since destination characteristics data is available solely at the country-level.[5] It was decided to fit and compare two types of discrete choice models. This in order to explain how destination countries are chosen for hazardous waste shipments: both, the conditional logit model and the mixed logit model, are based on the random utility framework, which assumes that an individual makes a choice that maximizes their utility. Although some facilities may profit from exporting waste, the majority choose the destination country to minimize the cost of waste disposal. Consequently, in the case of this research, maximizing utility is equivalent to minimizing the cost of waste disposal.

If the utility of facility g choosing country k from among J alternatives is defined as U_{gk}, then country k will be chosen when $U_{gk} > U_{gj}$ for $k \neq j$. As the true utility U_{gj} is unknown, prediction of the facility's choice can only be made in terms of probability. The observable component of the utility, V_{gj}, can be computed based on the destination country's attributes, whereas the random component, ε_{gj}, can only be known by a facility making the decision.

$$U_{gj} = V_{gj} + \varepsilon_{gj} \tag{4.8}$$

Since the observable component is based on the attributes that determine the cost of waste disposal, (4.8) can be written as:[6]

$$U_{gij} = \beta_0 + \beta_1 C_{gij} + \varepsilon_{gij}, \tag{4.9}$$

where C_{gij} is the cost of waste disposal incurred by facility g for shipment i to country j, $C_{gij} = t * d_{gj} * q_{gi} + f_j * q_{gi}$. In order to compute the probability $P_{gik} = P(U_{gik} > U_{gij})$, a probability density function must be imposed on the random component ε_{gij}. In the conditional logit model ε_{gij} follows the extreme value distribution and is assumed to

[5] Malta is excluded from the choice set because it did not import any waste during the period under study (2007-2015).

[6] Note that U_{gj} becomes U_{gij} because in the dataset the same facility can appear several times. It is a repeated choice situation, which can be better modeled using a mixed logit approach.

be independent and identically distributed (iid). The probability of facility g choosing country k for shipment i from among J alternatives is computed as:

$$P_{gik} = \frac{e^{V_{gik}}}{\sum_{j=1}^{J} e^{V_{gij}}} = \frac{e^{Z'_{gik}\beta}}{\sum_{j=1}^{J} e^{Z'_{gij}\beta}}, \tag{4.10}$$

where Z'_{gij} is a vector including explanatory variables (a country's attributes determining the cost of disposal), and β is a vector of coefficients obtained from the model. The conditional logit model assumes that, all else being equal, a facility's choice between two destinations is independent of what other destinations are available. Stated differently, the ratio P_{gik}/P_{gij} is unaffected by the remaining probabilities. This property of the conditional logit model is called the independence from irrelevant alternatives (IIA) and is often violated in the real world.

Over time several models have been developed in order to relax the IIA assumption. The mixed logit model is particularly flexible and differs from the conditional logit model in that it allows coefficients to vary across individuals or, in the case of this research, across facilities. It also allows for the panel nature of data to be fully exploited (Greene, 2012). A facility's g utility from alternative j in time (choice situation) t is:

$$U_{gjt} = Z'_{gjt}\beta_g + \varepsilon_{gjt}, \tag{4.11}$$

where β_g differs across facilities. In order to estimate U_{gjt} a researcher has to choose a distribution for random parameters (e.g., normal, uniform, triangular). In the situation when there is only one choice per facility, the probabilities are estimated as a weighted average of the standard logit formula evaluated at different values of random parameters β. The weights are given by the density f(β):

$$P_{gk} = \int \left(\frac{e^{Z'_{gk}\beta}}{\sum_{j=1}^{J} e^{Z'_{gj}\beta}}\right) f(\beta) d\beta \tag{4.12}$$

The solution to (4.12) is obtained by simulation in place of the infeasible direct integration (Greene, 2012).

In the case of panel data, a facility makes a sequence of choices, which can be defined as $\mathbf{k} = (k_1, k_2, \ldots, k_T)$. When a facility chooses one destination in each of the T time periods, the probability of making this sequence of choices can be expressed as the product of logit formulas. The probability conditional on β is:

$$L_{g\mathbf{k}}(\beta) = \prod_{t=1}^{T} \left[\frac{e^{Z'_{gkt}\beta_g}}{\sum_{j=1}^{J} e^{Z'_{gjt}\beta_g}}\right] \tag{4.13}$$

Finally, the unconditional probability is computed as the integral of the product in (4.13) over all values of β:

$$P_{g\mathbf{k}} = \int L_{g\mathbf{k}}(\beta) f(\beta) d\beta \tag{4.14}$$

Equation (4.14) differs from equation (4.12) in that the product of logit formulas is integrated instead of just one logit formula (Train, 2009).

4.3.2 Data

The dependent variable, CHOICE, is equal to 1 if facility g exports waste to country k and 0 otherwise. From 29 European countries there are a total of 2869 facilities which, between 2007 and 2015, exported hazardous waste in excess of 2 tonnes at least once. The total number of shipments amounts to 15249.[7] The choice set comprises 28 European countries.[8]

Since the empirical model is based on the utility maximization (cost minimization) framework, the explanatory variables include the most important factors that affect the cost of disposing of waste abroad. These variables can be divided into two groups: those associated with transportation costs and those associated with the disposal fee.

The first group consists of two variables: Distance and Border. The distance between countries is calculated as Euclidean distance between their capital cities. As the distance increases, so do the transportation costs. The fact of having to cross multiple borders is also important because of the bureaucratic burden becoming greater with each additional transit country. In this study, however, only a simple distinction is made between a neighboring country and all other countries. The distance variable is expected to have a negative coefficient, while, in the case of the Border variable, the coefficient is expected to be positive.

The second group includes variables assumed to determine disposal fees, necessary as actual data on the average disposal fees in countries from the sample is not available. The most important factors affecting the fees are related to the costs of constructing and running a waste management facility, the level of competition in the waste management market and the stringency of environmental policy. In order to represent these factors, the same variables as used in Section 4.2 of this chapter: Pop. Dens., Lab. Cost, Total Cap. together with the three regulatory stringency variables (SER, the EPI, and PRS)

[7] If a facility reported more than one shipment to the same country in the same year and slated for the same type of treatment (either disposal or recovery), it is counted as one shipment.

