Several Aspects of E-waste Problems---E-waste Definitions, International Trading Patterns, and China's Solutions

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ABSTRACT

Electrical and electronic equipment has infiltrated into every aspect of our lives, and created great waste problems. These problems have become popularized as electronic waste (e-waste) and received increasing attention both from the public and the government. This thesis concentrates on three different aspects of these problems: the definition of e-waste, the pattern of the global trade of e-waste, and China's e-waste problems and solutions.

Many countries' government documents related to e-waste have provided their own definitions of e-waste, but these definitions vary. This variety in e-waste definitions can bring significant problems (Khetriwal et al., 2011; Cantin and Bury, 2012; Milovantseva and Fitzpatrick, 2015). However, only a few researchers have focused on this area, and none of these studies have considered e-waste definitions other than the ones from the EU Directive and American states. This study collects formal e-waste definitions from countries all over the world, published in English or Chinese, and finds their differences mainly lay in two areas: 1) the approaches to defining their covered equipment; and 2) how the covered equipment becomes waste. The influences of these differences are that they determine a different overall nature of the e-waste issue in the jurisdiction where given regulations apply. Different definitions of e-waste lead to different e-waste volumes and compositions, different responsible parties, and different possible solutions. The differences show that e-waste has no natural definition, and that the e-waste problem is an indeterminate problem (Wynne, 1987).

Multiple e-waste problems have been caused by the international transfer of e-waste (BAN, 2002; Greenpeace International, 2005; Greenpeace, 2008; BAN, 2016). The se-

cond part of this research examines data from the United Nations COMTRADE database using a proxy method and analyzes the temporal pattern of the global trade of e-waste. This analysis results in three main findings: 1) the total international trade volume of at least certain types of e-waste has grown remarkably in the last 20 years, in which the summation of several of the biggest trade transactions account for the bulk of the total trade; 2) between 1996 and 2015, more than 80% of the international trade of e-waste measured by the COMTRADE data was intra-regional trade; and 3) the results of the trade data analysis can tell different stories when different categorization schemes for 'developing' and 'developed' countries are used to classify the trade data. Under the Basel Convention categorization scheme, the amount of the transfer of e-waste from developed countries to developing countries is very small, while under the World Trade Organization scheme (WTO), the volume of this type of trade is big and growing. These findings point to a broader problem than the specifics of either the Basel Convention or the WTO. It means not only the category of e-waste but also the categorization defined by the countries generate a fundamentally indeterminate waste management problem (more generally, see Wynne, 1987).

China has been famous as a global e-waste recipient with a terribly destroyed environment (Puckett and Byster, 2002; Tong and Wang 2004; Schwarzer et al., 2005; Ongondo, Willianms, and Cherrett, 2011; CNN, 2013), the second largest e-waste generator (Wei and Liu, 2012; StEP, n.d.), and the largest producer and consumer of electronic appliances in the world (Chi et al., 2011). The third part of this thesis will comprehensively analyze the situation of China's e-waste problems and the effectiveness of China's policy solutions. This research finds that the volumes of e-waste generated inside China and e-waste already smuggled into China are both large and neither issue should be ignored by police makers. However, the Chinese government treats domestic e-waste and smuggled e-waste in completely different ways. For the domestic e-waste, China has successfully built a regulation system to control it. If collected under this system, China's formal e-waste disposal industry has the ability to dispose of more than 90% of its domestic e-waste. Even though problems still exist with this system (e.g., collection remains a problem), the conclusion can still be drawn that the Chinese government has put great efforts into trying to control its domestic e-waste problem. Meanwhile, the e-waste already smuggled into China remains largely uncontrolled. China's policy approach toward its e-waste importation is a trade ban. This ban policy has not been replaced for nearly ten years and it appears to be not working well. This finding is supported by evidence coming from different sources. Every piece of e-waste already smuggled into China will end up in the informal e-waste disposal industry. The Chinese public as well as their government will still have to suffer environmental problems brought by this industry. The Chinese government still needs to take more actions to enforce domestic environmental laws that cover issues of environmental quality raised by the processing of e-waste already smuggled into the country.

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LIST OF ABBREVIATIONS

Basel Action Network	BAN
Chinese Household Electrical Appliances Research Institute	CHEARI
Commonwealth of Independent States	CIS
electronic waste	e-waste
European Free Trade Association	EFTA
European union	EU
Solve the E-waste Problem	StEP
TVs, refrigerators, washing machines, air conditioners, and microcomputers	TRWACs
United Nation	UN
waste and scrap of primary batteries, electric accumulators, spent primary batteries and spent electric accumulators	WPBs
waste electrical and electronic equipment	WEEE
World Trade Organization	WTO

CHAPTER 1. INTRODUCTION

1.1 Background

Electrical and electronic equipment has infiltrated into every aspect of our lives, and created substantial waste problems. These problems have become popularized as electronic waste (e-waste) and received increasing attention for the following three reasons. First, e-waste poses a great challenge because of its fast growing size. The total amount of e-waste is experiencing exponential growth with a rate three times faster than other solid wastes (Schwarzer, 2005; Ongondo, Willianms, and Cherrett, 2011). This growth is accelerated by two factors. On one hand, many electrical and electronic equipment companies upgrade their products frequently. For example, Apple upgrades its iPhone product every one or two years. On the other hand, the lifespans of these products are declining by design. For instance, in 2005, the lifespan of computer's central processing units was two years, about half of its lifetime in 1997 (Babu, Parande, and Basha, 2007).

