Electronic Waste Disposal in the European Union:
Avoiding the Once-ler's Dilemma

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Abstract

Electronic disposal poses a threat to human health through the use of a variety of carcinogens and mercury. Electronic waste (e-waste) is comprised of discarded electronics. In this thesis, I focus on the history of international hazardous waste legislation, as well as why e-waste is a problem, and what the European Union is doing to make e-waste less of a problem. The literature review examines the current state of e-waste policy literature, especially that regarding the WEEE Directive. The methods described are those I used to analyze the effectiveness of implementation of the European Union's Directives 2002/96/EC regarding IT and telecommunications e-waste. I evaluate whether population density, recycling culture, or irresponsible disposal are correlated to higher rates of e-waste collection. The results of my research are that there is no such correlation. This research will help direct the attention of policy makers to what indicators lead to effective WEEE collection.

Keywords: e-waste, WEEE, electronic waste, RoHS, EPR, Extended Producer Responsibility, EU, European Union, Directive 2002/95/EC, Directive 2002/96/EC, collection

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Table of Contents

Index of Abbreviations

- **CLRTAP:** 1998 Protocol on Persistent Organic Pollutants to the Convention on Long-Range Transboundary Air Pollution
- **EPR:** Extended Producer Responsibility
- **ERP:** European Recycling Platform
- **EU:** European Union
- **PIC:** Prior Informed Consent
- **PWBs:** Printed wire boards
- **RoHS:** Restriction of Hazardous Substances Directive
- **WEEE:** Waste Electronic and Electrical Equipment

CHAPTER 1

Introduction

The Once-ler is the industrious, faceless man from Dr. Seuss's *The Lorax* (1971). The Once-ler built a factory thinking that he was helping the world, and in so doing ruined the environment around him. He cut down all of the Truffula trees, created massive air pollution, and thereby forced the Lorax and his friends to leave their beloved home. The Once-ler, upon seeing what he has done, regrets every bit of it. This story seems very well suited for the story of electronic use around the world. We in the industrialized world buy as many electronics as we can, and producers keep supplying for our demand. But what does this mean for the environment? Electronic producers had better heed the Once-ler's warning that "Unless someone like you cares a whole awful lot, nothing is going to get better. It's not" (Geisel, 1971).

Any electronic that someone wants to dispose of is labeled electronic waste. Electronics contain many components, some of which are valuable, and some toxic. Proper separation of these valuable and toxic components is important to ensure safety of workers and the public at large. This is a difficult process, which has incentivized the inappropriate disposal of e-waste that is now posing a threat to environmental justice.

> Accurate figures about the shady and unregulated trade [in e-waste] are hard to come by. However, experts agree that it is overwhelmingly a problem of the developing world. They estimate that 70 percent of the 20 million to 50 million tons of electronic waste produced globally each year is dumped in China, with most of the rest going to India and African nations. (Bodeen, 2007)

E-waste poses a toxic threat worldwide, especially in developing countries where people are exposed to end-of-life electronics that they are expected to dismantle for pay. Some of these electronics are sent under the pretext of charitable donations, but are nonfunctioning pieces of equipment that only add to the environmental burden of developing countries.

Electronics generate 20 to 50 million metric tons of waste worldwide each year, comprising more than 5% of all municipal solid waste (United Nations Environment Programme, 2006). It comes as no surprise that as various electronic technologies have become more common, the amount of waste produced by their disposal has increased (Frazzoli, 2010, p. 388). Waste of this sort includes spent "televisions, monitors, computers, audio and stereo equipments [sic], video cameras, telephones, fax photocopy machines and printers, mobile phones, wireless devices, chips, motherboards, cathode ray tubes and other peripheral items" (Frazzoli, 2010, p. 388). This waste is known as electronic waste (e-waste), electronic scrap (e-scrap), and waste electronic and electrical equipment (WEEE) (Townsend, 2011). These terms will therefore be used interchangeably from here on.

Many international agreements have been created to govern the flow of various types of hazardous waste. Some of these agreements directly influence e-waste exchange and production while others indirectly influence electronic waste disposal by means of such mechanisms as international norms (in other words, behavior that is seen as being either morally correct or generally accepted).

The European Union is known for having some of the most progressive electronic waste (e-waste) legislation in the world because of its requirements regarding extended producer responsibility (EPR) as enacted first in the Waste Electronic and Electrical Equipment of 2003 (WEEE) Directive, and the limiting of hazardous chemical use in the Restriction of Hazardous Substances Directive of 2003 (RoHS). EPR is a principle that holds producers responsible for the disposal of their products, in addition to their production and period of use. In the WEEE

Directive, specific standards for collection for appliances varied between 70% of "small domestic appliances, lighting equipment, electrical and electronic tools, toys, leisure and sports equipment and monitoring and control instruments" and 80% of "large domestic appliances and automatic dispensers" by weight. It also requires anywhere between at least 50% "for small domestic appliances, lighting equipment, electrical and electronic tools, toys, leisure and sports equipment and monitoring and control equipment" and 80% for "discharge lamps", of materials by weight, be recycled or reused. (Europa, Waste electrical and electronic equipment accessed April 1, 2013)

Since 2003, the WEEE law has been revised to better serve the purpose of reduced e-waste production. But only by examining what works and what does not work regarding e-waste collection and recycling can effective policy be created. My research examines what is correlated to the effective collection of IT and telecommunications waste. This research attempts to better determine what leads to more effective collection of IT electronic waste. By knowing whether proportion of population in urban centers, individual concern about the environment, or responsible IT e-waste recycling influence e-waste collection effectiveness, better waste collection policy might be made, regarding at least this specific categorization of e-waste.

As with all waste, there are five basic ways to handle electronics when they no longer prove useful to their owners: repair them, recondition them, remanufacture them, recycle them, or dispose of them (King, Burgess, Ijomah, & McMahon, 2006, p. 259-263). The methods of handling useless electronics are generally more complex than those of handling most other useless products because electronics contain many dangerous substances (Kroepelien, 2000). These toxic components create a real health hazard (Frazzoli, 2010). In one study, e-waste recycling workers were tested for various toxins and were found to have 18 times higher concentrations of PCDD/F (a toxin) than non-workers (Ma, Cheng, Wang, Kunisue, Wu, & Kannan, 2011). Dust from electronics is generally toxic and has elevated the amount of toxins in humans (Wu et al., 2007).

European Union legislation in 2003 has been heralded as the most progressive e-waste legislation, but it did not focus on the social justice issues regarding electronic waste. Human rights abuses caused by electronic waste were not discussed in this legislation.

One reason for the creation of revised e-waste legislation was improving e-waste collection rates. This can only be done if there is an understanding of what leads to higher collection rates. The literature suggests that e-waste would be collected most effectively in densely populated areas and places where there is much concern about the environment. Logic suggests that e-waste collection rates might also be higher in countries where the waste collected, rather than being properly disposed of, is simply brought to the dump. I hypothesized that these three independent variables-- population density, environmental care, and e-waste disposal method would all be correlated to the dependent variable, IT e-waste collection. My research does not support the European Union's claims regarding e-waste recycling, nor my assertion about what might lead to increased e-waste collection rates.

I then ranked the two best and three worst IT and telecommunications e-waste collection countries, Slovenia and Bulgaria and Romania, Luxembourg, and Ireland, respectively. I chose these countries because they ranked highest and lowest on my indicator scale, would provide generalizable results, and many studies of e-waste directive implementation focus on 2-5 case studies at a time. Luxembourg was dropped from the analysis due to its per-capita wealth. I believe that by understanding how the directives have worked to influence collection in these countries, better e-waste collection mechanisms can be developed either via further refining of the WEEE Directive, more effective transposition, or more individual support for e-waste collection.

My research seeks to answer the question "What countries in the EU are most and least effective at collecting WEEE and why?" In answering this question, I hope to help inform the discussion about how EU directives regarding e-waste can be most effectively implemented, and hence help the WEEE Directive fulfill one of its goals, reducing the amount of e-waste that is disposed of inappropriately.

CHAPTER 2

<u>Historical Background Literature: Waste Electronic and Electrical Equipment:</u> *Why is it important, and what is the European Union doing to protect the world from it?*

I. INTRODUCTION

E-waste disposal in the European Union is an emerging field of study that has many foci. This literature review will first present a history of international hazardous waste agreements, as the EU directives are a continuation of this history. We then consider the methods currently being used to dispose of e-waste, as this is one of the foci of the literature regarding e-waste disposal around the world. This is followed by an exploration of the electronic waste directives the European Union adopted to regulate e-waste disposal (and have been heralded as the world's most progressive e-waste legislation) which sets the stage for discussing their implementation, which is the main focus of recent literature.

International environmental regulations are a recent development, while hazardous waste regulations aimed at preserving human and ecosystem health are even newer. An understanding of international hazardous waste agreements frames the context in which we see the European Union's adoption of the WEEE and RoHS directives. Researchers focus on the various ways of handling e-waste, as well as on the implementation of e-waste legislation. The evaluation of the implementation of the WEEE Directive makes assumptions about what leads to increased collection rates of all WEEE, such as how urban a country is and how environmentally conscious its residents are.

II. HISTORY OF INTERNATIONAL HAZARDOUS WASTE AGREEMENTS

International agreements have addressed hazardous chemicals since the St. Petersburg Declaration of 1868 banned the use of flammable and fulminating substances in military projectiles weighing less than 400 grams (Shaw, 1983, as cited by Selin, 2011, p. 132). Since then the focus on chemicals has changed to one on human health. Rachel Carson's *Silent Spring* (1962) drew attention to the effects of DDT (dichlorodiphenyl trichloroethane) (Selin, 2011). Current concerns regarding chemicals include persistence, toxicity, bioaccumulation, and biomagnification (Selin, 2011, p. 134). Persistence refers to how long a chemical remains both in its current form and in its mutations. Persistence poses a problem when a chemical is detrimental to the environment or human health. Toxicity can cause cancer (an example of such a toxin is an endocrine disruptor) or toxins can change human development both in the womb and in childhood (Selin, 2011, p. 134). Bioaccumulation occurs when a hazardous substance collects in the fatty tissue of any organism over time due to exposure to a hazardous substance. Biomagnification occurs as we go up the food chain. A low-level organism may have high levels of a given hazardous substance in its system, and then the next organism on the food chain eats 100 of those animals, thereby collecting all of their hazardous substances in its own body. Hazardous substances pose a real threat to the environment. Overuse of DDT caused bird populations to be subjected to dangerous levels of DDT, leading to a decline in bird populations; the decline in population was caused by eggshells thinning, which left baby birds poorly protected (Ehrlich, Dobkin, & Wheye, 1988).

There are four chemical treaties that comprise the hazardous waste regime. These are (1) the 1989 Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and Their Disposal, (2) the 1998 Rotterdam Convention on the Prior Informed Consent

Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, (3) the 1998 Protocol on Persistent Organic Pollutants to the Convention on Long-Range Transboundary Air Pollution (CLRTAP), and (4) the 2001 Stockholm Convention on Persistent Organic Pollutants (Selin, 2011). These four treaties aid in the understanding of Europe's past mentality regarding hazardous chemical disposal, especially regarding the burden that should be placed upon less developed countries.