[8] More than 90 percent of hazardous waste stays within the EU's borders. A small fraction of waste that has been shipped outside the EU is ignored in this study.

were employed. The difference here is that, in this section, they represent characteristics of the destination country.

The stringency of environmental policy within an origin country is also taken into account and is a part of a dummy variable (Policy Diff.), which equals 1 if the environmental policy of an origin country is more stringent than the environmental policy of a destination country and 0 otherwise. Additionally, interaction terms, using a dummy variable Recovery, are included, said variable taking the value 1 if a shipment is destined for recovery and 0 otherwise.

Negative coefficients on the Pop. Dens. and Lab. Cost variables are expected, while the coefficients on the Total Cap. and Policy Diff. variables are predicted to be positive. A positive coefficient on the Policy Diff. variable would mean that facilities are more likely to export waste to a country whose environmental standards are less strict than the standards of their own. This would be in line with the PHH. If the hypothesis is valid, negative coefficients are expected on the policy stringency variables, however, the sign of those coefficients is not obvious when it comes to recovery services. Most hazardous waste cannot be recycled, but parts of it that can often require sophisticated technology, which has been developed in response to stringent regulations.[9] The negative impact of the policy stringency is, therefore, expected to be weaker in the case of shipments destined for recovery. This effect should be confirmed by positive coefficients on the interactions between regulatory stringency variables and the Recovery dummy.

The description and sources of explanatory variables are provided in Table 4.A.1 in Appendix 4.A. The basic descriptive statistics for most variables are presented in Table 4.A.3 in Appendix 4.A. The variable Border, which is not included in the table, takes only the values 1 and 0.

Table 4.5 Average values of explanatory variables depending on the value of the CHOICE variable

CHOICE	Distance	Lab. Cost	Pop. Dens.	Total Cap.	SER	EPI	PRS
0	13.44	20.83	1.22	0.75	36.34	84.12	37.25
1	6.56	31.17	2.49	2.01	48.72	82.84	52.84

Table 4.5 shows the average values of variables for countries categorized according to whether they were chosen as destinations or not. Except for the EPI variable these values are considerably different, depending on the category. In the case of the Border

[9] This prediction is consistent with the Porter hypothesis (see, e.g., Porter, 1991; Porter and van der Linde, 1995; Ambec et al., 2013).

variable, it transpires that as much as 55.13% of all shipments were sent to a neighboring country.

The average distance between pairs of countries that traded waste with each other is shorter than between those that did not engage in bilateral waste trade, a result totally expected. Similarly, the average waste treatment capacity of countries chosen as destinations is larger than that of countries that were not: according to SER and PRS, the chosen countries had, on average, more stringent regulations. The opposite is true in the case of the EPI. The destination countries, surprisingly, appear to be more densely populated and have higher labor costs than the exporting countries. The possible reasons for these counterintuitive results are explored in the later part of this section.

Figure 4.8 presents the content of Table 4.5 in percentage terms, allowing for comparison of the magnitudes of difference in the values of the explanatory variables, depending on the value of the CHOICE variable. The largest differences are observed for the Distance, Pop. Dens., and Total Cap. variables.

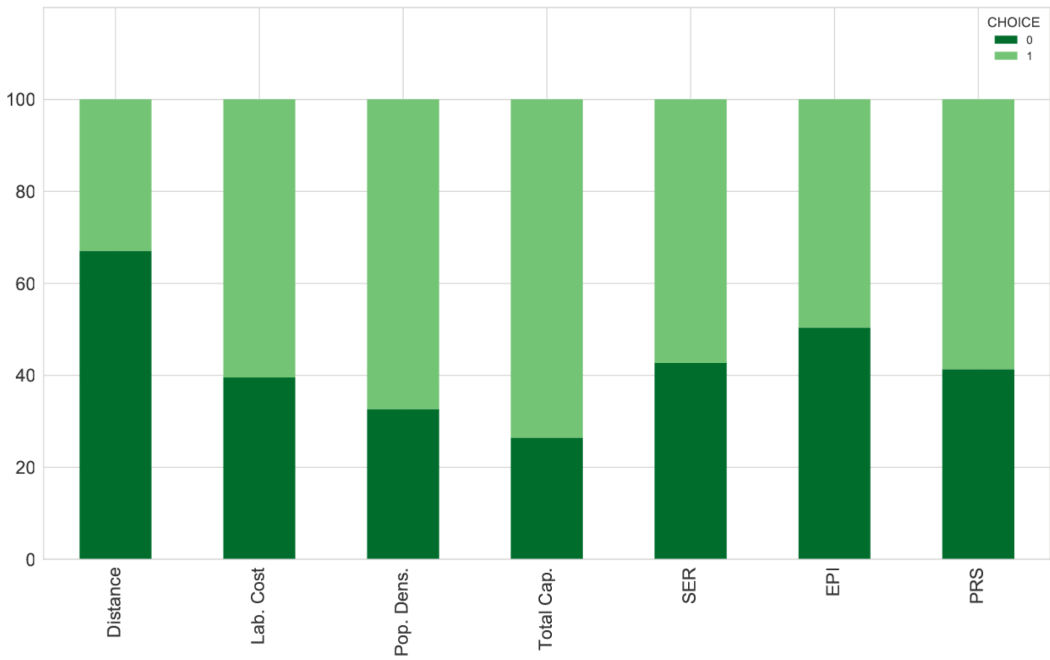

Figure 4.8 Differences in the average values of explanatory variables depending on the value of the CHOICE variable. Source: Own elaboration

4.3.3 Estimation and results

Nine different specifications were estimated. Table 4.6 and Table 4.7 show the results of specifications (1) to (6), and (7) to (9) respectively. Models in Table 4.7 are similar to those in Table 4.6, except they include interactions with the dummy variable Recovery. Specifications (1), (2), and (3) are conditional logit models, whereas specifications (4)-(9) are mixed logit models. Specifications (1), (4), and (7) include SER, specifications (2), (5), and (8) include the EPI, and specifications (3), (6), and (9) include PRS, as the environmental policy stringency variable.