A second issue behind the public concern over e-waste arises due to the fact that most types of e-waste contain hazardous substances. They can cause public health crises and serious environmental problems unless the equipment is being disposed of properly. If processed improperly, such as being burned or melted with acid (Fu et al., 2008), these hazardous substances will leak out, attach to media, such as dust, food or water, and threaten the health of individuals exposed to them (Grant et al., 2013). The chemical classification of e-waste components, sources and routes of exposure are shown in Table 1.1.

Table 1.1 Chemical classification of e-waste components, sources and routes of exposure (Grant et al., 2013)

	Component of electrical and electronic equipment	Ecological source of exposure	Route of exposure
Persistent organic pollutants			
Brominated flame retardants Polybrominated diphenyl ethers	Fire retardants for electronic equipment	Air, dust, food, water, and soil	Ingestion, inhalation, and transplacental
Polychlorinated biphenyls	Dielectric fluids, lubricants and coolants in generators, capacitors and transformers, fl uorescent lighting, ceiling fans, dishwashers, and electric motors	Air, dust, soil, and food (bioaccumulative in fish and seafood)	Ingestion, inhalation or dermal contact, and transplacental
Dioxins			
Polychlorinated dibenzodioxins and dibenzofurans	Released as combustion byproduct	Air, dust, soil, food, water, and vapour	Ingestion, inhalation, dermal contact, and transplacental
Dioxin-like polychlorinated biphenyls	Released as a combustion byproduct but also found in dielectric fluids, lubricants and coolants in generators, capacitors and transformers, fl uorescent lighting, ceiling fans, dishwashers, and electric motors	Released as combustion byproduct, air, dust, soil, and food (bioaccumulative in fi sh and seafood)	Ingestion, inhalation, and dermal absorption
Perfluroalkyls	Fluoropolymers in electronics	Water, food, soil, dust, and air	Ingestion, dermal contact, inhalation, and transplacental
Polyaromatic hydrocarbons			
Acenaphthene, acenaphthylene, anthracene, benz[a] anthracene, benzo[a]pyrene, benzo[e]pyrene, benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[j] fl uoranthene, benzo[k]fl uoranthene, chrysene, dibenz[a,h]anthracene, fl uoranthene, fl uorene, indeno[1, 2, 3-c,d]pyrene, phenanthrene, and pyrene	Released as combustion byproduct	Released as combustion byproduct, air, dust, soil, and food	Ingestion, inhalation, and dermal contact
Elements			
Lead	Printed circuit boards, cathode ray tubes, light bulbs, televisions (1·5–2·0 kg per monitor), and batteries	Air, dust, water, and soil	Inhalation, ingestion, and dermal contact
Chromium or hexavalent chromium	Anticorrosion coatings, data tapes, and floppy disks	Air, dust, water, and soil	Inhalation and ingestion
Cadmium	Switches, springs, connectors, printed circuit boards, batteries, infrared detectors, semi-conductor chips, ink or toner photocopying machines, cathode ray tubes, and mobile phones	Air, dust, soil, water, and food (especially rice and vegetables)	Ingestion and inhalation
Mercury	Thermostats, sensors, monitors, cells, printed circuit boards, and cold cathode fl uorescent lamps (1–2 g per device)	Air, vapour, water, soil, and food (bioaccumulative in fi sh)	Inhalation, ingestion, and dermal contact
Zinc	Cathode ray tubes, and metal coatings	Air, water, and soil	Ingestion and inhalation
Nickel	Batteries	Air, soil, water, and food (plants)	Inhalation, ingestion, dermal contact, and transplacental
Lithium	Batteries	Air, soil, water, and food (plants)	Inhalation, ingestion, and dermal contact
Barium	Cathode ray tubes, and fluorescent lamps	Air, water, soil, and food	Ingestion, inhalation and dermal contact
Beryllium	Power supply boxes, computers, x-ray machines, ceramic components of electronics	Air, food, and water	Inhalation, ingestion, and transplacental

Source: Grant et al., 2013

Furthermore, the transportation of e-waste from developed countries to developing ones has brought extra environmental problems and attracted a huge amount of attention. In these developing countries, e-waste may be disposed of by simple methods like burning or acid melting, which will release hazardous substances directly into the environment. These hazardous substances have a relation with various physical illnesses like thyroid disorders, reproductive health problems, low lung function, growth disorders, and changes to cell functioning (Grant et al., 2013). The health problems are mainly suffered by direct exposure, and people more vulnerable to these pollutants like pregnant women, infants and children (Grant et al., 2013; Han et al., 2011; Zheng et al. 2013; Guo et al., 2012). Less developed countries, such as India and China, suffer from these multiple problems brought by imported e-waste (BAN, 2002; Greenpeace International, 2005; Greenpeace, 2008), while rich countries get rid of their e-waste problems by a cost-effective method: dumping them outside. In 2008, Greenpeace estimated that besides the uncollected e-waste, around 25% of the EU's collected e-waste was exported (Greenpeace, 2008). Estimates on the amount of e-waste exported from the US vary and are in dispute. For example, the Basel Action Network (BAN) has long claimed that 50-80% of e-waste sent to US recyclers is exported to Asia, mostly to China (BAN 2002). More recently, the group has revised their estimate down to 40% (BAN, 2016).