The 1989 Basel Convention on the Control of Transboundary Movements of Wastes and their Disposal was created in large part due to the increase in waste trade from the global North to the global South (Selin, 2011, p. 137). Despite the Basel Convention, the dumping of chemicals is still a problem today, as exemplified by the *Probo Koala* vessel dumping on August 19, 2006 (Selin, 2011, p. 137). This Greek owned and Panama-registered ship dumped approximately 500 tons of toxic waste near the city of Abidjan in the Ivory Coast, which led to many deaths and serious health problems for tens of thousands of people living nearby (Selin, 2011, p. 137). The Dutch company paid $200 million to the Ivorian government because it did not clean the hazardous waste up quickly enough to prevent excessive injuries (Selin, 2011, p. 137-8). The Basel Convention attempts to reduce the amount of hazardous waste created worldwide (Zoeteman, Krikke & Venselaar, 2010; Selin, 2011) as well as control its movement (Selin 2011, p. 138). The Basel Convention regulates the trade of hazardous waste, requiring prior informed consent (PIC) for trade of hazardous waste between signatories (Dreher & Pulver, 2008; Selin, 2011). PIC requires that the exporting company get permission to export its hazardous waste to the receiving country prior to its export.

The European Union ratified the convention in 1993 (Zoeteman, Krikke, & Venselaar, 2010). In 1995, the Ban Amendment to the Basel Convention was adopted. The Ban Amendment prohibits Annex VII countries (including the European Union) from exporting hazardous wastes to all other states and parties, but this has not been put into force due to the economic desires of both developed and developing countries (Selin, 2011, p. 138). The Basel Protocol on Liability and Compensation addresses the lack of funds and technologies for developing countries to handle hazardous waste spills by determining who is financially responsible in case of a hazardous waste mishap, though it has not yet entered into effect (Selin, 2011, p. 139).

The 1998 Rotterdam Convention creates PIC for commercial chemicals. This PIC requires three things. The first is that national governments speak to the potential importing country for the domestic firm that wishes to export and disclose to the potential importing country any restrictions or banning due to human health or environmental effects that has been done in the exporting country regarding that chemical (Selin, 2011, p. 140). Then the importing country must respond. Finally, the exporting country must convey this response to the exporting company (Selin, 2011, p. 140). The potentially importing country can accept the import as is, reject the import, or consent to the import with specific stipulations (Selin 2011, p. 140). This international treaty sets the stage for a strong PIC process. The European Community signed this in 1998, showing EU support for laws supporting human and environmental health, while supporting the rights of less-developed nations.

The 1998 Protocol on Persistent Organic Pollutants to the Convention on Long-Range Transboundary Air Pollution (CLRTAP) was created to minimize the release of Persistent Organic Pollutants (POPs) (Selin, 2011, p. 141-2). POPs are toxic chemicals that stay in the environment for a long time (Selin, 2011, p. 133). This legislation was especially important to Canada, as the health effects of POPs had become a major issue among Canadian indigenous groups (Selin, 2011, p. 142). There are three categories of chemicals under CLRTAP Annex I, Annex II, and Annex III. Annex I chemicals are banned and Annex II chemicals are to be used only for certain purposes (Selin, 2011, p. 142). Annex III lists POP byproducts whose emissions nations should control (Selin, 2011, p. 142). However, this legislation is limited as it only includes countries in the Northern Hemisphere (Selin, 2011, p. 143). The banning of these chemicals has reduced the type of hazardous pollutants used in electronics manufacture, which is very much like the RoHS Directive, which also limits the use of specific hazardous substances in manufacture.

The 2001 Stockholm Convention on Persistent Organic Pollutants includes both developing and developed nations (Selin, 2011, p. 143). The Stockholm Convention, like the 1998 CLRTAP, focuses on POP management (Selin, 2011, p. 143). The Stockholm Convention has three Annexes. Annex A chemicals and pesticides are generally prohibited, but can be allowed for country and time-limited exemptions (Selin, 2011, p. 143). Annex B contains chemicals that are restricted in their use. Annex C contains the byproducts that should be regulated through “best available techniques and best environmental practices for their minimization” (Selin, 2011, p. 143). The Stockholm Convention covers all of the “dirty dozen” POPs (Selin, 2011, p. 143). These “dirty dozen” are: aldrin, chlordane, DDT, Dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, toxaphene, hexachlorobenzene, polychlorinated biphenyls (PCBs), hexachlorobenzene, polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/PCDF), and PCBs (Secretariat, 2008). A 2009 study shows that women living near a hazardous waste incinerator in Catalonia, Spain have elevated PCB and PBDE levels in their breast milk (Schuhmacher, Kiviranta, Ruokojärvi, Nadal, & Domingo, 2009). PCBs are carcinogens (United States Environmental Protection Agency, 2008).

These four international hazardous waste laws form an international hazardous waste regime, or a semi-cohesive block of international laws and norms governing hazardous chemicals (Selin, 2011, p. 132). Hazardous chemicals used in electronics manufacture are related to all of these laws. Electronics disposal is currently being addressed in a variety of ways. Though not all of these e-waste mitigation methods have been solidified into law, they do hold promise for future laws and norms.

Legislation in the European Union is currently addressing the types of chemicals allowed in electronics manufacture. This can be beneficial to producers, consumers, and disposers as this means that electronics are less toxic. Johnson-Restrepo and Kannan (2009) found that polybrominated diphenyl ethers (PBDEs) are common in households in the United States due to their presence in electronics and other devices. PBDEs are neurotoxins that lead to developmental and reproductive harms, in addition to being endocrine disruptors (which cause cancer) (Kodavanti, Ward, Ludewig, Robertson, & Bimbaum, 2005). As mentioned before, a 2009 study shows that women living near a hazardous waste incinerator in Catalonia, Spain have elevated PCB and PBDE levels in their breast milk (Schuhmacher, Kiviranta, Ruokojärvi, Nadal, & Domingo, 2009). Both PCBs and PBDEs are carcinogenic. Electronics, both in their usage period and their disposal, cause harm to human health. There are so many toxic components in electronic waste that we will not discuss it in depth. Understanding that e-waste is toxic, and that it causes many health problems is sufficient for the purposes of this literature review.

Before we look at current research on the WEEE Directive, we need to understand the strategies used to dispose of or repurpose e-waste.

III. CURRENT STRATEGIES FOR HANDLING ELECTRONIC WASTE

There are various ways to handle e-waste. It can be thrown out, recycled, remanufactured, reconditioned, or repaired (King, Burgess, Ijomah, & McMahon, 2006). These categories are listed in both above and below, in greater detail, in order of worst-case scenario to best-case scenario as determined by King, Burgess, Ijomah, & McMahon, 2006. King et al. emphasize these methods of disposal and reuse, while other authors mention them in passing (all save repair). Currently, extended producer responsibility (EPR) is a major focus of e-waste management that focuses on remanufacturing and recycling. This section will discuss dumps, recycling, remanufacture, reconditioning, repairs, and EPR as methods for e-waste management.

Dumps

E-waste could be disposed of in special hazardous waste disposal sites, but there are three factors that constrain this from happening: hazardous waste dumps are not widely available, hazardous waste dumps are expensive, there is not much space for hazardous landfills (Niu & Li, 2007). Therefore, research is being done on how e-waste can be disposed of in normal dumps (Niu & Li, 2007). This research includes making printed wire boards (PWBs) into cement, a method that does not allow lead to leach out, even under extreme conditions (Niu & Li, 2007). PWBs have “the most toxicants in both quantity and variety” of any electrical product component (Niu & Li 2007, p. 410). The cemented e-waste is not liable to leach toxins, which is a problem that occurs with most e-waste. Because e-waste can release toxins into water, it should be kept away from water at all costs (Dagan, Dubey, Bitton, & Townsend, 2007).

E-waste is often disposed of via landfills and incineration. This is done both domestically and when e-waste is sent abroad. According to Zoeteman, Krikke, & Venselaar (2010, p. 426) sending e-waste abroad either has or will create an economic opportunity for the e-waste collectors who will charge both those disposing of electronic waste as well as those buying the e-waste. People buy e-waste because some of its components are valuable (Zoeteman, Krikke, & Venselaar, 2010).

Recycling

Currently, technology to disassemble electronic devices for recycling purposes is being explored due to the drastic increase in the amount of electronic waste being disposed of and due to the demands of the directive by the European Commission (Kopacek & Kopacek, 2005). This is important because levels of toxins (such as PBDEs) are especially high in e-waste recycling workers (Ma, Cheng, Wang, Kunisue, Wu, & Kannan, 2010), so automation may help keep workers from being exposed to these toxic substances.

One problem with the European Union Directive 2002/96/EC (a directive regarding the recycling of electronic waste) is that it does not encourage the recycling of trace metals such as gold, tin, nickel, and palladium (Chancerel, Bolland, & Rotter, 2011). The European Union Directive 2002/96/EC actually discourages trace metal recovery due to its various stipulations requiring that a certain weight of waste be recycled, not that specific components be targeted. Therefore, unfortunately, recovering these metals from printed wired boards (PWBs) is not economically viable, which can lead to them simply being thrown out (Niu & Li, 2007). PWBs are in most electronics and contain the greatest variety and amount of toxicants present in most electronics. PWBs are very toxic, but the recovery of their trace metals is not economical, as the cost of handling secondary pollutants is higher than the profit to be garnered by the recovered resources. This means that PWBs are not recycled, and are instead thrown out.

“Backyard recycling” of e-waste is a dangerous process that has taken root in various countries (Manomaivibool, 2009). This method of recycling is done without much consideration for environmental degradation (Manomaivibool, 2009). It is an attempt to salvage the economically valuable parts from electronic waste products to be sold for profit. For example, a "backyard recycling" operation would heat PWBs over flames to recover lead solders (Manomaivibool, 2009). Then the PWBs undergo an acid bath that helps recover gold and copper while polluting the environment with the acid solution. The result of these processes is that carcinogens are deposited into the soil, along with heavy metals that end up in rivers and in the air (Yu et al., 2006 and Wong et al., 2007 as interpreted by Manomaivibool, 2009). Backyard recycling is not well regulated so people simply do whatever they chose to do with the toxic outcome.

Reconditioning and remanufacturing

Reconditioning requires the rebuilding of a significant number of the components of an electronic device, while not completely remanufacturing the good. Reconditioned goods are generally of inferior quality to new goods. Remanufactured products can be as good as, or even better than, new products (Zoeteman, Krikk, & Venselaar, 2010, p. 423 referencing personal communication with Comperen, 2006; King, Burgess, Ijomah,& McMahon, 2006). Remanufactured goods are given warranties identical to those of new products; this guarantee shows that the product is of high quality (King, Burgess, Ijomah, & McMahon, 2006). Some refurbished (reconditioned) products can cost even less than 50% of what they would have cost new (Zoeteman, Krikk, & Venselaar, 2010, p. 423 referencing personal communication with Comperen, 2006). While these processes do create e-waste, the reuse of various components leads to a reduced need for materials as they can be obtained by simply reusing or reprocessing components.