Table 4.6 Conditional logit and mixed logit estimates

	Dependent variable:					
	CHOICE					
	(1)	(2)	(3)	(4)	(5)	(6)
Distance	−0.11***	−0.11***	−0.11***	−0.15***	−0.15***	−0.14***
	(0.003)	(0.003)	(0.003)	(0.01)	(0.01)	(0.01)
Border	1.48***	1.53***	1.48***	2.50***	2.37***	2.82***
	(0.02)	(0.02)	(0.02)	(0.05)	(0.05)	(0.06)
SER	−0.01***			−0.01***		
	(0.001)			(0.002)		
EPI		−0.13***			−0.20***	
		(0.005)			(0.01)	
PRS			−0.01***			−0.005**
			(0.001)			(0.002)
Policy Diff.	0.35***	0.32***	0.09***	0.43***	0.22***	0.18***
	(0.03)	(0.03)	(0.03)	(0.05)	(0.04)	(0.04)
Total Cap.	0.79***	0.70***	0.68***	1.19***	1.15***	1.07***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Lab. Cost	0.09***	0.07***	0.08***	0.12***	0.12***	0.14***
	(0.002)	(0.001)	(0.002)	(0.003)	(0.003)	(0.003)
Pop. Dens.	0.48***	0.28***	0.56***	0.58***	0.44***	0.76***
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
Observations	15,249	15,249	15,249	15,249	15,249	15,249
Log Likelihood	-28,137	-27,651	-28,394	-22,228	-21,990	-22,291
Note:						*p<0.1; **p<0.05; ***p<0.01

The conditional logit model has, in fact, been used before in the context of waste shipments. Alberini and Frost (1999) investigated the determinants of American halogenated solvent waste generators' choice of the destination state for their waste. They fitted two separate conditional logit models, one for the shipments slated for landfilling, and the other for the shipments slated for incineration.[10]

[10]The authors changed their approach in subsequent years and published another paper, where

For the purposes of this research it was decided to test the conditional logit specifications with the Hausman-McFadden test for independence of irrelevant alternatives (IIA). Since they failed the test, mixed logit models that relax the IIA assumption, were subsequently fitted. It is a fact that the mixed logit models yield a higher log likelihood value, meaning they are more efficient. However, as Train (2009) suggests, violation of IIA, in the case of estimating average preferences is acceptable, provided a researcher treats the model as an approximation.

The coefficients reported in Table 4.6 are all highly significant and have the same signs regardless of specification: as can be seen, their magnitudes are similar for the three conditional logit models as well as for the three mixed logit models. Generally speaking, mixed logit specifications tend to have larger coefficients than do conditional logit specifications. It is worth noting here, that changing between three environmental policy stringency variables has only a marginal effect on the coefficients.

The general conclusions, to be drawn, for the first six models are mostly the same. The coefficients on the Distance, Border, and Total Cap. variables have the expected positive and negative signs. Consistent with prediction, the further the distance to a country, the less attractive it is as a destination for waste shipments. Sharing a border with a waste generator's country has the opposite effect, making a potential destination more attractive. The positive coefficient on the waste treatment capacity variable indicates that countries with a large waste management industry are more likely to be chosen as destinations for waste shipments.

The signs of the coefficients on the labor cost variable and the population density variable are opposite to what might be expected. In the case of labor cost, a similar effect is reported by Levinson (1996), Alberini and Frost (1999) as well as Stafford (2000). Several explanations are proposed. Firstly, it is possible that the labor cost variable captures general economic activity in a country, which increases the demand for disposal services, and thus the disposal capacity. It is also possible that the cost of labor is not an important factor in determining the disposal fees because the hazardous waste management industry is not very labor intensive. The positive coefficient on the Pop. Dens. variable might result from the correlation with the general economic activity of a country or some unobserved factors, which make a country attractive for waste shipments.

Finally, the negative and significant coefficients on the SER, EPI, and PRS variables suggest the presence of a pollution haven effect. The positive coefficient on the Policy Diff. variable further adds weight to this conclusion. Stringent regulations of a

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instead of the conditional logit model, they fitted the nested logit model allowing a waste generator to first choose a treatment option and then the destination (Alberini and Frost, 2007).

destination country deter facilities from shipping there, at the same time facilities are attracted by standards lower than those of their own country.

Table 4.7 Mixed logit estimates with interaction terms

	Dependent variable:		
	CHOICE		
	(7)	(8)	(9)
Distance	−0.133***	−0.134***	−0.144***
	(0.009)	(0.008)	(0.01)
Border	2.611***	2.540***	2.706***
	(0.068)	(0.069)	(0.076)
SER	−0.012***		
	(0.002)		
SER x Recovery	−0.023***		
	(0.002)		
EPI		−0.164***	
		(0.012)	
EPI x Recovery		−0.067***	
		(0.011)	
PRS			−0.006**
			(0.002)
PRS x Recovery			−0.005**
			(0.002)
Policy Diff.	0.145	−0.098	−0.759***
	(0.09)	(0.092)	(0.088)
Policy Diff. x Recovery	0.003	−0.155*	0.686***
	(0.094)	(0.090)	(0.084)
Total Cap.	1.323***	1.112***	1.098***
	(0.026)	(0.020)	(0.026)
Lab. Cost	0.142***	0.099***	0.133***
	(0.004)	(0.004)	(0.005)
Pop. Dens.	0.627***	0.509***	0.707***
	(0.024)	(0.023)	(0.025)
Observations	15,249	15,249	15,249
Log Likelihood	-22,016	-22,001	-22,070
Note:			*p<0.1; **p<0.05; ***p<0.01

The addition of interaction terms (see Table 4.7 above) revealed that, contrary to predictions, waste generators shipping hazardous waste for recovery are deterred, to a greater degree, by the environmental policy stringency of the destination country than are waste generators shipping waste for disposal. It is possible that this results from EU legislation aimed at discouraging hazardous waste shipments to countries characterized by lax regulations, especially if it is intended for final disposal. Another plausible explanation is linked to the fact that shipments destined for recovery account for almost 70% of all shipments included in the sample. It is still possible that some of these shipments follow the PH-like pattern, confirmation of this prediction, however, could only be achieved with the availability of more detailed data specifying a particular treatment option.