1.2 Central Research Questions

This thesis is divided into three parts. Each part focuses on separate phenomena and will answer its own research questions. The first part is about the differences of e-waste definitions from different sources, and will answer two research questions: what are the differences among these e-waste definitions? How do these differences of definition matter? The second part is about the pattern of the global trade of e-waste and will answer two research questions: how has the pattern of global trade of e-waste changed over time? What characteristics of this pattern will be demonstrated under different country categorization methods? The third part is about China's e-waste problems and solutions, and will answer one research question: considering e-waste from importation and domestic generation, are the Chinese government's solutions focusing on its e-waste problems effective?

1.3 Literature Review

1.3.1 The Definition of E-waste

The significance of e-waste problems has received increasing attention both from the general public and governments. Many countries' governments attempt to solve this problem with various measures. Documents such as laws, guidelines and acts are issued to reduce the environmental effect of e-waste problems. Most of these documents have provided their own definitions of e-waste, but these definitions vary.

These differences in e-waste definitions can bring significant problems for controlling international trade of e-waste, managing domestic e-waste problems and conducting research on e-waste issues. Milovantseva and Fitzpatrick (2015) analyzed nine different cases to identify the main factors that influence the transboundary reuse of e-waste, and the first influential element they found is the "definitions, classification, operating procedures, and enforcement" (Milovantseva and Fitzpatrick, 2015, p.170) of e-waste. Khetriwal et al. (2011) found that international trade processes, like requiring shipment licenses, could possibly take more time when trading partners are using different e-waste definitions. Cantin and Bury (2012) found that the research focusing on comparing different countries' estimated volume of e-waste or e-waste management systems confronts problems of clarifying the scope of e-waste.

Even though the differences of e-waste definitions have brought a number of problems and many researchers have mentioned it as controversial (Borthakur and Singh, 2012; Cantin and Bury, 2012; Widmer et al., 2005), only a few studies really focus on this topic. Townsend (2011) attempts to summarize different definitions of waste electrical and electronic equipment (WEEE), but he only reviewed the e-waste definition from the EU Directive and American states, and most of his efforts are focused on analyzing the chemical contents contained by them. Khetriwal et al. (2011) have conducted research on e-waste definitions, provisions and agreements, but only countries who apply the EU Directive are compared.

This study will attempt to collect formal e-waste definitions from countries all over the world, which are available in English or Chinese, investigate the differences among these definitions, and analyze the influences they may have.

1.3.2 The Pattern of the E-waste Global Trade

As mentioned above, multiple e-waste problems have been caused by the international transfer of e-waste. Due to the lack of accurate and authoritative data for this transfer, only a small number of studies focus on it. Most of these studies apply estimated data and are not able to focus on the temporal characteristics of this transboundary movement. Greenpeace (2008) estimated that, besides the uncollected e-waste, around 25% of the EU's collected e-waste is exported. Only a few researchers have examined trade data from authoritative sources. Lepawsky and McNabb (2010) mapped the international trade and e-waste using data from the COMTRADE database, and found that the international trade of e-waste is more likely to happen intra-regionally and that besides the trade moving from developed countries to developing countries, the trade moving between developing countries is also substantial. While their research did not explore the temporal characteristics of e-waste global trade, Lepawsky's (2015) later work did.

That work shows the e-waste trade from developing to developed regions is growing with a trend that confounds the usual way the e-waste problem is presented as principally a concern about e-waste flows from the developed world to the developing world.

Since data supporting the analysis of illicit e-waste dumping is scarce, this research will apply the data from the COMTRADE database, and only focus on the international e-waste trade reported by governments. By analyzing these data, this study will examine how the pattern of the global trade of e-waste has changed over time, explore the characteristics of this pattern among different economic zones, and examine the different stories these trade data tell when different criteria for classifying developing and developed countries are applied.

1.3.3 China's E-waste Problems and Policy Solutions

China has been famous as a global e-waste recipient with a terribly destroyed environment since the 1990s (Puckett and Byster, 2002; Tong and Wang 2004), and this problem has continued at least to the 2010s (Schwarzer et al., 2005; Ongondo, Willianms, and Cherrett, 2011; CNN, 2013; BAN, 2016). In 2005, it was claimed that China received 90% of all the e-waste from the Asian recycling market (Basel Action Network et al., 2002) (see Figure 1.1). In 2013, a spokesperson from Greenpeace claimed that 80% of e-waste from all over the world ended up in China (CNN, 2013). The Basel Action Network tracked the transfer of 205 used electronic devices, and found that 23.4% of the total ended in China: 37 of them ended in Hong Kong China, and 11 of them ended in Mainland China (BAN, 2016). Furthermore, e-waste informal disposal locations in China, like Guiyu and Taizhou, all suffered from hazardous pollutants and unhealthy environments (Han et al., 2011; Zheng et al. 2013; Guo et al., 2012).

In addition to being a primary destination for e-waste flows, China is also known as the second largest e-waste generator (Wei and Liu, 2012; StEP, n.d.) and the largest producer and consumer of electronic appliances in the world (Chi et al., 2011). In 2014, it generated 14% of e-waste worldwide (StEP, n.d.). Therefore, in addition to problems brought by imported e-waste, environmental problems possibly caused by e-waste generated inside China have received increasing attention (Chi et al., 2011).

Figure 1.1 China received a large amount of e-waste oversea (Basel Action Network et al., 2002).