Repairing

Repairing is the ideal way to handle e-waste, as it requires only that the product be serviced, and therefore there is no necessary production of e-waste. If a product is capable of being serviced forever, then it never generates waste from disposal. However, there are a few problems with this. One problem is that this is impractical as far as technological innovation is concerned. For example, air conditioners used to use CFCs (Chlorofluorocarbons), but they proved to be causing a hole in the ozone layer, and so they stopped being used ("Auto Air Conditioners," 2010). Sure, we could keep adding more CFCs to these old air conditioners so that we did not have to dispose of them one way or another, but it would cause a hole in the ozone layer. Maintaining CFCs in older vehicles is an option, but it will become progressively more expensive both due to supply and demand, and to the federal tax on CFCs ("Auto Air Conditioners," 2010). However, there are other refrigerants that can replace CFCs ("Auto Air Conditioners," 2010). Sometimes repairs simply make no technological sense. Another problem with repairs is that everything wears down over time, so continuous repair will not eliminate all waste. Yet another problem with repairs is price. Between the 1980s and the 1990s the cost of washing machines increased by 40% while the cost of repairs increased by 165% (King, Burgess, Ijomah, & McMahon, 2006). The increase in cost for repairs may lead fewer people to seek repairs when their electronics break. It may make more economic sense for consumers to instead purchase a new good.

Extended Producer Responsibility

Extended producer responsibility (EPR) is a principle in which businesses are responsible for the entire lifecycle of their products. Under EPR a company must consider disposal of its products as a legitimate cost, and not as an externality. This allows producers to be a part of all aspects of a product's life, except the time that the product spends in use (Nakajima &

Vanderburg, 2005). EPR creates an incentive for companies to engage in technological innovation to design products to be easily recycled and dismantled (Castell, Clift, & France, 2004). But, Røine and Lee (2006) show in their examination of Norway that although the relationship between technological innovation and EPR is existent in Norway, EPR did not create a sufficient incentive for innovation. Additionally, they found that the need to stay competitive and to comply with the Restriction of Hazardous Substances Directive (RoHS) does lead to innovation in Norway. EPR is clearly an extension of the "polluter pays" system that claims that because pollution is created when a product is manufactured, the manufacturer should be liable for any costs related to pollution created by their products (King et al., 2006).

The goal of EPR is to give companies the incentive to create products that are easy to recycle or reuse, and a disincentive to partake in planned obsolescence (King et al., 2006; Kroepelien, 2000; Mayers, 2007; Nakajima & Vanderburg, 2005). Kroepelien claims that EPR actually has three core tenets "(a) incentives for technological innovation; (b) integration of costs in a market economy; and (c) increased responsibility for economic actors" (Kroepelien, 2000, p. 167). This is similar to bottle returns in the United States (Nakajima & Vanderburg, 2005, p. 508). However, because electronics are more complex than bottles and require a greater variety of inputs, it is arguably more appealing to electronic manufacturers to partake in EPR because EPR could actually provide companies with components that they could reuse in subsequent products. If companies know that they will have to handle the disposal of their products, they will likely see it as in their best interest to make products both easy to remanufacture or reuse, and to recycle (Nakajima & Vanderburg, 2005). The concept of circular materials flow is one that governs EPR, encouraging producers to reuse products rather than recycle them (Nakajima & Vanderburg, 2005, p. 511).

Unfortunately, most plastic in WEEE is not recycled. This is an overwhelming problem as 35% of shredder residue is plastic (Nakajima & Vanderburg, 2005, p. 512). There seems to be little that can be done with the plastics involved in WEEE. Moreover, because WEEE contains toxins, recycling WEEE can be very difficult (Nakajima & Vanderburg, 2005, p. 508).

There are two obvious problems with extended producer responsibility: freeriding (a situation in which a company that should be paying for e-waste disposal does not, and so benefits from the investments of others in the reclamation of e-waste), and recovery rates. As a solution to the freeriding problem, individual producer responsibility (IPR), posits that e-waste recycling should be the financial responsibility of only the producer of the product (Lee & Shao, 2009, p. 6). Another problem with extended producer responsibility is that even though it makes producers pay for disposal, only one third of e-waste in the European Union has been recovered for proper disposal (European Commission, 2010 as cited by Erp & Hulsman, 2010).

Self-regulation by businesses occurs when it is beneficial for businesses (Zoeteman, Krikke, & Venselaar, 2010). In other words, if it is more economically sound for businesses to reclaim their products at the end of their lives, then they will reclaim them (Zoeteman, Krikke & Venselaar, 2010). Governments could help eliminate e-waste dumping by creating financial and legal incentives (Zoeteman, Krikke, & Venselaar, 2010, p. 422). This could include taxes for mining for more metals. A closed-loop system in which businesses always receive their products at the end of their lives supports high efficiency of recycling because businesses would not want to dispose of potentially valuable materials (Zoeteman, Krikke, & Venselaar, 2011). Recovery of various components of products already occurs in many consumer goods, showing that quality is not always sacrificed because of recycling, which appears to be a fear of the public's (Zoeteman, Krikke, & Venselaar, 2010). Such reclamation occurs with “large office equipment, computers, and small printers” (Zoteman, Krikke, & Venselaar, 2010, p. 426).

In summary, e-waste is currently seen as a problem of recovery, toxins, and recyclability. The European Union has the greatest “absolute volume” of e-waste recycled yearly (Zoeteman, Krikke, & Vensellar, 2010) which may be due to the fact that the European Union is considered to have the most progressive e-waste legislation in the world (Townsend, 2011). Since the European Union has the most progressive e-waste legislation, a more detailed analysis of the European Union case may provide some insight into what and how legislation can be effective in promoting progressive e-waste disposal.

IV. THE EUROPEAN UNION AND ELECTRONIC WASTE DISPOSAL

The European Union’s Legislative Action Regarding Electronic Waste

The European Union has a variety of laws addressing e-waste disposal. Some consider reducing the toxicity of the electronics being produced. Others consider producers responsible for their products from their production to their consumption (EPR). The two directives that will be discussed here are those that have prompted the European Union to be cited as having the most progressive legislation on electronic waste: Directive 2002/96/EC and Directive 2002/95/EC.

Directive 2002/96/EC

Directive 2002/96/EC is known as “the WEEE Directive.” It became law in February 2003 (Nakajima & Vanderburg, 2005). This directive addresses the prevention of e-waste creation, in addition to creating efficient recovery and recycling of e-waste. To this end, the directive includes a plethora of regulations with specific target dates for implementation. For example, by December 31, 2006, the recovery rate for all e-waste must reach a minimum requirement of 70%, though certain types must be 80% recycled (Nakajima & Vanderburg, 2005, p. 509).

There are 10 e-waste categories as listed by WEEE. They are “[1] large household appliances [2] small household appliances; [3] IT and telecommunications equipment; [4] consumer equipment; [5] lighting equipment; [6] Electrical and electronic tools (with the exception of large-scale stationary industrial tools); [7] toys, leisure and sports equipment; [8] medical devices (with the exception of implanted and infected products); [9] monitoring and control instruments; [10] automatic dispensers” (Directive 2002/96/EC).

The Directive 2002/96/EC requires different actions from national governments, consumers, and manufacturers. National governments of the European Union states must keep a register of producers, submit a report on implementation every three years starting in the 2004-2006 period, and must create penalties for noncompliance (Nakajima & Vanderburg, 2005, p. 510).

Consumers must be able to return e-waste for free by municipal disposal, “return-to-retail,” or some similar means (Nakajima & Vanderburg, 2005, p. 510). Return-to-retail, also known as “old-for-new” or “one-for-one” means that a consumer must return a used good when they go to purchase a new one (for example, a consumer walks into a store with his/her old printer and must give it to the cashier before he can purchase another) (Nakajima & Vanderburg, 2005, p. 510).

Meanwhile, producers (defined as whoever introduces a product to the European Union market), among other things, are required to finance the retrieval, recycling, disposal, and processing of all e-waste (King et al., 2006; Lee & Shao, 2009; Thorpe, 2006). The financing of this directive can be done through either visible or invisible fees to consumers, but the fees must be invisible for new goods (Nakajima & Vanderburg, 2005, p. 510). Visible fees are those seen when the product is sold, while invisible fees are those internalized by companies (Nakajima & Vanderburg, 2005, 515).

There are problems, however, with Directive 2002/96/EC. The first pertains to difficulties in implementation. The challenge most frequently referenced in the literature is "free riders." "Free riders" in this scenario are any manufacturers who do not pay for take-back despite being legally obligated to do so. This could occur if a company went out of business. In this scenario, other companies pick up the slack and pay for the recycling for which the free riders should have paid (Nakajima & Vanderburg, 2005, p. 512). In programs similar to this directive, less than 10% of manufacturers in Belgium and 25% in the Netherlands are free riders (Nakajima & Vanderburg, 2005, p. 512-513).

Another barrier regarding this legislation is a lack of adequate information. This applies to the public, the private sectors, and the government. There are various ways in which this information is being disseminated including guide books, seminars, and workshops (Lofthouse, 2007). However, a new tool to provide information is the web-based tool, Sort ED (Lofthouse, 2007). Sort ED helps producers of e-waste figure out what to do with their end-of-lifecycle products by providing them with information about various tactics they can use to comply with the European Union's WEEE Directive (Lofthouse, 2007).

Extended Producer Responsibility also poses the challenge of attributing various e-waste to the correct producer. This difficulty is seen as surmountable as there are technologies, such as barcodes, which can be attached to every product that at the end of its life is considered e-waste (Saar, Stutz, & Thomas, 2004). Saar, Stutz, and Thomas (2004) developed a system through which the barcodes already present on cell phones, when scanned, give information about how to properly dispose of that individual product. This technology does not only identify how to disassemble the product, but the identity of the manufacturer as well (Saar, Stutz, & Thomas 2004).

An additional problem regarding the WEEE Directive is effectiveness. The effectiveness of the law is something that has to be operationalized. Effectiveness can be measured either by adherence to the law, or by environmental impact (Bodansky, 2010).

Legal compliance with the Directive WEEE allows for flexibility in transcription (Cahill, Grimes, & Wilson, 2011). The freedom of European Union nations to implement the directive at their own discretion, though obviously within certain parameters, has led to a wide variety of management tactics (Clift & France, 2006, p. 5; Pires, Martinho, & Chang, 2011). Take for example the need for funds to handle e-waste disposal. Each European Union nation is approaching the issue of funding e-waste recycling and recovery differently. The European Union simply said that most visible fees (or seen by consumers upon purchase) should be seen only until 2009, and 2011 for others (Clift & France, 2006). France has a mandatory visible fee (The Centre for Sustainable Design, Accessed April 28, 2013) while the United Kingdom allows for the use of visible fees, but does not usually do so, due to retailer preferences (Premier Farnell, Accessed April 19, 2013).

Directive 2002/95/EC

Directive 2002/95/EC, or "Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment" (RoHS) was companion legislation to, and was passed at the same time as, Directive 2002/96/EC (Lee & Shao, 2009, p. 4). This directive limited the use of six hazardous substances in electronics: lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB), and polybrominated diphenyl ethers (PBDE) (Christen, 2003;

Lee & Shao, 2009). By banning the use of these hazardous substances, the European Union set a standard for production (Christen, 2003). This standard prevents any product from being sold in the European Union that contains any of these hazardous substances unless there is no substitute (Christen, 2003, p. 13A). By limiting the use of hazardous substances, the European Union effectively made it easier to recycle e-waste, which often contains those hazardous substances.

Why has European Union Created Directives 2002/96/EC and 2002/95/EC?