The coefficients on the Policy Diff. variable, as well as on the interaction between this variable and the Recovery dummy, are insignificant in the specification which includes SER. However, they are significant in specification (9) and suggest that hazardous waste tends to travel from countries with lax regulations to countries with strict policies. This effect appears to be much stronger in the case of waste destined for final disposal. In contrast, the coefficient on the Policy Diff. x Recovery interaction, in specification (8), indicates that it is essentially waste intended for recovery that travels from lax regulations countries to those with stricter regulation. This result differs from the one obtained in specification (5), it is, however, significant only at the 10% level.

4.3.4 Discussion

Analysis of the coefficients in Table 4.7 reveals that facilities place different values on destination country characteristics depending on the type of treatment their waste is destined to undergo. The data, unfortunately, allows only for the distinction between two kinds of operations: recovery and disposal. Recovery is a very broad category as it includes both recycling and incineration with energy recovery: very different ways of dealing with waste. The latter resembles, to a degree, disposal operations, for example it is not labor intensive. However, the most important consideration for this study is the fact that in the main, recovery operations require more advanced and expensive technology than do disposal operations.[11] It is often the case that only countries with high environmental protection standards possess the state of the art recovery technology because stringent regulations have fostered innovations in the waste management industry (consistent with the Porter hypothesis). This explains why some facilities have a positive coefficient on the environmental policy stringency variable. Using the mixed logit model, it is possible to pinpoint the share of facilities that have a positive coefficient on the regulatory stringency variable.

[11] Disposal of hazardous waste in general is, of course, more expensive and more capital intensive than disposal of regular waste.

Table 4.8 Standard deviations and means of the coefficients (Model (4))

	Distance	Border	Lab. Cost	Pop. Dens.	Total Cap.	SER	Policy Diff.
SD	0.13***	2.52***	0.11***	0.94***	0.85***	0.05***	1.69***
Mean	−0.14***	2.50***	0.12***	0.58***	1.19***	−0.006***	0.42***

Table 4.8, above, presents standard deviations and means of the coefficients estimated with the specification (4). With this information, the share of facilities with positive and negative coefficients can be determined for each variable. SER, because it is a critical variable in this study, will be the subject of specific focus.

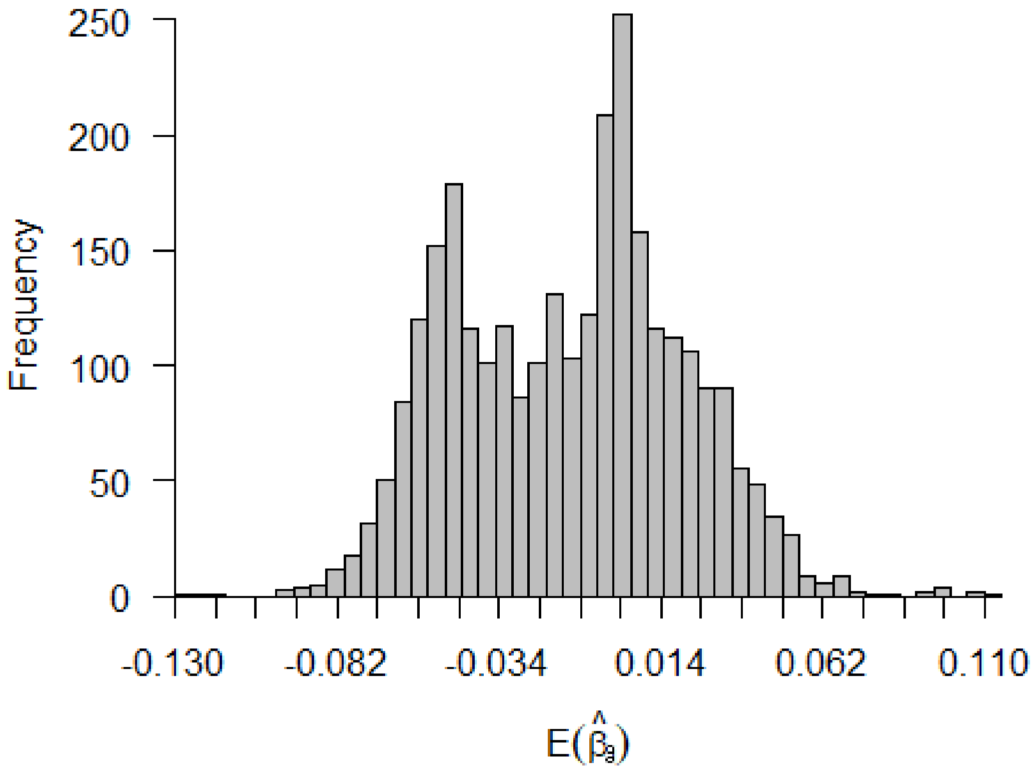

Figure 4.9 Conditional distribution for SER (Model (7)).

The coefficient of SER is normally distributed with mean -0.006 and standard deviation 0.05.[12] The cumulative standard normal distribution evaluated at 0.006/0.05=0.12 is 0.548, indicating that about 55% of facilities are estimated to have negative SER coefficients. About 45% of facilities are attracted by the stringency of environmental regulations and since shipments intended for recovery account for almost 70% of all shipments in the sample, some of the 45% must be facilities exporting waste for recovery. Presumably, many of them actually sell waste products because they contain valuable materials that can be recovered, it is impossible, however, to confirm this presumption with the available data.

There are two groups of facilities: one attracted and the other deterred by the stringency of environmental regulations; a fact that can be clearly seen from the plot of the conditional distribution for SER (see Figure 4.9 above). Plots of conditional distribution for the rest of the variables are available in Appendix 4.B.

The coefficient on the Policy Diff. variable, in most specifications, indicates that facilities tend to choose countries with environmental regulations laxer than those in their own countries. There is yet one more way to examine the relationship between the regulatory stringency of an origin country (SER_{orig}) and that of the destination country (SER_{dest}). Explained in Sarrias et al. (2017), it is possible to include facility specific variables (SER_{orig} and $Recovery$ in the case of this study) to explain the mean of the random parameter (SER_{dest}) in the mixed logit model. It is assumed that the response of a facility to the regulatory stringency of the destination country is dependant on the regulatory stringency of its own country and the type of treatment option it chooses:

$$\beta_{ser,g,t} = \beta_{ser} + \theta_{ser,1} SER_{orig_{g,t}} + \theta_{ser,2} Recovery_{g,t} + \sigma_{ser}\eta_{ser,g}, \tag{4.15}$$

where $\eta_{ser,g} \sim N(0,1)$, σ_{ser} is the standard deviation, and $\beta_{ser}+\theta_{ser,1}SER_{orig_{g,t}}+\theta_{ser,2}Recovery_{g,t}$ is the mean of the distribution.