A large number of studies have focused on China's e-waste problems. Some of these researchers exclusively concentrate on China's e-waste management system. They analyze China's e-waste policies, and then provide advice for further improvement of these polices. Yu et al. (2010) examined the e-waste management framework in China and proposed two policy recommendations for improving this framework in the future, such as the share of financial responsibility with different stakeholders and distribution of works between informal and formal sector. Chung and Zhang (2011) evaluated three major issues in China's e-waste regulation system: "take-back issues, controls on hazardous substances in WEEE [,] and the assurance of good environmental management in WEEE plants" (p.2638), and found shortcomings in these issues. The shortcomings identified by Chung and Zhang (2011) include vaguely defined responsibility of the take-back system and inconsistent enforcement of policies. Zhang et al. (2015) reviewed the "process of WEEE recycling in China", and proposed "an integrated recycling system" to increase the recycling rate for WEEE (p.361). For Zhang et al. (2015) the new WEEE system should establish "a reasonable and workable legal system" to optimize China's existing "recycling and technical systems" (p.370). Zeng et al. (2017) reviewed China's e-waste management system, and found that the "economic incentives are key to the success of the new WEEE regulations" (p.1082).

Some of these researchers exclusively concentrate on estimating the volume of China's e-waste. They apply different calculation methods to estimate the volume of one or more types of e-waste in China, and offer simple conclusions and recommendations. Liu, Tanaka, and Matsui (2006b) estimated the volume of TVs, refrigerators, washing machines, air conditioners and computers in Beijing, and analyzed their destination after their expected life-span. Liu, Xue and Huang (2016) applied a Gompertz model to estimate the volume of TVs, refrigerators, washing machines, air conditioners and computers in China, and provided suggestions for the geographical distribution of China's future e-waste disposal industry. Song et al. (2016) employed a combination of standard method and Gompertz curve model to estimate the volume of the generation of abandoned printers. Zeng et al. (2016) used "material flow analysis and the lifespan model" (p.

1347) to estimate and predict China's e-waste generation from 2010 to 2030, and drew a conclusion that China will become the leading e-waste producer in the world in this time period.

These two types of studies are both important for providing policy advice to the Chinese government, but the studies focusing on China's e-waste policy can easily lack enough supportive data, and the studies focusing on China's e-waste volume always need further analysis for detailed policy recommendations. Only a few researchers have successfully analyzed China's e-waste volume and policy together. Lu et al. (2015) conducted research reviewing China's e-waste sources and policies, and they try to provide policy recommendations based on their data analysis. However, they fail to analyze China's e-waste problem and policy comprehensively. This research will comprehensively analyze the situation of China's e-waste problems and the effectiveness of China's policy solutions.

1.4 Methodology Overview

This thesis has three different research questions concerning the differences of the definition of e-waste, the pattern of e-waste global trading, and China's e-waste problem. To answer these questions, different research methods are applied. I discuss these different methods in the following sections.

1.4.1 The Definition of E-waste

To investigate the differences of the definitions of e-waste, I collected legislative documents related to e-waste and passed by different territories. The list of the name of the documents as well as territories they belong to were found from the United Nation's (UN) Solve the E-waste Problem (StEP) initiative's e-waste world map (StEP, n.d.). All such documents in English or Chinese were collected from the StEP e-waste world map and analyzed. Most of these documents come from federal level legislation, except for America and Canada. Neither of these two countries have federal level e-waste legislation, but several American states and Canadian provinces have formulated their own regulations or programs related to e-waste. Therefore, the documents from America and Canada are state or provincial level legislation.

Among these collected documents, some of them provided an explicit definition of e-waste, and 12 different types of e-waste definitions are found. Others do not have an explicit e-waste definition, but their contents do provide information related to one or more aspects of the meaning of e-waste as it is being used in those documents. In chapter 2, a comparison is made between two aspects of these various meanings of e-waste: 1) the approaches to defining what equipment is covered by various legislation, and 2) the identification of how this covered equipment becomes waste.

1.4.2 The Pattern of the E-waste Global Trade

A method of proxy data analysis is employed to study how the pattern of the global trade of e-waste has changed over time and the implications of this pattern. The waste and scrap of primary batteries, electric accumulators, spent primary batteries and spent electric accumulators (WPBs), whose HS 2002 code is 854810, and whose globally international trade data is stored in the UN's trade database COMTRADE, is chosen as the proxy of e-waste to analyze the pattern of its global trade.

This method has its disadvantages. No proxy is perfect at covering the identities of all categories of e-waste, in part because definitions of e-waste vary. Also, the same statistical indicator may have different potential meanings in different countries. Moreover, the amount of illegal and unreported e-waste trading data is unknown. However, there are also advantages to using these proxy data from COMTRADE. The UN COMTRADE database is an authoritative source of consistently defined data. The data for the WPBs category ensures that all the trading data reported by different countries refer to a consistent statistical category, which offers an important advantage for research on the international trade of e-waste involving multiple countries. Moreover, WPBs are identified as e-waste under many international agreements and national laws. For example, the Basel Convention lists WPBs as e-waste specifically (Basel Convention, 1998). China also lists WPBs in its 'Catalog of Prohibited Imports' (Environmental Protection Agency of the People's Republic of China et al., 2008).

To explore the implications of patterns in the trade data, other means are also applied. Section 3.4 divides all the countries in the world into seven economic zones based on categories used by the World Trade Organization (WTO): Africa, Asia-Pacific, Commonwealth of Independent States (CIS), Europe, Middle East, North America, and South and Central America (World Trade Organization, 2015) to investigate the characteristics of different economic zones shown in the process of international e-waste trade.