What led the European Union to adopt this legislation? A traditional interest-based framework of analysis does not explain the European Union's actions regarding e-waste (Dreher & Pulver, 2008, p. 309). A traditional interest-based framework says that the European Union is primarily an e-waste producing state (as opposed to an e-waste importing state), just like the United States. As e-waste producing states, a lack of regulation might be regarded as in their best interests (Dreher & Pulver, 2008). By this line of thought, the European Union is going against its self-interest by promoting progressive e-waste regulation, which is more or less opposite the strategy that the United States has adopted (Dreher & Pulver, 2008). It is conversely in the best self interest of developing nations where e-waste is disposed of to support the type of legislation that the European Union has produced. Another argument that e-waste legislation works against the European Union's self interest is due to its high population density in comparison to the United States. If storing toxic waste domestically went wrong, it would be more likely to hurt the European Union because of this distribution, and yet the European Union is supporting strong e-waste initiatives while the United States is not (Dreher & Pulver, 2008, p. 309). This would suggest that limiting toxic waste creation is not in the interest of either the European Union or the United States as both nations can simply send toxic waste abroad for disposal.

If legislation supporting EPR is not in the European Union's self interest, then why is it adopting it? As of 1998 the European Union banned the shipment of hazardous waste to countries other than those in the Organization for Economic Co-operation and Development (OECD) in the Convention by Council Regulation (EEC) No 259/93, the Waste Shipment Regulation (Zoeteman, Krikke, & Venselaar, 2010, 416). OECD countries are Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, and the United States (The Organisation, 2011). These 34 countries all have high incomes, high Human Development Indexes, and are considered developed countries. This distinction was made by the European Union to prevent the shipping of hazardous waste to developing countries. This legislation changes the balance of self-interest regarding Directives 2002/95/EC and 2002/96/EC. Since the European Union has limited where it can legally send its waste, it makes reduced the amount of waste that it could create so that it would have less e-waste to dispose. Additionally, since the most economically poor nations who are often willing to accept hazardous waste despite the health effects can no longer be exported to, the cost of disposal will increase. In other words, the EEC No 259/93 made Directives 2002/95/EC and 2002/96/EC into self-interested behaviors. Unfortunately, that leaves the question as to why the European Union created EEC No 259/93 to begin with.

Perhaps the European Union, rather than the United States, has been active in seeking EPR due to its comparatively weak valuation of property rights, high trust in government, and lack of land (Sachs, 2006). Americans generally dislike the idea of their physical possessions being taken from them, and they distrust their government, while the EU is not nearly as drastic in these respects (Sachs, 2006 interpreting Williams E. Kilbourn et al. 2001). The United States also has lots of land compared to the EU, so it does not worry as much about pollution of some bits, as those can easily be sacrificed because land is abundant (Sachs, 2006).

Another potential explanation for the European Union's action is a domestic politics approach. Dreher (2008) interprets DeSombre (2000) as saying that nations with strict national environmental legislation are likely to support internationalization of standards as it then levels the playing field for industries and it helps support the environmentalist goals by creating stricter environmental standards for more nations (Dreher & Pulver, 2008, p. 310). Dreher and Pulver (2008) then argue that this does not work with e-waste. They argue that waste can be gotten rid of via trade, and so strict domestic laws can be upheld by simply exporting garbage abroad, but this would not happen if the same standards held internationally (p. 310). However, they are missing DeSombre's (2000) point. If a nation-state decides to have very stringent production regulations for electronics created within their boarders so as to reduce the amount of e-waste it generates, then the industries in that nation-state have to abide by those standards with all of the goods they produce, even for the export market. This would hurt industries, as they would have to charge more for their products than they otherwise would, and hence they would become less economically competitive in foreign markets. This sort of reasoning seems to have motivated Braun, Electrolux, Hewlett-Packard, and Sony to support European Union wide EPR (Lee & Shao, 2009, p. 1). These manufactures created the European Recycling Platform (ERP) in 2002 in response to European Union WEEE legislation. ERP, by 2007, was able to help increase competition, and hence decrease the cost of recycling e-waste (Lee & Shao, 2009, p. 1).

Domestic institutions are another potential explanation of the European Union's action. Domestic institutions form the basic ways in which individuals or groups are able to influence domestic policy. The various ways that institutions influence policy include the level of accountability of the government to constituents, the institutions structuring formal decision making, and institutions that determine who has what access to the political process (Dreher & Pulver, 2008, p. 310). Dreher and Pulver argue that domestic institutions should make some difference in national decisions, or even decisions among European Union members, but that that should not have led the European Union to take the lead in regulating hazardous waste (p. 310).

A systems-level approach suggests that the European Union may have been more targeted by transnational advocacy groups than the United States, but Dreher and Pulver's research shows that that is not the case. The European Union seems to find good international environmental policy to be necessary for solid international policy (Dreher & Pulver, 2008, p. 311). This explanation would therefore claim that the United States does not see international environmental issues as being high on the international priority list (Dreher & Pulver, 2008, p. 311).

Since 2003, the European Union has found it necessary to create new directives regarding electronic waste twice, the first being Directive 2008/34/EC and the second Directive 2012/19/EU. This further refinement of WEEE legislation was made necessary in part by the need to “increase the amount of WEEE that is appropriately collected” (Eurostat: Waste Electrical and Electronic Equipment). Commission Decision 2005/369/EC led to the monitoring of Directive 2002/96/EC, which provides useful data for measures of efficacy of implementation.

CHAPTER 3

Review of E-waste Collection Literature

Many researchers have investigated e-waste collection and disposal around the world. Some research is focused simply on one facet of e-waste collection in a small geographic area, such as Bouvier and Wagner's (2011) case study of Maine which examines the collection of televisions and computer monitors at collection facilities by taking fees charged, days open, and driving distance into account. They found that recycling rates increased when the facilities charged no fees and were open daily, and that proximity to a recycling center decreased the likelihood of WEEE recycling (though they assert that this might be due to the fact that urban centers have curbside recycling, which means that people are not going to a recycling center for normal recycling, so recycling WEEE requires too much additional effort). Joel Boon (2006) focuses instead on the entirety of the United States, and how it has a patchwork of e-waste policies that must be made more cohesive. He also draws the connection from the state-by-state variance of United States e-waste legislation to the WEEE and RoHS directives' patchwork implementation, suggesting a more uniform system of e-waste regulation.

There is also a body of research dedicated to the WEEE Directive. This research consists of comparative and case-study literature regarding e-waste disposal around the world. Common focus areas are European countries, Japan, and the United States. Less widely researched, though present in the literature are China, Canada, and India (Walther, et al., 2010; Bandyopadhyay, 2008; Khetriwal, Kraeuchi, & Widmer, 2009). Some research, such as Wäger, Hischier, and Eugster's (2011), evaluates a comprehensive view of e-waste collection and recovery within a given nation. Their research measures the environmental impact of WEEE collection and processing via such measures as ozone depletion within a country.

Most researchers draw conclusions about how effective e-waste collection has been in a given country and why it has been that effective. There has also been research done regarding what should be seen as a measure of effective implementation. Atasu, Wassenhove, and Sarvary (2009) say that e-waste collection in the EU aimed at implementing EPR should not focus on weight, but on toxicity, the cost of recycling that product, the competition in that market, and the willingness of customers to pay for a more positive environmental impact. Meanwhile, Koh, Gunasekaran, and Tseng (2012) have looked at the spillover effects of the WEEE and RoHS legislation into the Taiwan IT industry. Yet another facet of the WEEE and RoHS literature is that which focuses on the human health aspects of e-waste disposal, especially those caused by the power dynamics of developed countries, such as the EU, US, and Japan, and developing countries such as China, Indian, Pakistan, and Nigeria (Sthiannopkao & Wong, 2012).

The European Union issues technical reports on the implementation of the WEEE directive. In one such report, *Europe as a Recycling Society*, Tojo and Fischer (2011) found that longer experience collecting WEEE along with engaging municipalities in WEEE collection were two common characteristics that led to more collection of WEEE share. This trend was found using the data from 20 EU countries in 2006. They used a ranking system, but only to compare the effectiveness of collection regarding the 10 types of e-waste as categorized by the WEEE Directive, not to run statistical analyses regarding the potential influence various factors might have on relatively high or low WEEE collection rates. They found that high rates of recycling and reuse were not necessarily connected with high collection rates.

This literature looks at individual countries without quantifiably justifying why they examine the case studies that they do. The ranking systems are used to compare performance, but do not take the next step of examining what might lead to comparably higher or lower rates of collection. The ranking system established by Tojo and Fisher (2011) does not look at specific cases, as most of the other literature on WEEE implementation does. Another interesting piece of literature is the Technical Report “Implementation of the Waste Electric and Electronic Equipment Directive in the EU” published by the European Commission in 2006. This document claims that “factors that impact the operation of compliance schemes” include “population size and density, where a higher population enables the generation of economic efficiencies and economies of scale,” “distance and geography” and

> "consumer behavior, with established European compliance schemes owing their success to prevailing consumer recycling behavior. The level of WEEE recycling awareness in relation to specific product groups is also a key driver of success.” (p. xi)

Though a goal of the revised directive is to increase e-waste collection rates, this outcome has not been evaluated as effectively as possible. Most evaluative tools regarding the WEEE directive involve looking at e-waste collection overall or in each category and then shifting to a case-study rather than looking for a correlation between the variables that might lead to increased e-waste collection.

This literature review delineates the various methods of handling e-waste and what current polices the European Union is implementing to control e-waste. The methods that the European Union is engaged in are EPR and regulation of toxic materials in electronic production. This combination of legislation is being used by the European Union to combat the issues related to electronic waste. Though these policies are considered some of the most progressive in the world, they are not sufficient to prevent the creation of all electronic waste. Analyzing the current goals and strategies of the European Union and its member states regarding e-waste shows these important gaps in both the literature and the policies which, when filled, could help to make e-waste a much less significant toxic threat.

Research Question

My research fills a gap identified by my literature review by analyzing the factors that correlate with high rates of IT e-waste collection in each member state of the European Union. I rank every EU country that has reported data in 2010 based not on collection rates for each division of WEEE, but for IT waste collection rates alone. By looking at a smaller segment of WEEE across all member countries, a more comprehensive understanding of what leads to effective or ineffective IT e-waste collection is established. With a smaller scope, the relationships between a variety of factors and IT WEEE collection rates can be examined, and conclusions suggested. Looking at all ten categories of e-waste at once would make it difficult to see if specific factors were related to higher WEEE collection rates overall, or just IT WEEE collection rates. Two factors the European Commission suggests as influencing the operation of compliance in its 2006 Technical Report form the backbone of my hypotheses, in addition to Tojo and Fisher's assertion that nations with high recycling and reuse rates do not necessarily have high collection rates. Complementing this work is more tailored look at WEEE collection via short case studies examining the two best and worst collectors of IT WEEE.

The goal of this research is to help establish which characteristics within a country promote effectiveness of the WEEE directive regarding collection of IT and telecommunications equipment in the European Union. I do this by calculating correlations between various measures of a country's population dispersion, individual care about the environment, and disposal of collected IT WEEE. These three factors are seen as gaps or contradictions provided by the literature. Population density and environmental care were suggested by the EU as possible explanations for WEEE collection rates but without any traceable evidence, and so are examined.

Population dispersion was also touched upon by a case study of Maine (Bouvier & Wagner, 2011) though it suggested the opposite relationship to that which the EU suggested. Recycling of what is collected is examined to see if collection rates are higher in some countries than others because those countries with high collection rates are disposing of electronic waste improperly. Each of these factors deserves a more in-depth review.