Table 4.9, below, shows the estimation results. The coefficient on $SER_{dest}.SER_{orig}$ is negative. This suggests that facilities located in countries characterized by stringent regulations tend to be even more deterred by the regulatory stringency of a destination country than those facilities from countries with laxer policies. It is possible that facilities from countries with stringent regulations look for pollution havens, and conversely some facilities from countries with lower environmental standards look for recycling options in countries with higher standards. The effect of the Recovery dummy on the mean of SER_{dest} is also negative, confirming that facilities exporting waste for recovery are more deterred by the environmental policy stringency of the destination country

[12] A researcher must choose a distribution for each random coefficient. In most applications, the distribution is specified to be normal or lognormal.

than those facilities shipping waste for final disposal.

Table 4.9 Estimation results with SER_{orig} and *Recovery* affecting SER_{dest}

Dependent variable:							
CHOICE							
Distance	Border	SER_{dest}	$SER_{dest} \cdot SER_{orig}$	$SER_{dest} \cdot Recovery$	Total Cap.	Lab. Cost	Pop. Dens.
-0.13***	1.40***	0.001	-0.0001**	-0.02***	0.98***	0.08***	0.59***
(0.003)	(0.02)	(0.004)	(0.00007)	(0.003)	(0.01)	(0.002)	(0.01)
Observations	15,249						
Log Likelihood	−26,202						

Note: Subscripts *orig* and *dest* refer to an origin and a destination country, *p<0.1; **p<0.05; ***p<0.01

In order to get an idea of the importance of the SER variable in determining the destination country for hazardous waste shipments it is useful to analyse the change in the predicted probability of receiving a shipment from a one standard deviation increase in SER.[13] Table 4.10 shows the results of this change for each country of the chosen set. Since there is a large group of facilities that place a positive value on SER, it can be expected, that in some cases, the predicted probability of receiving a shipment will increase as a result of implementing more stringent regulations. In fact, Table 4.10 confirms that a total of five countries would import more waste in such a situation.

Countries in Table 4.10 are ranked based on the SER score, with the highest score at the top. It is clear that negative values are concentrated in the lower part of the table. This indicates countries that would experience a decrease in waste imports as a consequence of implementing more stringent regulations are those that have relatively lax environmental policies to begin with.

[13]The values of all other variables do not change.

Table 4.10 Change in predicted probabilities from an increase of SER by 1 SD (calculated for Model (4))

Country	Predicted Probabilities	Probabilities after an SER increase	Difference in Predicted Probabilities	Percentage Change	SER
Norway	0.024	0.021	-0.003	-12.500	99.629
Luxembourg	0.013	0.018	0.005	38.462	90.018
Denmark	0.006	0.006	0.000	0.000	73.903
Sweden	0.008	0.008	0.000	0.000	69.838
Germany	0.348	0.370	0.022	6.322	61.351
France	0.109	0.130	0.021	19.266	55.515
Finland	0.010	0.006	-0.004	-40.000	49.830
United Kingdom	0.077	0.081	0.004	5.195	48.913
Netherlands	0.084	0.099	0.015	17.857	43.753
Ireland	0.019	0.012	-0.007	-36.842	42.151
Austria	0.024	0.014	-0.010	-41.667	40.365
Latvia	0.003	0.002	-0.001	-33.333	38.563
Slovenia	0.007	0.005	-0.002	-28.571	37.805
Lithuania	0.002	0.001	-0.001	-50.000	32.738
Italy	0.028	0.020	-0.008	-28.571	30.499
Spain	0.015	0.009	-0.006	-40.000	29.529
Belgium	0.163	0.115	-0.048	-29.448	25.063
Romania	0.006	0.006	0.000	0.000	25.037
Estonia	0.002	0.001	-0.001	-50.000	21.910
Poland	0.006	0.005	-0.001	-16.667	21.142
Cyprus	0.004	0.001	-0.003	-75.000	20.168
Croatia	0.005	0.002	-0.003	-60.000	16.977
Hungary	0.004	0.002	-0.002	-50.000	14.249
Bulgaria	0.008	0.006	-0.002	-25.000	13.439
Slovakia	0.004	0.002	-0.002	-50.000	11.013
Czech Republic	0.005	0.002	-0.003	-60.000	10.663
Portugal	0.006	0.002	-0.004	-66.667	4.501
Greece	0.010	0.003	-0.007	-70.000	2.256

The magnitude of change in the predicted probability varies greatly across countries.

The three biggest importers are Germany, France, and Belgium. Germany and France, which have high values of SER, would experience a moderate change in the predicted probability of receiving a shipment as a result of an increase in the stringency of environmental policy. In marked contrast, with Belgium, which has much laxer regulations, the predicted probability would decrease by as much as 30%.

For the sake of comparison, the same calculations have been made for the Total Cap. variable.[14] The results are presented in Table 4.A.5 in Appendix A.4. Generally, a change in the total disposal and recovery capacity of a destination country appears to have a larger effect on the exporting facility's choice than a similar (1 SD) change in the value of the environmental policy stringency variable.

4.4 Concluding remarks

This chapter has addressed the hotly debated PHH in a novel way, using highly disaggregated data on international waste flows together with the mixed logit model, which is much more flexible than most other discrete choice methods.

The basic findings are consistent with the existing literature. Well developed countries tend to have larger waste management markets (due to larger domestic demand for disposal and recovery services), better technology, and hence a comparative advantage in waste treatment activities. There is no evidence, as yet, strong enough to support the PHH with respect to the waste management industry. Nonetheless, this study has revealed a significant pollution haven effect, albeit one smaller in magnitude than some other factors influencing waste generators' choices. Baggs (2009) and Fikru (2012) reached the same conclusion.