Section 3.5 then compares the results obtained from the COMTRADE data when two different developing versus developed country classification standards are used: the WTO schema (as in Section 3.4) and the Basel Convention's schema. The Basel Convention is one of the most influential international trade agreements focusing on preventing cross-border movement of hazardous waste (Basel Convention, 2016). As one type of hazardous waste, WPBs' international trade is mainly constrained by the Basel Convention. The WTO has 164 members as of 29 July 2016 (World Trade Organization, n.d.), and its classification criterion as well as WTO's published reports using it will have great influence among its members. After the division, comparisons of the trading patterns using the same data set but different country classifications (based on those of the Basel Convention versus those of the WTO) are made to further analyze different features demonstrated in the global e-waste trade.

1.4.3 China's E-waste Problems and Policy Solutions

Reliance on proxy data (more details, see Section 1.4.2) is also used to analyze China's domestic e-waste generation. The summation of wasted TVs, refrigerators, washing machines, air conditioners and microcomputers are chosen as the proxy. These five types of e-waste are chosen because that they are the main regulatory objectives of China's e-waste policies before 2015. The total amount of these five types of e-waste is analyzed using data published by China's federal government reports and estimated data from researchers. The evidence about the existence of China's imported e-waste is also provided in this chapter from the COMTRADE data, research reports, and news articles. A simple assumption method is used to determine the relative contribution to volume of e-waste arising in China that comes from importation versus domestic generation.

Finally, the legislation from the Chinese government is analyzed as China's solution to addressing its e-waste problems. China's provincial and lower level policies are made according to federal policy. Consequently, only federal legislation is analyzed in Chapter 4. The legislative control concerning this problem is analyzed from the point of view of policies concerning China's domestic e-waste, policies banning the importation of e-waste, and policies concentrating on e-waste already smuggled into China. All the federal legal documents are analyzed in term of the effectiveness of these policies for addressing China's e-waste problems. This effectiveness is determined by the policy structures and their consequences.

CHAPTER 2. DEFINING E-WASTE

2.1 Introduction

Many different terms are used when referring to e-waste. In these terms, different key words, like ‘waste’, ‘end’, or ‘unwanted’ are applied. Even though these terms do not have exactly the same literal meaning, they are often used interchangeably in their corresponding documents. This phenomenon hints at an important point made by Wynne (1987) about the character of waste and especially hazardous waste. According to his point, waste has no natural definition and the meanings given to wastes are indeterminate. The interchangeability of key words I found in these documents lead me to further develop Wynne’s argument of indeterminacy, especially in relation to what I call the different routes the documents take to defining e-waste (e.g. through a measure of the voltage of electricity used in the product, or through the components of which the product is composed, or based on a device’s screen size. For more details, see Section 2.3).

In this chapter, I will analyze various definitions of e-waste to identify their differences and discuss the impact of these differences in determining the nature, solution, and influence of the e-waste problem. These definitions come from legislation provided by different territories. I will compare the differences of these definitions based on the two components common to all definitions of e-waste: 1) the approaches to defining their covered equipment; and 2) how this covered equipment is determined to become waste.

2.2 Collecting Information about Definitions of E-waste

For this study, information about e-waste definitions was collected using the StEP E-waste World Map which gathers information about policies covering e-waste in various countries of the world (StEP, n.d.). For the purpose of this study, only definitions found in official legislative documents were chosen. While the map in Figure 2.1 includes all countries, my research analyzes documents available in English and Chinese.

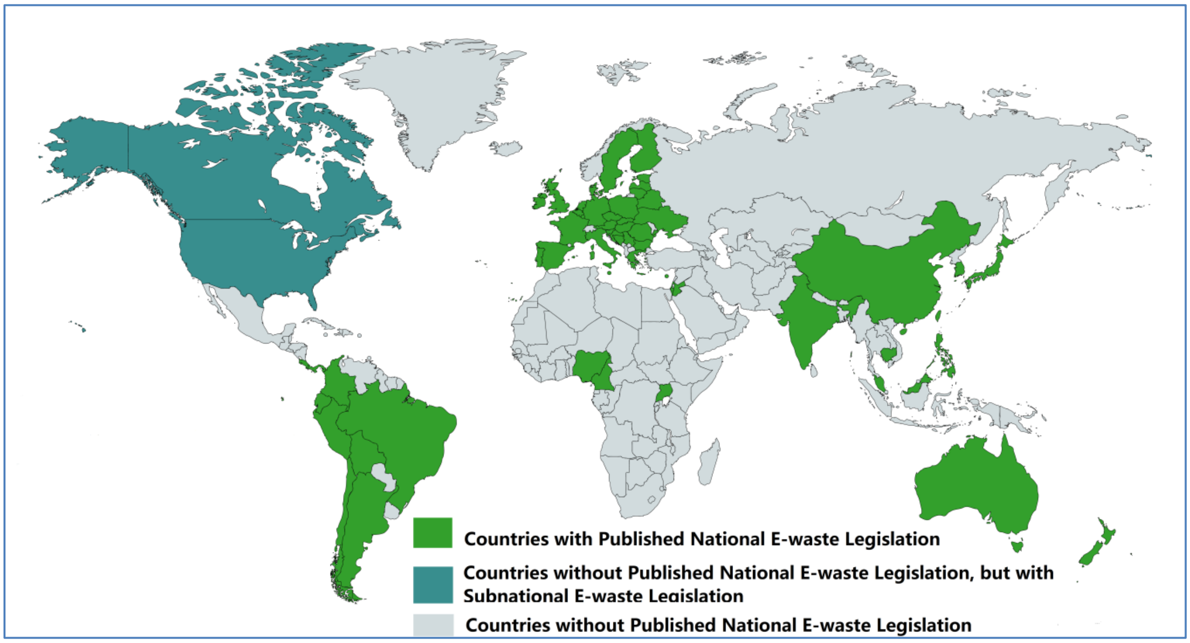

Figure 2.1 Countries and their basic situation of e-waste publications

The countries in Figure 2.1 can be divided into three different types:

1) Countries with published national e-waste legislation. Among these countries, 40 of them have provided explicit e-waste definitions in English or Chinese, from which seven different types of e-waste definitions are collected. Some countries have not provided explicit e-waste definitions, but the documents collected contain implicit definitions of the meaning of e-waste within them.