Population Density: More urban countries and countries with higher populations are thought to be more effective at collecting e-waste. This is based on the implication of the Implementation of the Waste Electric and Electronic Equipment Directive in the EU Report of 2006 which stated that “population size and density, where a higher population enables the generation of economic efficiencies and economies of scale” (p. xi) and therefore better WEEE Directive compliance. One that this could be based on is the assumption that it is easy to collect e-waste if it is all in a relatively compact geographic area, which would lead to an economy of scale. However, the literature also suggests that population as a whole influences e-waste collection rates. This is thought to be the case due to economies of scale and efficiency of e-waste collection schemes in compact areas. This leads to Hypothesis 1.

Environmental Care: Environmental care is a variable of perceptions and actions regarding the importance of the environment. The Implementation of the Waste Electric and Electronic Equipment Directive in the EU Report of 2006 states that “Consumer behavior, with established European compliance schemes owing their success to prevailing consumer recycling behavior” (p. xi) would be more successful at implementing the WEEE Directive. If someone cares more about the environment in general, s/he has been assumed, by the European Union, to be responsible with his/her e-waste disposal, as e-waste disposal has an impact on the environment, especially animal and human health. This is the likely reasoning behind the EU reports regarding e-waste collection, leading to Hypothesis 2.

Proper E-Waste Disposal: Electronic waste is difficult to dispose of properly. It requires processing that most waste does not, due in part to its use of toxic components. It would be financially tempting to avoid paying for the infrastructure required to properly process IT e-waste. However, this would not be condoned by the European Union. However, it might happen that a country works hard at collection because it has, compared to other EU countries, poor e-waste recycling or reusing rates. As such, it might focus on collection so as to appear compliant, but not adhering to the spirit of the WEEE Directive. This is based on the idea that a nation could collect more e-waste per electronic sold because it does not recycle or reuse the collected products, but simply bypasses the intent of the legislation either legally or otherwise. This nation may care more about being seen as a good collector of IT e-waste than it does about being a good recycler, or may only have the infrastructure to be a good collector. The possibility that collection and recycling rates might be inversely correlated can be inferred from Tojo and Fischer's (2011) research. This led to Hypothesis 3.

I supplement these correlations by examining the two most and least successful countries as determined by ranking the ratios of tonnes of IT and telecommunications e-waste collected per tonnes of IT and telecommunications electronics sold in each country in 2010.

CHAPTER 4

Methods

In beginning this research I examined a variety of websites and journals to ascertain how the WEEE directive of 2003 was being effectively and ineffectively implemented. There are many ways to determine effectiveness, which made it necessary to create an operationalized definition. The collection rate of WEEE was a major factor influencing the efficacy of the 2003 legislation (without a high enough return rate, companies could not implement EPR principles). As such, success at collecting WEEE became the operationalized measure of effectiveness.

This focus then narrowed to examine only IT and telecommunications waste. The reason for this focus is that IT WEEE includes computers and cell phones, which I expect will be the most important electronics referred to in the WEEE directive in the years to come, if only for their ubiquity. Also, it is possible that different factors are correlated with the collection rates of different types of e-waste. By looking at only one type of e-waste, this research can draw more specific correlations, which could lead to more effective collection of this specific type of e-waste, than if the definition included all e-waste.

In this research, effectiveness is defined as "weight of IT and telecommunications equipment collected" per "weight IT and telecommunications equipment sold." This definition considers the weight rather than the number of items due to the focus of the WEEE Directive on the weight of waste collected. Another factor leading to a ratio of weight instead of number of items the availability of data. However, this data set was limited as it excluded Malta. As such, Malta is excluded from this research.

Another way to evaluate the effectiveness of collection would be based on the weight of IT WEEE collected, but that does not take the size of the market into account. This assumes that electronics are bought and returned in their country of origin with every country selling the same weight of IT WEEE products yearly. Instead of looking simply at collection weight, this research looks at collection weight per weight of IT WEEE sold so as to account for the size of the market. The data used for this ranking system were obtained from the EU reporting website Eurostat.

This research examines whether population density, environmental care, and recycling rates of IT WEEE are correlated with the dependent variable of effectiveness, as the literature suggests. These factors are measured using data from surveys, Eurostat, the World Bank, and research articles. Alan Howard, of the University of Vermont Statistical Consulting Clinic, suggested the software "SPSSStatistics" to run a two-tailed Pearson correlation. Using SPSSStatistics, I found the Pearson correlation between the IT WEEE collection effectiveness and the independent variables. However, this is limited in that it looks for linear correlations, and might not detect more complicated correlations. It is important to note that the sample size is too small to determine significance.

The Dependent Variable

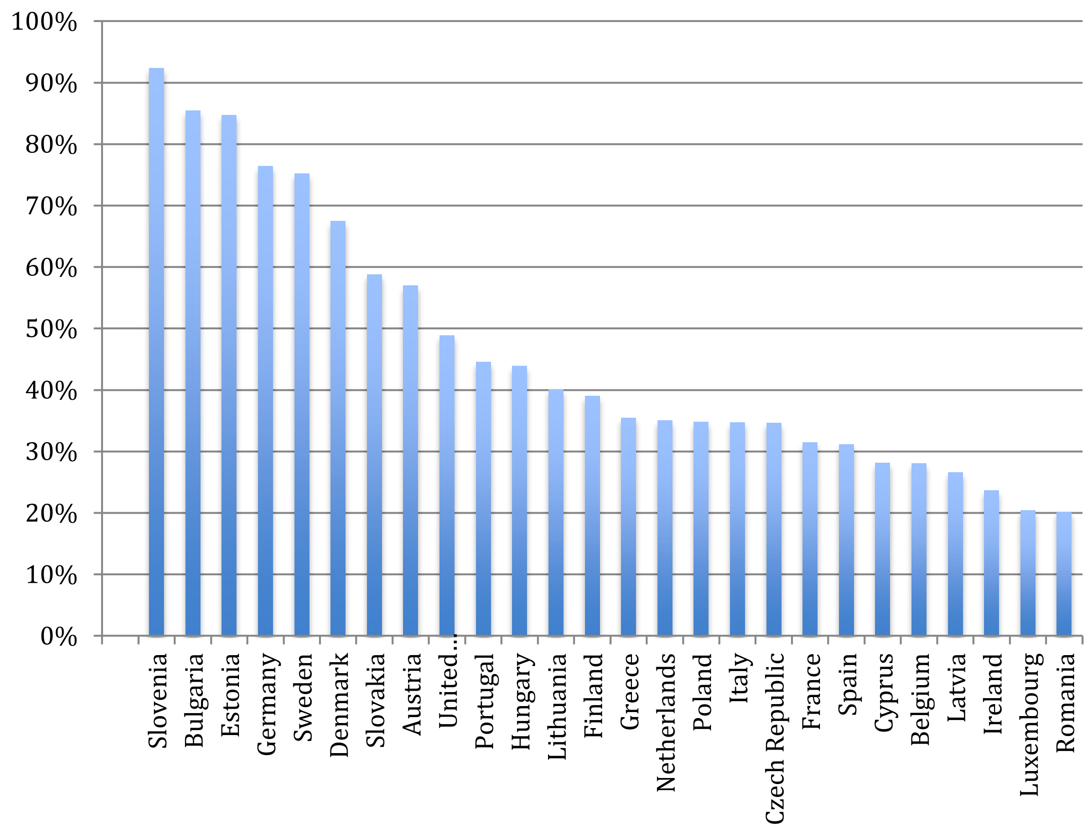
The dependent variable used throughout this research is tonnes of IT WEEE collected per tonnes of IT WEEE sold. This will be referred to from here on as "IT WEEE collection effectiveness." This was established by dividing the "IT Waste Collected in Tonnes in 2010" by the "Weight of IT Equipment Sold in 2010 in Tonnes." See Table 1.

Table 1: IT E-waste Collection Effectiveness Ranking

Country	IT Waste Collected in Tonnes 2010 [1]	Weight of IT Equipment Sold in 2010 in tonnes [1]	IT WEEE Collection Effectiveness	Country Rank in In IT WEEE Collection Effectiveness
Slovenia	2838.6	3073.3	92.36%	1
Bulgaria	2850.2	3335.5	85.45%	2
Estonia	1131.6	1336	84.70%	3
Germany	217916.9	285284.5	76.39%	4
Sweden	31756	42212	75.23%	5
Denmark	18325	27165	67.46%	6
Slovakia	3243.8	5517.8	58.79%	7
Austria	16331.6	28656	56.99%	8
United Kingdom	165626.3	338837.7	48.88%	9
Portugal	7272	16316	44.57%	10
Hungary	5024.7	11449.3	43.89%	11
Lithuania	1146.9	2863	40.06%	12
Finland	8034	20602.5	39.00%	13
Greece	7241.7	20410	35.48%	14
Netherlands	20620	58891	35.01%	15
Poland	18082.2	52004.5	34.77%	16
Italy	38237	110221	34.69%	17
Czech Republic	11785.3	34042.5	34.62%	18
France	63407	201576	31.46%	19
Spain	25924.2	83215	31.15%	20
Cyprus	547.2	1945.5	28.13%	21
Belgium	18625.9	66446.4	28.03%	22
Latvia	561.9	2116.8	26.54%	23
Ireland	4319	18276	23.63%	24
Luxembourg	910.5	4461.9	20.41%	25
Romania	6459.8	31994.2	20.19%	26

1. Data accessed March 10, 2013 from
http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/key_waste_streams/waste_electrical_ electronic_ equipment_weee

Figure 1: Collection Effectiveness[1]



1. Data accessed March 10, 2013 from http://epp.eurostat.ec.europa.eu/portal/page/portal/waste /key_waste_streams/waste_electrical_electronic_equipment_weee

Slovenia and Bulgaria are the most and second most effective IT WEEE collectors respectively, while Luxembourg and Romania are second least and second least, respectively. Slovenia collects three times the percentage of IT waste that Romania does. Luxembourg is rich and tiny, with the highest per capita income of the EU countries, and, depending on the ranking system, the world. Considering the literature's claims about e-waste collection only being cost-effective if it is done on a large scale, I decided to drop Luxembourg from the in-depth review. Luxembourg's relative wealth, one might suppose, could overcome the cost-efficiency issue, but it does not appear to do so with e-waste. Due to Luxembourg's demographic characteristics, the causes of its low IT collection rate are likely not generalizable to the rest of the EU. As such, I focus my study on Romania and Ireland on the "bad" side and Slovenia and Bulgaria on the "good" side.

The tonnes collected to tonnes sold ratio is rounded to the nearest tenth for the sake of sorting. This chart shows the ratio of IT e-waste weight collected per IT products sold in each country. The data set did not include Malta, and as such, it was not ranked.

Hypothesis 1

The more urban and/or populous a country is, the more effective it is at collecting IT e-waste.

I operationalize this definition by looking at population based on urban-rural typology data from January 1, 2011, provided by Eurostat, but compiled by Allen and Corselli-Nordblad (2012).

"The urban–rural typology is based on a classification of grid cells of 1 km^2 as either urban or rural. To be considered as urban, grid cells should fulfill two conditions: a population density of at least 300 inhabitants per km^2 and a minimum population of 5000 inhabitants in contiguous cells above the density threshold. The other cells are considered as rural. NUTS 3 regions have been classified into three groups based on the classification of these grid cells:

- predominantly urban region: population in grid cells classified as urban make up more than 80% of the total population;

- intermediate region: population in grid cells classified as urban make up between 50% and 80% of the total population (population in rural cells between 20% and 50%);

- predominantly rural region: population in grid cells classified as rural make up 50% or more of the total population." (2012 , p. 3)

This data categorizes what percentage of the population lives in urban, intermediate, or rural areas.