Using a mixed logit approach allowed the confirmation of the prediction that some facilities do not follow a pattern consistent with the presence of a pollution haven effect. In fact, as much as 45% of all exporting facilities, from the sample, were attracted by the stringency of environmental regulations. Perhaps many of those are the facilities whose waste can be recovered and has a positive price, but only if shipped to technologically advanced countries with high environmental standards. This prediction cannot be confirmed with the available data, but the fact that facilities from countries with laxer regulations are less deterred by the regulatory stringency of the destination country makes it even more plausible.

Finally, an important conclusion to be drawn from this study is that any further

[14] These calculations help to give a sense of the relative importance of studied variables. Obviously, in reality, it is hard to imagine that the disposal or recovery capacity of a country would increase dramatically without any change in other variables.

research on the relationship between environmental policy and the waste management industry should take into account the fundamental differences among various types of waste products and treatment methods. Hopefully, in the future, more detailed data will be available. This research would have been greatly enhanced if it were possible to distinguish between recycling and incineration with energy recovery in the E-PRTR database. A further way to improve the approach presented in this chapter would be to include waste generators' characteristics, such as size. Unfortunately, only a few facilities had reported the relevant data to the E-PRTR during the period under study.

Appendix

4.A Tables

Table 4.A.1 Description of the variables

Variable	Name	Unit of measurement	Sources
Distance	Distance	100 kilometers	CEPII Gravity Dataset
Border	Border	1 if countries share a border and 0 otherwise	CEPII Gravity Dataset
Labor Cost	Lab. Cost	Euro	Eurostat
Population Density	Pop. Dens.	100 Inhabitants per km^2	Eurostat
Total Capacity	Total Cap.	Hundred million tonnes	Eurostat
Stringency of Environmental Regulations	SER	Score on a 1-100 scale	IEA Database, Eurostat, The Yearbook of International Organizations
Environmental Performance Index	EPI	Score on a 1-100 scale	Yale Center for Environmental Law and Policy
Proxy for Regulatory Stringency	PRS	Score on a 1-100 scale	Transparency International, Eurostat
Quantity of waste	Quantity	1000 tonnes	E-PRTR

Table 4.A.2 Descriptive statistics (binomial analysis)

	Lab. Cost	Pop. Dens.	Total Cap.	SER	PRS	EPI	Quantity
Min	2.600	0.155	0.008	1.000	1.000	72.700	0.000
Mean	26.356	1.759	1.829	43.281	42.597	84.727	1.461
Max	56.400	13.695	3.706	100.000	100.000	90.860	5600.000
SD	8.822	1.060	1.253	18.781	16.062	3.145	20.665

Table 4.A.3 Descriptive statistics (multinomial analysis)

	Distance	Lab. Cost	Pop. Dens.	Total Cap.	SER	PRS	EPI
Min	0.191	2.600	0.155	0.010	1.000	1.000	72.700
Mean	13.114	20.790	1.253	0.769	36.783	37.807	84.079
Max	37.663	56.400	5.029	3.706	100.000	100.000	90.860
SD	7.047	12.835	1.047	0.946	24.890	24.474	3.731

Table 4.A.4 List of countries

Country	SER	PRS	EPI
Norway	99.63	77.12	87.19
Luxembourg	90.02	100.00	86.21
Denmark	73.90	66.98	88.26
Sweden	69.84	65.29	89.05
Germany	61.35	55.32	83.13
France	55.51	43.99	86.41
Finland	49.83	62.41	90.64
United Kingdom	48.91	50.26	87.73
Netherlands	43.75	64.82	80.66
Ireland	42.15	57.38	87.63
Austria	40.37	54.63	84.35
Latvia	38.56	13.28	84.61
Slovenia	37.80	30.60	85.13
Lithuania	32.74	18.28	82.71
Italy	30.50	22.04	83.14
Spain	29.53	33.98	87.30
Malta	29.43	26.16	87.41
Belgium	25.06	50.39	78.63
Romania	25.04	4.53	78.57
Estonia	21.91	30.19	87.48
Poland	21.14	18.56	78.75
Cyprus	20.17	34.15	78.88
Croatia	16.98	10.33	82.11
Hungary	14.25	16.99	80.81
Bulgaria	13.44	1.20	78.20
Slovakia	11.01	16.06	82.71
Czech Republic	10.66	21.36	83.43
Portugal	4.50	29.05	87.33
Greece	2.26	13.22	82.99

Notes: SER, PRS and the EPI are average values over 2007-2015.

Table 4.A.5 Change in predicted probabilities from an increase of Total Cap. by 1 SD (calculated for Model (4))

Country	Predicted Probabilities	Probabilities after an increase in Total Cap.	Difference in Predicted Probabilities	Percentage Change	SER
Norway	0.024	0.035	0.011	45.833	99.629
Luxembourg	0.013	0.025	0.012	92.308	90.018
Denmark	0.006	0.011	0.005	83.333	73.903
Sweden	0.008	0.014	0.006	75.000	69.838
Germany	0.348	0.475	0.127	36.494	61.351
France	0.109	0.213	0.104	95.413	55.515
Finland	0.010	0.014	0.004	40.000	49.830
United Kingdom	0.077	0.125	0.048	62.338	48.913
Netherlands	0.084	0.186	0.102	121.429	43.753
Ireland	0.019	0.022	0.003	15.789	42.151
Austria	0.024	0.033	0.009	37.500	40.365
Latvia	0.003	0.004	0.001	33.333	38.563
Slovenia	0.007	0.009	0.002	28.571	37.805
Lithuania	0.002	0.003	0.001	50.000	32.738
Italy	0.028	0.051	0.023	82.143	30.499
Spain	0.015	0.022	0.007	46.667	29.529
Belgium	0.163	0.240	0.077	47.239	25.063
Romania	0.006	0.014	0.008	133.333	25.037
Estonia	0.002	0.003	0.001	50.000	21.910
Poland	0.006	0.014	0.008	133.333	21.142
Cyprus	0.004	0.005	0.001	25.000	20.168
Croatia	0.005	0.007	0.002	40.000	16.977
Hungary	0.004	0.007	0.003	75.000	14.249
Bulgaria	0.008	0.014	0.006	75.000	13.439
Slovakia	0.004	0.006	0.002	50.000	11.013
Czech Republic	0.005	0.008	0.003	60.000	10.663
Portugal	0.006	0.008	0.002	33.333	4.501
Greece	0.010	0.014	0.004	40.000	2.256