2) Countries without published national e-waste legislation but with subnational e-waste legislation. Neither America nor Canada has federal e-waste legislation policies, but several American states and Canadian provinces have formulated their own regulations or programs related to e-waste. Where such e-waste definitions from the states and provinces also have great influence on their e-waste policies, these definitions are also collected for

further analysis. Five different types of e-waste definitions are collected from these states and provinces. Together with the seven types identified in countries with national legislation, a total of 12 different types of e-waste definitions are found.

3) Countries without any legislation related to e-waste.

After carefully looking at the documents related to e-waste from governments all over the world, 12 different types of e-waste definitions are collected for further analysis. Information related to one or more aspects of the e-waste definition are also collected from documents related to e-waste and without explicit e-waste definitions.

2.3 Differences between Different Definitions and Their Influences

After examining the information from legislative documents all over the world, especially the 12 different types of explicit e-waste definitions, I find that they are different in two aspects: 1) the approaches and restrictions in defining the equipment covered, and 2) the criteria for determining when this equipment becomes waste.

2.3.1 Diversity in Defining the Covered Equipment

There are significant differences among e-waste definitions in terms of what equipment they cover. These differences lie both in the routes they use to define the covered equipment and the restrictions they set. This section will first investigate the various routes to defining the equipment covered, and then analyze the different restrictions they set. Finally, I will analyze the effects this diversity of e-waste definitions might have for framing how the e-waste problem is managed.

2.3.1.1 Routes to Defining the Covered Equipment

Among all the e-waste definitions, there are three routes to defining their covered equipment, either through reference to the energy used by the equipment, through a description of the components of this equipment, or through a specific list of devices (e.g., TVs, air conditioners, or cell phones). In other words, despite there being 12 different types of e-waste definitions apparent in the documents I analyze, all of that variety comes down to only three different approaches to defining their covered equipment: 1) defining the energy they use, 2) defining their components, or 3) a list of specific products that will count as covered items.

The first approach to defining the covered equipment is from a general description of the energy source of this equipment. Many countries apply this description without any limitation. For example, Singapore defines its covered equipment as "anything powered by an electrical source" (Singapore National Environment Agency, 2016). India defines its covered equipment as "equipment which [is] dependent on electric currents or electro-magnetic fields to be fully functional" (Ministry of Environment, Forests and Climate Change of India, 2016, p.3). South Korea defines its covered equipment as "a machine/appliance (including parts thereto) functioning by electric currents or electromagnetic fields" (Korean Ministry of Environment, 2007b, p.5). Meanwhile, some countries and organizations apply this description with certain limitations. The EU defines its covered equipment as "[depending] on electric currents or electromagnetic fields" that is "designed for use with a voltage rating not exceeding 1 000 volts for alternating current and 1 500 volts for direct current" (DIRECTIVE 2012/19/EU, 2012, p.43). While each of these examples used different specific wording, they share the approach of using energy to define what counts as equipment to be covered in their meaning of e-waste. More importantly, one might notice how this approach can lead to a very wide meaning of e-waste that might include items that may not intuitively seem electronic (e.g., toasters, ovens, and toys).

The second approach to defining the covered equipment is from their components. One definition of this type is from the American state of Indiana, which defines covered electronic devices as those with their "functions provided by electronic circuitry and components" (The General Assembly of the State of Indiana, 2007, p.5), and which defines e-waste as

> Any waste that is one or more of the following or has one or more of the following components: (1) A circuit board. (2) An electronic component, such as a: (A) diode; (B) resistor; (C) capacitor; or (D) coil. (3) A display device, such as: (A) a CRT; (B) a liquid crystal display screen; (C) a plasma display screen; or (D) another such display device. (4) A computer. (5) An electronic device. (The General Assembly of the State of Indiana, 2007, p.5)

In this definition, having or not having certain components, rather than a certain energy type or voltage, becomes the criteria to determine whether a piece of equipment is covered equipment. Again, however, one might notice how capacious a category e-waste comes to be under such a definition.

The third method for defining the covered equipment is providing a list of specific products that the definition covers. For example, the American state of Colorado defines "electronic devices" as

> A computer, peripheral, printer, facsimile machine, digital video disc player, video cassette recorder, or other electronic device specified by rule promulgated by the commission; or (II) A video display device or computer monitor, including a laptop, notebook, ultrabook, or netbook computer, television, tablet or slate computer, electronic book, or other electronic device specified by rule promulgated by the commission that contains a cathode ray tube or flat

panel screen with a screen size that is greater than four inches, measured diagonally. (The General Assembly of State of Colorado, 2012, p.2)

In this third strategy, the meaning of e-waste is much more constrained. For example, if a cell phone or other device lacks a screen larger than four inches measured diagonally it will not count as e-waste. Other items, such as kettles, toasters, ovens for example, will not count at all (unless in the unlikely event they contain a screen of sufficient type and size).