The hypothesis also makes a claim about the effects of overall population. As such, 2010 population and population density data obtained from the World Bank website are also included in the table below. While the population data addresses the theory about population, population density is another indicator of how urban a country is as a whole. This data can be found in Table 2.

Table 2: Population Density

Country	Population Urban[1]	Population Intermediate[1]	Population Rural[1]	Population Density in 2010 (people per square km of land)[2]	Population in 2010[3]
Slovenia	26%	31%	43%	102	2048583
Bulgaria	17%	45%	38%	69	7534289
Estonia	0%	52%	48%	32	1340161
Germany	43%	40%	17%	235	81776930
Sweden	22%	56%	22%	23	9378126
Denmark	22%	36%	42%	131	5547683
Slovakia	12%	38%	50%	113	5430099
Austria	35%	27%	39%	102	8389771
United Kingdom	71%	26%	3%	257	62231336
Portugal	49%	15%	36%	116	10637346
Hungary	17%	36%	47%	110	10000023
Lithuania	26%	31%	43%	52	3286820
Finland	27%	31%	43%	18	5363352
Greece	47%	11%	43%	88	11315508
Netherlands	71%	28%	1%	493	16615394
Poland	28%	34%	38%	126	38183683
Italy	36%	44%	20%	206	60483385
Czech Republic	24%	43%	33%	136	10519792
France	36%	36%	29%	119	65075569
Spain	49%	38%	13%	92	46070971
Cyprus	0%	100%	0%	119	1103647
Belgium	68%	24%	9%	360	10895785
Latvia	49%	13%	38%	36	2239008
Ireland	27%	0%	73%	65	4474356
Luxembourg	0%	100%	0%	196	506953
Romania	11%	44%	46%	93	21438001

1. Data from *Urban-Intermediate-Rural Regions: Around 40% of the EU 27 population live in urban regions.*Allen and Corselli-Nordbald March 1, 2012.

2. Data accessed April 17, 2013 from http://data.worldbank.org/indicator/EN.POP.DNST?order=wbapi_data_value2010+wbapi_datavalue&sort=asc

3. Data accessed April 17, 2013 from http://data.worldbank.org/indicator/SP.POP.TOTL?order=wbapi_data_value _2010+wbapi_data_value&sort=as

Hypothesis 2

The more environmentally friendly the citizens of a nation are, the more effective it is at collecting IT e-waste.

This level of care must be quantified to see whether it might be correlated with higher rates of e-waste collection. Ideally, there would be data regarding how much people know and care about e-waste in each nation, and especially regarding IT e-waste. However, as that is not the case, the level of care indicator uses the proxy data indicated below.

Table 3 is dedicated to indicators of mentality regarding the environment. It contains survey data regarding the answers to two indicators of environmental care. The first data set is the percentage of people who answered the question “How important is protecting the environment to you personally?” with “Very Important.” The other data set drawn from the same survey is the documentation about whether an individual answered “Yes” to the question Have you “separated most of your waste for recycling” in the past month for environmental reasons (Eurobarometer, 2007, p. 23

Table 3: Care About the Environment

Country	(2007) How important is protecting the environment to you personally? Very Important [1]	(2011) Percent of total waste recycled and composted [4]	(2007) Separated most of your recycling waste in the past month for environmental reasons [5]
Slovenia	81%	40%	64%
Bulgaria	72%	6%	24%
Estonia	62%	30%	46%
Germany	56%	62%	68%
Sweden	89%	48%	69%
Denmark	71%	43%	51%
Slovakia	61%	11%	64%
Austria	51%	64%	71%
United Kingdom	65%	39%	74%
Portugal	67%	20%	54%
Hungary	71%	22%	49%
Lithuania	55%	21%	30%
Finland	47%	35%	67%
Greece	88%	18%	32%
Netherlands	51%	60%	69%
Poland	58%	28%	44%
Italy	64%	34%	47%
Czech Republic	63%	17%	66%
France	79%	37%	82%
Spain	63%	33%	52%
Cyprus	94%	20%	20%
Belgium	66%	56%	78%
Latvia	62%	11%	25%
Ireland	55%	41%	70%
Luxembourg	68%	47%	83%
Romania	49%	1%	18%

1. Data from “Attitudes of European Citizens Towards the Environment” Special Eurobarometer 295. Fieldwork: November-December 2007.
2. Data from *In 2011, 40% of treated municipal waste was recycled or composted, up from 27% in 2001.* Corselli-Nordblad, L. March 4, 2013.

Hypothesis 3

The more effective a country is at collecting IT e-waste, the lower the ratio of IT WEEE collected that is recycled and reused. See Table 4.

Table 4: Proper IT E-waste Disposal

Country	Total Weight of Recycled and Reused IT and Telecommunications Equipment in Tonnes in 2010[1]	Total Weight of IT Equipment Sold in Tonnes in 2010[1]	Total Weight of IT Waste Collected in Tonnes in 2010[1]	Percentage of total IT WEEE Recycled and Reused[1] per Weight Sold[1]	Percentage of total IT WEEE Recycled and Reused[1] per Weight Collected[1]
Slovenia	2110.6	31994.2	6459.8	68.68%	74.35%
Bulgaria	2009.6	4461.9	910.5	60.25%	70.51%
Estonia	914.7	18276	4319	68.47%	80.83%
Germany	179170.6	2116.8	561.9	62.80%	82.22%
Sweden	26623	66446.4	18625.9	63.07%	83.84%
Denmark	15915	1945.5	547.2	58.59%	86.85%
Slovakia	2875	83215	25924.2	52.10%	88.63%
Austria	12772.2	201576	63407	44.57%	78.21%
United Kingdom		34042.5	11785.3		
Portugal	6675	110221	38237	40.91%	91.79%
Hungary	4433.4	52004.5	18082.2	38.72%	88.23%
Lithuania	811.7	58891	20620	28.35%	70.77%
Finland	7353.1	20410	7241.7	35.69%	91.52%
Greece	7475	20602.5	8034	36.62%	103.22%
Netherlands	17369	2863	1146.9	29.49%	84.23%
Poland	8630.2	11449.3	5024.7	16.60%	47.73%
Italy		16316	7272		
Czech Republic	9617.3	338837.7	165626.3	28.25%	81.60%
France	45175	28656	16331.6	22.41%	71.25%
Spain	15372.4	5517.8	3243.8	18.47%	59.30%
Cyprus	310.1	27165	18325	15.94%	56.67%
Belgium	14522	42212	31756	21.86%	77.97%
Latvia	473	285284.5	217916.9	22.35%	84.18%
Ireland	3363	1336	1131.6	18.40%	77.87%
Luxembourg	687.7	3335.5	2850.2	15.41%	75.53%
Romania	4956.9	3073.3	2838.6	15.49%	76.73%

1. Data accessed March 10, 2013 from http://epp.eurostat.ec.europa.eu/portal/page/portal/waste /key_waste _streams/waste_electrical_electronic_equipment_weee

"Percentage of total IT WEEE recycled and reused per weight sold" finds the percentage of total IT WEEE recycled and reused per weight sold. It does this by dividing the weight recycled and reused by the weight sold in a given country. This examines whether what is sold is being disposed of properly. "Percentage of total IT WEEE recycled and reused per weight collected" finds the percentage of total IT WEEE recycled and reused per weight collected. It does this by dividing the weight of IT WEEE recycled and reused by the weight collected in a given country. This examines whether the waste that is being collected is being recycled or reused, which are the two environmentally friendly processes through which the IT WEEE could be processed.

Controls

It is possible that other variables that do not fall into either hypothesis are related to more effective IT WEEE collection.

Table 5: Controls

Country	IT Waste Collected in Tonnes in 2010 from Households[1] (accessed April 13, 2013)	Population in 2010[2]	Kilograms of IT WEEE Collected Per Person[2] from Households[1]	Weight of IT Waste Collected in Tonnes 2010[1]	Weight of IT Equipment Sold in 2010 in Tonnes[1]	Total Weight of Recycled and Reused IT and Telecommunications Equipment in Tonnes in 2010[1]
Slovenia	5029.6	2048583	1.28	2838.6	3073.3	2110.6
Bulgaria	836.5	7534289	0.38	2850.2	3335.5	2009.6
Estonia	3729	1340161	0.81	1131.6	1336	914.7
Germany	532.4	81776930	2.41	217916.9	285284.5	179170.6
Sweden	18081	9378126	2.59	31756	42212	26623
Denmark	547.2	5547683	3.21	18325	27165	15915
Slovakia	23074.3	5430099	0.60	3243.8	5517.8	2875
Austria	49161	8389771	1.83	16331.6	28656	12772.2
United Kingdom	11590	62231336	2.57	165626.3	338837.7	
Portugal	38237	10637346	0.68	7272	16316	6675
Hungary	16271.2	10000023	0.46	5024.7	11449.3	4433.4
Lithuania	20361	3286820	0.34	1146.9	2863	811.7
Finland	6320.9	5363352	1.28	8034	20602.5	7353.1
Greece	6864.1	11315508	0.56	7241.7	20410	7475
Netherlands	1111.2	16615394	1.23	20620	58891	17369
Poland	4591.1	38183683	0.43	18082.2	52004.5	8630.2
Italy	7267	60483385	0.63	38237	110221	
Czech Republic	160022	10519792	1.10	11785.3	34042.5	9617.3
France	15341.2	65075569	0.76	63407	201576	45175
Spain	3243.8	46070971	0.50	25924.2	83215	15372.4
Cyprus	17825	1103647	0.50	547.2	1945.5	310.1
Belgium	24291	10895785	1.66	18625.9	66446.4	14522
Latvia	197251.9	2239008	0.24	561.9	2116.8	473
Ireland	1085.2	4474356	0.83	4319	18276	3363
Luxembourg	2847.8	506953	1.65	910.5	4461.9	687.7
Romania	2631.4	21438001	0.23	6459.8	31994.2	4956.9

1. Data accessed March 10, 2013 from http://epp.eurostat.ec.europa.eu/portal/page/portal/waste /key_waste_streams/waste_electrical_electronic_equipment_weee
2. Data accessed April 17, 2013 from http://data.worldbank.org/indicator/SP.POP.TOTL?order=wbapi_ data_value _2010+wbapi_data_value&sort=

“Weight of IT Waste Collected in Tonnes”, “Weight of IT Equipment Sold 2010 in Tonnes”, and “Total Weight of Recycled and Reused IT and Telecommunications equipment in Tonnes in 2010”, are all indicators of potential economies of scale that might influence the effectiveness of IT WEEE collection. Meanwhile, “Kilograms of IT WEEE collected per person” is the number established by dividing the IT waste collected from household in 2010 by the number of people in that country in 2010 to establish the weight of IT WEEE collected per person per household. This is then converted this measure of tonnes to kilograms. This variable does not take consumption patterns into account. A nation might have a higher weight collected per person due to its people consuming more, not necessarily because they are more environmentally responsible regarding IT WEEE disposal. This is a dummy variable. Due to its reflection of the economy and consumption patterns of the nation, I do not expect it to be correlated with the dependent variable.

Most WEEE research looks at one or more countries in depth. In keeping with the goal of determining what factors matter most in the effectiveness of IT WEEE collection, this research includes a comparison of the two most and least effective collectors of IT WEEE as established in Table 1. This closer examination complements the quantitative research regarding factors correlated with IT WEEE collection rates by allowing for comparison between and among the two most and two least effective collectors. If there were only one on each end of the spectrum, they could only be compared to one another, which would eliminate any comparison between either the two most or two least successful countries. Examining more than two countries on each end of the spectrum would lead to more convoluted comparisons, when two would suffice in explaining potential reasons for the level of collection effectiveness of a given country.