4.B Figures

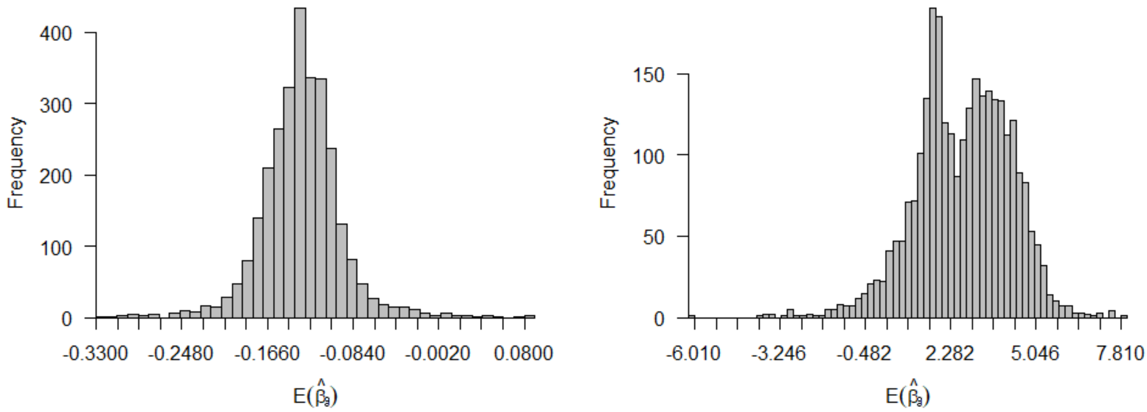

Figure 4.B.1 Conditional distributions for Distance (left) and Border (right) computed for Model (7).

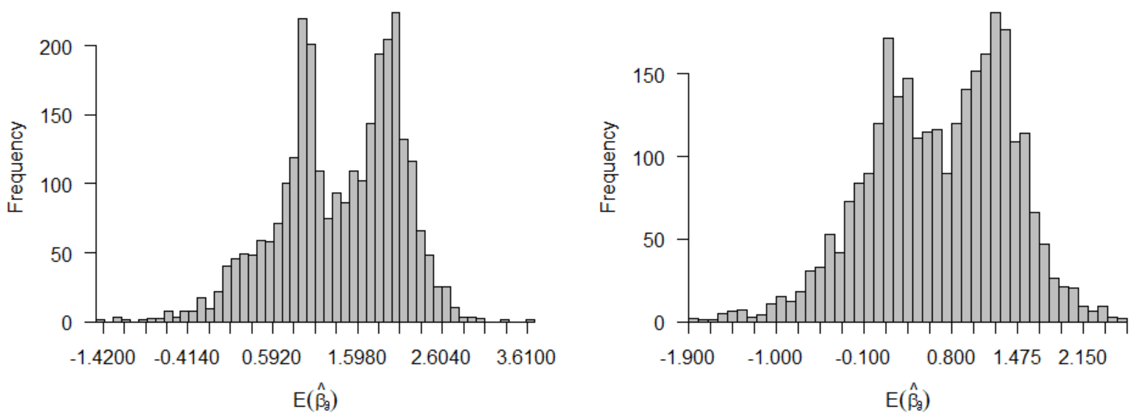

Figure 4.B.2 Conditional distributions for Total Cap. (left) and Pop. Dens. (right) computed for Model (7).

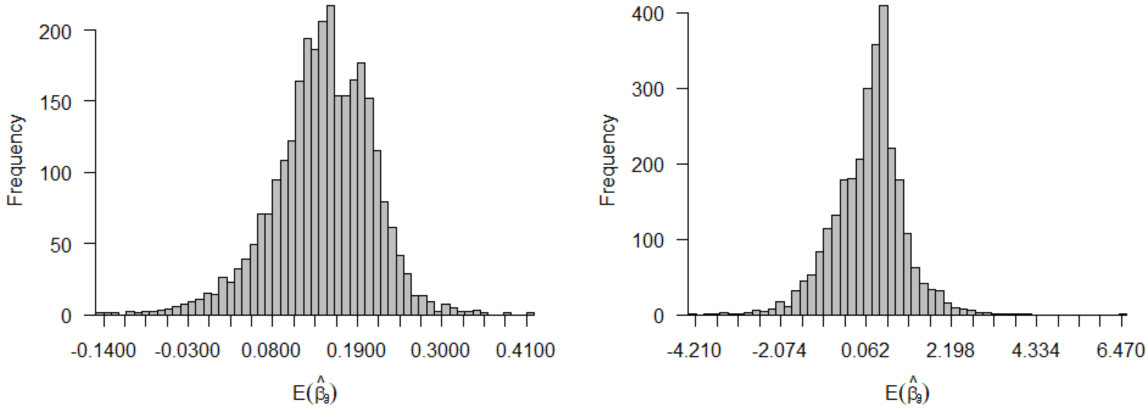

Figure 4.B.3 Conditional distributions for Lab. Cost (left) and Policy Diff. (right) computed for Model (7).

Chapter 5

General Conclusions

This study set out to investigate the relationship between environmental policy and location patterns of waste management firms as well as trade patterns in hazardous waste. It also touched upon some broader issues, such as the possible complementarity of the PHH and the PH.

The results obtained in the present study are generally consistent with existing research in that they confirm a pollution haven effect in the waste management industry. The approach here, however, allowed for enriching previous conclusions in two ways. First, by investigating not only trade patterns but also location patterns it was possible to include both hazardous and non-hazardous waste in the analysis. This resulted in the discovery that predictions consistent with the PH rather than the PHH might be of more importance if the whole waste management industry is considered. Second, the analysis of very disaggregated data allowed for showing the PH might be relevant with respect to some waste shipments, even in the case of hazardous waste. These two findings have substantial implications both for future research and for practice.