These three different routes of defining the covered equipment show great variety in what counts as e-waste. One device in a certain condition can be considered as e-waste in one territory while not in another with a different categorization scheme. Moreover, besides these three routes, many e-waste definitions set further restrictions on the existing definition. In these restrictions, certain types of electronic equipment are indicated as not being covered. Among all the e-waste definitions I collected, there are three types of restrictions that are applied: through the systems they belong to, through their sizes, or through their sources.

Many e-waste definitions do not cover equipment belonging to certain systems. One of the most widely applied restrictions of this kind is the exclusion of parts of a vehicle. The EU specifically regulates that its Directive should not be applied to parts of "means of transport for persons or goods, excluding electric two-wheel vehicles which are not type-approved" (DIRECTIVE 2012/19/EU, 2012, p.43). Many American states, such as California (California State Legislature, 2003) and New York (New York State Department of Environmental Conservations, 2010), exclude parts of motor vehicles as e-waste in their legal documents. Another restriction of this kind is excluding parts of large equipment with specified functions from e-waste. The EU excludes parts of waste equipment "designed to be sent into space" or "solely for the purposes of research" (DIRECTIVE 2012/19/EU, 2012, p.43) from e-waste. In California, "a video display device that is contained within or a part of a piece of industrial, commercial, or medical equipment, including monitoring or control equipment" (California State Legislature, 2003) is excluded as its covered equipment.

Some e-waste definitions are based on size limits. This type of restriction is popular among American states. The American state of California excludes video display devices containing a screen smaller than four inches, measured diagonally, as covered equipment (California State Legislature, 2003). The American state of Indiana excludes "a television or computer monitor, including a laptop computer [that] contains a cathode ray tube or flat panel screen" (The General Assembly of the State of Indiana, 2009, p.9) that is smaller than 4 inches, and "a telephone [or] a device capable of using commercial mobile radio service [that] contains a video display area" (The General Assembly of the State of Indiana, 2009, p.9) smaller than 9 inches as its covered equipment.

Some e-waste definitions do not cover equipment from certain sources, such as hospitals or governments. For example, the American state of Indiana defines that a piece of equipment is not considered as covered equipment if it is

> a video display device, including a touch screen display, that is functionally or physically part of or connected to a system or equipment designed and intended for use in: (A) an industrial; (B) a commercial, including retail; (C) a library checkout; (D) a traffic control; (E) a security, sensing, monitoring, or counterterrorism; (F) a border control; (G) a medical; or (H) a governmental or research and development (The General Assembly of the State of Indiana, 2009)

These restrictions increase the diversity of the e-waste issue. Under these restrictions, two units of the same equipment, with the same production process, outlook and function, containing the same hazardous material and requiring the same disposal technique, can be considered to be e-waste or not just because they are installed in different systems, with different sizes, or used by different departments.

2.3.1.2 Influences of the Diversity of the Covered Equipment

Even though only three approaches are used to define the covered equipment, they provide a source of diversity on what is considered as e-waste. Furthermore, the restrictions set on the covered equipment increase this diversity. Taken together, these sources of diversity have a number of effects. Firstly, this diversity leads to differences on the nature of e-waste issues. With different covered equipment, even in the same area (e.g., within America), not only will the volume of e-waste be different, so will the composition of e-waste. The volume and composition can determine whether e-waste generation is a serious problem with potential hazardous threats, or is just a phenomenon with little effect on a society. Therefore, the diversity of defining the covered equipment makes a great difference in the identification of e-waste as a waste management problem, which will influence many different aspects of this issue.

Secondly, with different definitions of covered equipment, parties who should be responsible for the environment degradation caused by the e-waste problem will also be different. Different types of electrical and electronic equipment come from different sources, with different producers or importers, and hence the parties who should accept the extended producer responsibilities will be very different. Furthermore, with different target markets, different types of electrical and electronic equipment have different consumers, like the public, different organizations, or the government. Therefore, the parties who should be provided with the resources for e-waste recycling and be responsible for the e-waste disposal will also be different.

Thirdly, this diversity will also make the possible solutions to the e-waste problem different. As the volume and composition of e-waste generation change, so do the possible solutions to the problem. Different types of electrical and electronic equipment need completely different methods to encourage the eco-design and to limit the usage of hazardous materials. Furthermore, when they become e-waste, they require different administrative system to be controlled effectively, different collection channels to be collected efficiently, and different technical standards to be disposed of in an environmentally friendly manner. Consequently, different definition of the covered equipment will bring a different solution to its e-waste problem.

Fourthly, the differences in covered equipment influence people's awareness about e-waste. On one hand, this diversity shows how different governments discriminate e-waste. Their approaches of defining what should be considered as e-waste, their idea of distinguishing what is or is not e-waste, and their categories of e-waste, are all different. No equipment in certain conditions can be accepted as universal 'e-waste' by all countries, because they all have their own criteria. On the other hand, this diversity can also create confusion on recognizing e-waste. The public may not be clear about what counts as e-waste in their country.

2.3.2 Identification of Becoming Waste

In addition to terms and approaches to defining the covered equipment, e-waste definitions from different sources also show great variety in their criteria of judging when this covered equipment becomes waste. Different criteria both related and unrelated to the conditions of the covered equipment are applied in decisions that determine when covered equipment becomes waste.