Limitations

Measure of IT e-waste collection effectiveness

This representation of effective waste collection uses weight numbers that would make one assume that IT bought is disposed of the same year as its purchase, that it replaces an object of equal weight, or that IT waste produced in a country is recycled within that country. E-waste is something that generally is not subject to yearly turnover. It is difficult to find data, but there is a general consensus that claims computers are replaced ever 2-3 years. That being the case, electronics are not recycled at the same rate they are purchased. For large electronics, however, like washers, it is very likely that they are being replaced when they are disposed of, which ought not to be every year. This research focuses on IT WEEE, which consists of smaller equipment that has a more rapid turnover rate, like computers and cell phones. Additionally, this research is ranking all EU countries using the same criteria, so the measure of effectiveness is not a 100% return rate, but whether a country is collecting a higher ratio than other countries.

Given the recent trend of IT products getting lighter, the ratio of tonnes recycled to tonnes purchased does pose a problem. This is evident perhaps most obviously in the television shift from cathode ray tubes to flat panels. There is a weight reduction of 82%, and a volume reduction of 75% (Pike Research, 2011, p. 1). One might worry about how these ratios might be affected. But, having a high weight of products collected per weight of products purchased as compared to other EU states shows that a recycling system is more effective at collecting e-waste than that of other EU states. It assumes that every nation is changing its consumption and disposal patterns at around the same time, so that while the people of France might be getting rid of all of their heavy e-waste in 2010 and replacing those objects with lighter ones, the same would be supposed of Spain. In other words, as this is a comparison between countries, the differences within countries practices for collection, rather than trends in production and disposal, should illuminated.

It is possible that nations are selling or buying IT products internationally. This creates a dilemma regarding what nation is the largest consumer of IT, rather than producer. If a nation were to purchase many electronics from abroad, those purchases would not documented by the country, but the electronics would be documented in and recycled by the country. As such, the data would show an inaccurate measure of the consumption of IT electronics, but an accurate measure of their disposal. This would make a heavy importer look better in the ratio of weight purchased to weight collected. But, wherever more e-waste is being collected, it could be assumed that the system is better at collecting e-waste. This assumes that the IT trade occurs only amongst EU countries. But this poses less of a problem as to the validity of the ranking system, as higher collection rates should correspond with more effective IT collection systems. If the ranking system were instead to assume that the country collecting the highest weight of IT e-waste was the most effective, this would fail to account for the consumption patterns of that nation. Ideally, I would use data about e-waste disposal comparing separate collection from disposal in the garbage, as this would show which countries are disposing of their IT WEEE most effectively, but such data is not available.

All that being said, the European Environmental Agency in its “Europe as a Recycling Society: European Recycling Policies in Relation to the Actual Recycling Achieved.” used the same calculations I used, though with 2006 data, to understand how effectively each EU country was at collecting e-waste. This research was limited to 20 EU countries, in which the Netherlands, Sweden, and Norway had the highest overall collection rates, while the worst collection rate was that of Romania, followed closely by France and Poland. These ranks held fairly consistently for IT waste, as the top three countries held their spots (Netherlands- over 50%, Sweden- 57.24%, Norway- 58.71%), while the bottom three countries simply shifted positions (with Romania collecting 1.09% of IT waste, Poland collecting 2.49%, and France collecting 4.20%).

Accuracy

EU countries are required to report their own data. As such, it is possible that the data was manipulated or subject to reporting errors.

Effectiveness of IT e-waste recycling

No, there is not enough information to answer how effective e-waste recycling is in the context of human and environmental health. This research is meant to be an exploratory study of which EU countries are most effective at collecting e-waste and why. It is not meant to cover all of the factors related to e-waste disposal, but to provide a better understanding of how IT e-waste recycling in the EU is being implemented most and least effectively, as measured by collection rate, and what factors might be contributing to this effectiveness.

CHAPTER 5

Results and Analysis

Below are the results of the correlation analysis from the two-tailed Pearson correlation. This correlates the IT e-waste collection efficiency with each factor used to test the hypotheses. The strength and direction of correlations can be established using this data. However, due to the sample size, significance cannot be established.

Hypothesis 1: Population Density

	IT WEEE Collection Effectiveness[1]		
	Pearson Correlation	p-value (2-tailed)	N
(2010) Population Density (people per square km of land)[2]	-.197	.336	26
Population Urban[3]	-.186	.362	26
Population Intermediate[3]	.008	.971	26
Population Rural[3]	.188	.357	26
Population[4]	-.043	.833	26

1. Data accessed March 10, 2013 from http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/key_waste_streams/waste_electrical_electronic_equipment_weee
2. Data accessed April 17, 2013 from http://data.worldbank.org/indicator/EN.POP.DNST?order=wbapi_data_value2010+wbapi_datavalue&sort=asc
3. Data from *Urban-Intermediate-Rural Regions: Around 40% of the EU 27 population live in urban regions.* Allen and Corselli-Nordbald March 1, 2012.
4. Data accessed April 17, 2013 from http://data.worldbank.org/indicator/SP.POP.TOTL?order=wbapi_data_value _2010+wbapi_data_value&sort=as

Hypothesis 1: *The more urban and/or populous a country is, the more effective it is at collecting IT e-waste*. This hypothesis is not supported by the data. There is a clearly negative, though weak, correlation between collection effectiveness and percentage of population living in urban areas. A similar correlation is present with the independent variable of population density. Overall population has a slight, weak correlation with collection effectiveness. Urban indicators are correlated in a negative direction. Meanwhile, the two indicators of less urban development are positively, weakly correlated with IT WEEE collection effectiveness. There is a positive, yet weak correlation between IT WEEE collection effectiveness and rural populations and a very weak correlation of nearly zero, so neither positive nor negative, between percentage of intermediate population and IT WEEE collection effectiveness.

Hypothesis 2: Environmental Care

	IT WEEE Collection Effectiveness[1]		
	Pearson Correlation	p-value (2-tailed)	N
(2007) How important is protecting the environment to you personally? Very Important [2]	.201	.324	26
(2011) Percent of total waste recycled and composted [3]	.151	.463	26
(2007) Separated most of your recycling waste in the past month for environmental reasons [2]	.048	.815	26

1. Data accessed March 10, 2013 from http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/key_waste_streams/waste_electrical_electronic_equipment_weee
2. Data from "Attitudes of European Citizens Towards the Environment" Special Eurobarometer 295. Fieldwork: November-December 2007.
3. Data from *In 2011, 40% of treated municipal waste was recycled or composted, up from 27% in 2001.* Louise Corselli-Nordblad, L. March 4, 2013.

Hypothesis 2: *The more environmentally friendly the citizens of a nation are, the more effective it is at collecting IT e-waste.* This hypothesis was weakly supported by the data. The correlation between environmental importance and IT WEEE collection effectiveness is weak and positive. The percentage of all municipal solid waste recycled and reused has a weak, yet positive correlation with IT WEEE collection rates. Separating most of your own recycling waste for the sake of the environment has a very weak positive correlation. Overall, there is a weak to moderate correlation between environmental care and IT WEEE collection effectiveness.

Hypothesis 3: Proper E-waste Disposal

	IT WEEE Collection Effectiveness[1]		
	Pearson Correlation	p-value (2-tailed)	N
Weight of total IT WEEE recycled and reused[1] per weight sold[1]	.967	.000	24
Weight of total IT WEEE recycled and reused[1] per weight collected[1]	.141	.512	24

1. Data accessed March 10, 2013 from http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/key_waste_streams/waste_electrical_electronic_equipment_weee

Hypothesis 3: *The more effective a country is at collecting IT e-waste, the lower the ratio of IT WEEE collected that is recycled and reused.* This hypothesis is not supported by the data. The data suggest the opposite with a moderate to strong correlation. The weight of IT WEEE recycled and reused per weight sold has a strong, positive correlation with IT WEEE collection effectiveness. This suggests that the more IT WEEE that is collected, the more that is recycled or reused per weight sold, which would support the opposite hypothesis. Higher collection rates are correlated with higher recycling and reuse rates. Percentage of IT WEEE recycled and reused per weight collected had a weak, positive correlation with IT WEEE collection effectiveness. This suggests that as collection rates increase, so do the recycling and reuse rates per weight of IT WEEE collected.

Controls

	IT WEEE Collection Effectiveness[1]		
	Pearson Correlation	p-value (2-tailed)	N
IT Waste Collected in Tonnes 2010[1]	.208	.307	26
IT Equipment Sold in Tonnes 2010[1]	.042	.838	26
Total Recycling and Reuse of IT and telecommunications equipment in tonnes[1]	.260	.220	24
Kilograms of IT WEEE collected from households[1] per person[2]	.382	.054	26

1. Data accessed March 10, 2013 from http://epp.eurostat.ec.europa.eu/portal/page/portal/ waste/key_waste_streams/waste_electrical_electronic_equipment_weee
2. Data accessed April 17, 2013 from http://data.worldbank.org/indicator/SP.POP.TOTL?order=wbapi_ data_value _2010+wbapi_data_value&sort=as

Controls: Total IT WEEE collected in tonnes has a positive weak correlation with IT WEEE collection effectiveness. IT Equipment sold in tonnes has a positive weak correlation with IT WEEE collection effectiveness. Total recycling and reuse of IT equipment in tonnes is weakly positively correlated with IT WEEE collection effectiveness. Kilograms of IT WEEE collected from households per person is weakly, positively correlated with IT WEEE collection effectiveness. With such a low p-value, with a larger sample size, this might be significant.

Discussion

The evidence suggests that the European Commission's technical report of 2006 was not accurate in all of its claims about the effectiveness of the WEEE directive. Some countries, such as Sweden, Belgium, and Norway already had e-waste take back systems in place before the WEEE directive. However, interestingly, these countries do not make it the top two spots, as the "Europe as a Recycling Society" report suggests.

The results regarding **Hypothesis 1: Population Density** suggest that the more urban or populous a country is, the lower its IT WEEE collection rate. This means that the idea that presented by the EU's 2006 technical report was inaccurate in regards to IT WEEE collection rates. The report stated that economies of scale are created by large populations, which would subsequently lead to more effective WEEE Directive implementation. . However, the data does not support this. It is possible that, like in Maine, people living in more rural places have more reason to go to recycling centers, and hence drop off all of their recycling, including IT WEEE, while in cities the recycling infrastructure does not include the collection of IT WEEE, and so would require additional trips to properly dispose of IT WEEE.

The results regarding **Hypothesis 2: Environmental Care** suggest that these measures of environmentally friendly behavior are weakly positive indicators of IT WEEE collection. These results might have been more robust if different proxies for environmental care relevant to IT WEEE collection rates were used, rather than the three data sets used in this research. Perhaps the opinion polls do not capture the essence of what indicates caring about properly disposing of IT WEEE. It is also possible that the time lag between the 2007 survey data and the 2010 collection effectiveness variable led to less robust correlations. Because the WEEE Directive was still relatively new, it is possible that individuals were not as aware of the problems IT WEEE poses for the environment, and as such, their behaviors regarding IT WEEE were not based upon how much they cared for the environment.