It is essential future research does not assume the whole waste management industry is polluting. Even when working with data comprising of only hazardous waste, it is worthwhile to look for ways of separating waste into various categories, for example, based on recoverability. The results of this study suggest that testing the PH with respect to the waste management industry is both feasible and desirable. One possible approach involves isolating waste that can be recovered effectively, but only with advanced technology, from waste that is generally unrecoverable. Markets for both kinds of waste are likely to be affected by different factors. Understanding those differences is a crucial step in the process of designing policy aimed at promoting the development of the preferred waste treatment options in a given country.

There is one more important area worthy of future research. If the waste management industry is not homogeneous and its pollution intensity varies greatly, depending on the treatment option, the impact of this industry on social welfare should be analyzed separately for each treatment option. The possibility exists for this to be investigated both theoretically and empirically.

Empirical research on the waste management industry is especially difficult for two reasons: first, the data on trade in non-hazardous waste is hard to obtain, second, it is possible that illegal trade in waste accounts for a large part of the total waste flow, and yet, for obvious reasons, cannot be included in an empirical analysis. This second difficulty constitutes the most important limitation of this study and any other empirical research examining trade in waste. According to various press articles and reports of environmental non-governmental organizations, the problem is very serious. It is entirely possible that if the exact data on illegal waste shipments were available, it would allow for the confirmation of the PHH in its strongest form (with respect to certain waste streams) and not just that of a pollution haven effect.

Issues related to data availability especially affect the facility-level analysis in Chapter 4. The lack of data forced the use of mainly country-level characteristics. In addition many variables, including the stringency of environmental policy and disposal (or recovery) fees, had to be proxied by indirect measures.

Nonetheless, the results of all empirical chapters provide a degree of evidence for a pollution haven effect, especially with respect to the treatment of hazardous waste. Chapter 2 confirms the opposite effect with respect to recycling services and Chapter 4 shows that many waste generators follow a different pattern than that predicted by the PHH. These observations lead to several policy recommendations.

It seems that stringent environmental policies promote innovations in the waste management industry, and thus stimulate the development of the recycling sector, which is based on technology to a much greater extent than is the disposal sector. However, a government needs to conduct a detailed cost-benefit analysis, taking into account the whole economy, prior to the introduction of stricter regulations.

The results of this study also have implications regarding the restrictions of trade in waste products. The presence of a pollution haven effect suggests that restricting trade in waste destined for disposal may well be justified in some cases. The European Community's waste legislation is based on the assumption that if there were no restrictions, large volumes of waste would end up in the landfills of countries with relatively lax environmental standards (mostly transition countries) instead of being recycled or managed in some other, more environmentally-friendly, way. However, if anything, EU policies seem to be too strict. In the case of hazardous waste, not only waste destined for disposal but also that destined for recycling is subject to very costly and lengthy bureaucratic procedures. This often makes international shipments too expensive for facilities and waste is eventually landfilled in the country of origin or, worse, is exported illegally. The first option might be especially relevant to low-income countries having access to cheap disposal services. It is probably not a common occurrence that a facility from a low-income country, whose waste can be efficiently recovered with advanced technology, profits from recovering waste in a high-income country, despite bureaucratic costs. It must be more common that a facility from a high-income country recovers waste in a low-income country because of the difference in prices. This is presumably why chapters 3 and 4 confirm a pollution haven effect with respect to the recovery of hazardous waste. Trade in waste intended for disposal is very rare because of EU legislation. Possibly many of the reported shipments refer to waste which requires advanced technology for its disposal. Waste generators who look for the cheapest way to dispose of waste are likely engaging in illegal trade, therefore, not only domestic regulations, but also international agreements should be designed in such a way as to take account of possible illegal activities. Apparently, the illegal waste trade is presently a very lucrative form of business for criminals (Appelqvist, 2013).

In the preface to this dissertation, I mentioned the 2014 protest against processing foreign waste that occurred in Poland. In conducting this study I wanted to discover whether accepting waste from abroad really is just a threat, or perhaps it provides an opportunity for the economies of transition countries.

On the one hand, this research produced some evidence showing that there is truly a danger of becoming a ”waste haven” if a country has low environmental standards: on the other hand, the current EU legislation prevents waste generators from exporting the most dangerous waste for disposal, by making it prohibitively expensive in the majority of cases. It goes without saying, that despite legislation, sometimes waste finds its way to poorer countries: from time to time scandals involving foreign companies disposing of their waste illegally in Poland make the headlines of Polish newspapers (Wprost, 2018). It is impossible to know precisely how serious the problem is as official data shows only that legal waste trade from the old EU Member States to the new Member States has been growing over recent years. The trade is still very small compared to the trade among Western European countries, but the current trends suggest that Poland, which is the largest country in the CEECs region, has an opportunity to substantially increase its share in the European recycling market.

This research was motivated by two ideas, which while relatively old are still vigorously debated. The PHH and the PH are both controversial, and they are often seen as conflicting. However, as Chapter 2 shows, it is possible to successfully integrate these hypotheses into one study. Here the analysis was focused on the waste management industry, but the approach presented can be equally applied to other industries. The

PHH and the PH may be true with respect to different product groups, just as they are relevant to different treatment options.

The existing literature offers little evidence supporting the PHH or the PH (especially in their original forms). This research confirmed only a pollution haven effect, just as in previous studies. As for the PH, the results obtained in Chapter 2 suggest that stringent environmental regulations might, in fact, increase the competitiveness of a country in the recycling business. However, the present study is just the first step in assessing the plausibility of the PH's predictions with respect to the recycling industry. Results presented in Chapter 2 need to be confirmed by future research, which would take into account some unique characteristics of the recycling sector, which is often heavily subsidized by governments. Ideally, an analysis would use data as disaggregated as possible, in addition, it would be instructive to isolate recyclable waste that has a positive price and compare it to recyclable waste that has not.

The waste management industry's diversity and complexity make it both a challenging and fascinating subject of study. The process of collecting data is painstaking, but worth the effort; being able to obtain meaningful results and contribute to the discussion on vital issues related to environmental protection is very rewarding. Hopefully, in the future, more researchers will study the waste management industry, waste and waste-related problems are probably more important than most people realize: as American journalist Edward Humes noted "One of the few relics of our civilization guaranteed to be recognizable twenty thousand years from now is the potato chip bag" (Humes, 2013).

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