Hypothesis 3: E-waste Disposal Method is not supported by the correlation found. Rather, IT e-waste recycling and reuse rates are positively correlated to IT WEEE collection rates. This evidence does not support hypothesis 3, but does paint a brighter picture of IT WEEE collection in the EU than support for hypothesis 3 would have. It appears that recycling rates increase slightly as collection rates increase.

It is possible that these correlations are stronger when we instead examine WEEE overall. It is also possible that the methods of reporting weight are different (some countries including packaging in their reported weights sold), which is leading to skewed numbers. However, due to the recycling and reuse rate being the only independent variable strongly, positively correlated with IT WEEE collection rates, the data suggest that factors other than population density, environmental care, and proper e-waste disposal are highly correlated with higher IT WEEE collection rates. Such factors could include the way in which the WEEE Directive was transcribed

The correlations found in the **controls** support the idea that individual IT WEEE recyclers matter to the overall IT WEEE collection rate. This is because it has a positive correlation with a low p-value that might be significant in a larger sample. The weak, positive correlation between tonnes of IT WEEE collected in 2010 and collection effectiveness suggests that the amount of IT WEEE might help create economies of scale. The same is evident from the weak, positive correlation between IT equipment put on the market in tonnes.

Now we examine the two most and least effective countries ranked for IT WEEE collection effectiveness.

Romania

Romania is the least effective country at collecting IT e-waste. Eleven percent of people from Romania reside in urban regions, 44% in intermediate, and 46% in rural regions. This constitutes the 4^{th} smallest urban population within the European Union (after Luxembourg, Cyprus, and Estonia, who all have a 0% urban population). When compared to the EU average of

41% urban, 35% intermediate, and 23% rural, it is obvious that Romania is more rural than the average EU country (Eurostat News Release, 2012). Romania, in 2010, had a population density of 93.2 inhabitants per square kilometer, lower than the EU27 average of 116.6. This helps support the theory that less densely populated areas face greater challenges to WEEE take-back. However, the correlations generated above do not support this theory. Romania has a nearly average overall population with 21,438,001 in 2010, while the average for the 26 EU countries in this study was 20,075,463.

It is also scores low on the recycling culture indicators. It recycled and composted only 1% of its treated municipal solid waste in 2011, while the average EU27 nation would do so with 40% of its waste. It also had the second lowest percentage, 49%, of responses to a 2007 EU survey claiming that Environmental Protection is very important and tying with Austria for the percentage that believe environmental protection is either not important or not at all important 8%. This is in comparison to an average of the EU 27 being split 64% claiming it is very important, 32% as fairly important, 3% as not very important, 0% not at all important, 1% DK. It is interesting to note that the only nation to have more than 1% of the population say that environmental protection was not at all important to them personally was Ireland, the next least effective country. The third and final recycling culture indicator is that of whether or not a person separated most of his or her recycling waste in the past month. In this measure, Romania scored lowest of the 26 EU nations evaluated with a response of 18%, while the EU 27 average was 59%.

Overall, the low levels of environmental care would lead one to believe that recycling is unimportant to the citizens of Romania, and hence lead to low collection rates. There are a variety of take-back systems in use in the EU. The three used in Romania are fixed dates in an area, old-for-new trade at the store, and going to municipal collection centers (Ciocoiu, Burcea, & Tartiu, 2010).

Ireland

Ireland is the next to least effective country at collecting IT waste. The EU report suggests that having a centralized population would help increase WEEE collection rates, and the evidence suggests that this might be the case with Ireland. Ireland has an urban population of 27% and a rural population of 73%, while the average EU27 has an urban population of 41%, 35% intermediate, and 23% rural, placing Ireland on the rural end of the spectrum, actually as the most rural of the 27 EU nations. Ireland also had a population density of 65.4 inhabitants per square kilometer in 2010, substantially lower than the EU27 average of 116.6. Ireland may be the most rural, but it is not the least densely populated.

Unlike Romania, Ireland had a higher rate of recycling and composting than did the EU27 average, standing at 41%. It also had a higher than EU27 average response regarding recent separation of recyclables with a 70% recycling rate. Perhaps the Irish system is not conducive to IT WEEE recycling because of the nature of collection. It might be simple to recycle, but difficult to return WEEE. The Irish expressed the sentiment that environmental protection was very important to them personally (55%) at a rate lower than the EU 27 average (64%). Ireland also had the highest rate of people saying it was not at all important, at 2%, which is higher than the EU 27 average of 0%. The percentage saying it was fairly important (36%) is higher than that of EU27 average (32%), while Ireland also had the highest DK response at 3%, while the EU27 average was 1%. The evidence suggests that perceptions of environmental importance are what are causing Ireland to have such low IT waste collection rates, as they are the only indicator that might be related to lower IT WEEE collection rates.. It might be that

Ireland has such an old recycling and composting culture that it is second nature, and therefore does not require high perceptions of environmental importance. However, as WEEE recycling is relatively new, and perceptions of environmental importance are not high in comparison to the rest of the EU, there is not enough intrinsic motivation to recycle IT waste.

Bulgaria

Bulgaria is the second most effective IT WEEE collector, boasting an 85.48% collection rate in 2010. What has made this an effective system?

With 17% of its inhabitants being urban residents, 45% intermediate, and 38% rural, Bulgaria does not support the idea that less rural areas are better at implementing WEEE collection. Looking at its 69.1 inhabitants per square kilometer density in 2010, when compared to the EU average of 116.6 inhabitants per square km, its relative dispersion is clear. Perhaps these rural areas are doing a better job at collecting IT waste due to word of mouth or more direct pressure from neighbors. Perhaps the e-waste is not being recycled at a stable rate, but instead was all unloaded at once in 2010. A longitudinal study might better control for this uncertainty.

Seventy-two percent of people in Bulgaria in 2007 said that protecting the environment is very important to them, 22% fairly important, 3% not very important, none saying not important, and 3% unsure. This level of care is higher than the EU 27 average of 64% thinking the environment is very important. It is therefore surprising to find that Bulgaria composted and recycled only 6% of its treated municipal solid waste in 2011, which puts it at ranking of second worst country ranked, with an EU27 average of 40%. Also, only 24% of individuals claimed to have sorted recycling in the past month. One might assume that the government sorted recycling so that individuals would not have to, seeing that only 24% sorted recycling in the past month, which is the third worst ranking in the EU. However, given that only 6% of the country’s waste is recycled or composted, this explanation does not seem likely. If only 6% of all municipally treated waste is composted or recycled, and only 24% of people recently sorted recycling, it is possible that that is all of the sorting that takes place. If, however, there was a high rate of recycling and composting, but a low rate of sorting, we might suppose that the government was sorting waste so that the individual would not be required to.

It would seem that such environmentally conscious individuals would sort their recycling more regularly, and that their country would dispose of it in environmentally friendly ways, such as recycling and composting. However, it appears that this mentality of supporting environmental protection has manifested itself more readily into the collection of IT waste. Perhaps this is because the EU had a high-profile WEEE recycling scheme on the books when Bulgaria was about to join the EU, so it created the proper infrastructure to be compliant, and hence prove itself to be a good member of the EU community, while recycling in general was considered old hat, and not nearly as politically important.

Slovenia

Slovenia is the most effective of the EU countries evaluated, with a collection rate of 92.36%. It entered the EU in 2004, another late-joiner to the EU. This alone lends credence to the idea of new countries transposing EU directives in the most effective way they can to signal their intentions within the EU. This may only occur with high profile directives, but with the WEEE directive, this mentality likely influenced transposition.

The urban, intermediate, rural population division is an interesting one. In Slovenia, as of January 1, 2011, 26% of the population lives in urban areas, 31% in intermediate, and 43% in rural areas. When compared with the average EU27 numbers of 41% urban, 35% intermediate, and 23% rural, this challenges the assumption that denser populations make for more effective

WEEE take-back. However, Slovenia did have the highest population density of the four countries examined, with 101.7 inhabitants per sq. km, but that is still well below the EU27 average of 116.6.

The government wanting to be seen as a good EU citizen is not the only possible reason for its high collection rate. Slovenia also has a high level of importance placed upon environmental protection with 81% of its citizens saying it is very important, 18% saying it is fairly important, 1% saying it is not very important, and 0% unsure or thinking it unimportant. This compares favorably to the EU27 average of 64% of respondents claiming it was very important, 32% fairly important, 3% not very important, 0% unimportant, and 1% unsure. Slovenia also has a greater than average EU27 rate of separating recycling, with a rate of 64%, 5% higher than the EU27 average.

Conclusions and Recommendations for Further Study

There is evidence that being rural compared to other nations is a common theme between the two least effective countries—Romania and Ireland. But neither Slovenia nor Bulgaria have higher than EU average percentages of urban residents. This indicates that perhaps the EU should reconsider the theory of urban populations leading to effective WEEE Directive implementation. In addition to these individual case studies, the data does not support urban populations as having a positive influence on effective e-waste collection. Rather, the correlation suggests that the more urban or populous a country is, the less effective it is at collecting IT WEEE. This is a result similar to that found by Bouvier and Wagner's (2011) study of Maine.

This research also supports the theory of new nations attempt to be in good compliance with EU WEEE standards, as Bulgaria and Slovenia were both late joiners to the EU, and yet are leaders of the pack in IT collection. However, this only appears to work in concord with public support of environmental principles. Meanwhile, Romania scored low on all indicators, and is also the least successful at collecting IT WEEE, but was also a late EU joiner. However, Ireland, the next-worst country, performs well on all indicators of environmental care, except for the perceived importance of environmental protection to the individual, and has been a member of the EU for decades.

The statistical analysis of this data suggests that the EU's suggestion regarding care about the environment leading better WEEE Directive compliance do extend to IT WEEE collection. The evidence in this study suggests a weak, positive correlation between IT WEEE collection rates and environmental care. It is possible that recycling culture does play a role in effective IT WEEE collection. This correlation might have been even stronger if a more relevant measure of environmental care had been used. More relevant data would have, at the very least, have been collected in 2010. However, this data was not available for this research.

The data suggest that IT WEEE that is collected is also being properly handled via recycling and reuse. However, there is incentive to report inaccurate numbers. Also, developing countries have seen that many of the electronics that are sent in the developing world in useable condition are simply e-waste. This problem should make us wary of self-reported IT WEEE being properly disposed of via reuse.

The data that the EU provides via surveys and self-reporting allows for comprehensive study. As such, it is feasible to do a study finding the correlation between overall WEEE collection rates and the variables of population density, environmental care, and recycling rates. The ideal study would also work to ascertain the influence that policy might have had on the effective collection of IT WEEE up to the present. If we can figure out which of these factors matters most, we can use it as a lever to more effectively implement IT WEEE collection, and hopefully WEEE collection in general.

Electronic waste laws generally favor either reducing the toxicity of e-waste or demanding EPR, which requires various recycling quotas. The goal of this legislation is to eliminate e-waste, and that goal is best served via repairing, remanufacturing, or reconditioning e-waste. There are various gaps both within e-waste policy and within the literature regarding e-waste policy. The policies discussed do not encourage repairing, remanufacturing, or reconditioning as much as they encourage recycling; this is a gap in e-waste policy. Another hole in the policy is that recovery of valuable metals is not encouraged, as e-waste laws only focus on the types of hazardous chemicals allowed in the electronics, and the weight of the items recycled. Yet another hole in the policy is that toxicity and ease of recyclability of products does not influence the price of disposal, only weight is a factor in disposal price. However, given these deficiencies, we must examine the effects of the legislation that currently exists to see what impact it has had on the problems it seeks to address.

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