The covered equipment's condition is an important criterion applied by many countries and organizations for determining when the covered equipment becomes waste. Criteria of this type are related to when an item loses the functionality for which it was originally designed. For example, Malaysia defines "used electrical and electronic equipment or components" (Ministry of Natural Resources & Environment of Malaysian, 2010, p.1) that have satisfied a series of function loss criteria, like "(a) [a] defect that materially affects its functionality; (b) [physical] damage that impairs its functionality or safety, as defined in the specification" (Ministry of Natural Resources & Environment of Malaysian, 2010, pp.7-9), as e-waste. These criteria can also be related to whether it is useful. South Korea defines waste as "no longer useful for human life or business activities" (Korean Ministry of Environment, 2007a). These criteria can be related to its market acceptance. In Malaysia, electrical equipment can be decided as e-waste if "there is no regular market for the used electrical and electronic equipment or components" (Ministry of Natural Resources & Environment of Malaysian, 2010, pp.7-9).

In some countries, these criteria may also have no direct relation with the condition of the covered equipment. Most criteria of this kind describe consumers' action. Many countries use 'discard', 'intended to discard', and 'no longer used/wanted/required' as criteria for deciding whether electrical equipment is e-waste. China defines "household appliances, electronic products and their components, parts and consumables which are discarded for losing or lacking use-value and cannot meet the consumers' requirement" as e-waste (Environmental Protection Agency of the People's Republic of China [now the Ministry of Environmental Protection of the People's Republic of China], 2006). The EU defines waste in the term of WEEE as "any substance or object which the holder discards or intends or is required to discard" (Directive 2008/98/EC, 2008, p.9). The Canadian province of Newfoundland and Labrador defines "an electronic product that is no longer used or required by a consumer" as e-waste (Newfoundland and Labrador House of Assembly, 2012). Other criteria, like defining the destination of the covered equipment, are also employed. The Philippines defines "[discarded] electrical and electronic devices, including scrap materials intended for reuse, resale, recycling or disposal" as e-waste (Republic of the Philippines Department of Environment and Natural Resources, 2015, p.3). The American state of New York defines e-waste as "covered electronic equipment ….[that] enters the waste collection, recovery, treatment, processing, or recycling system" (New York State Department of Environmental Conservations, 2010).

As stated above, different criteria are applied in different e-waste definitions to decide whether the covered equipment becomes waste. These criteria relating to the condition, the functionality, or the consumer action add to the great variety of what is considered to be e-waste. The same electronic equipment in a certain condition can be considered as e-waste in one territory, but may not be considered the same in another. With some of these e-waste definitions, the equipment has to have functional deficiencies to be counted as e-waste, while with other definitions, a piece of well-functioning brand-new equipment can be considered as e-waste just because it is discarded by its owners.

The variety highlighted has a number of interrelated effects. Firstly, this diversity can affect the nature of the e-waste problem. In the same territory, even though using the same category of covered equipment, with different criteria of becoming waste, the volume, the composition, and the condition of the e-waste generated can still be very different. For example, a covered device such as a cellphone may not enter a waste stream, but be stored in a user's home. If this happens in New York, the item is covered by e-waste legislation, but is not (yet) e-waste only because of where it sits in the user's home.

Secondly, the diversity in definitions highlighted above shows how different governments act on deciding when the covered equipment becomes waste. Some of these governments have considered the condition of the equipment, and accept it as waste only if it is no longer suitable for use or has lost their function. Others have not considered these conditions directly and believe it becomes waste when it is discarded by the owner or enters the waste disposal processing infrastructure. This difference will influence people's idea of what should be considered as e-waste, and then influence their attitude towards used equipment and how to manage it.

Thirdly, the different criteria, by which equipment becomes e-waste, point to different solutions, especially collection methods and disposal methods. For example, according to different criteria, a unit of electronic and electrical equipment becomes e-waste in different stages of its lifecycle when belonging to different owners, and therefore the possible methods to collect it will be different. Meanwhile, e-waste discarded by its owner, but which does not have any functional problems, might make refurbishment a good solution; while for e-waste with functional problems a solution may be repair—yet in some jurisdictions, like New York, those options would be precluded if the item entered a waste stream. Meanwhile, equipment at its end of service life might best be handled through materials recovery (recycling), waste to energy conversion, or landfill. As these examples suggest, how e-waste is defined plays an important role in what solutions are imagined to be appropriate.

2.4 Conclusion

Based on the collection and the comparison of the information of e-waste definitions from different countries and organizations, this chapter has analyzed the differences among these definitions and their influences. Great differences are found in two aspects of e-waste definitions: 1) definitions of the equipment they cover, and 2) the criteria by which this covered equipment becomes waste.

These differences will influence the nature of the e-waste issue. In two similar territories, if different e-waste definitions with different covered equipment and criteria of becoming waste are applied, the volume and composition of their e-waste generation will be different. This difference can determine whether e-waste generation is deemed to be a problem with potential threats to human health and environment, or just a phenomenon with little effect on a given society. Even if they are all decided as e-waste problems, with different volumes and compositions, their collection methods, disposal methods, potential environmental threats caused by this e-waste generation, and the parties who should be responsible for it also can be all different. That is to say, with different volumes and compositions of the e-waste generation, the appropriate solutions to this problem will vary even when the underlying equipment is identical.

Furthermore, these differences will influence the awareness of the public. Different e-waste definitions will influence the e-waste recognition of people who implement the policy and people who follow these rules, like organizations, corporations and the public. These differences in recognition of e-waste will influence people's awareness of e-waste, and then affect the behaviors of people who produce e-waste.

In conclusion, with different e-waste definitions, the overall nature of an e-waste problem varies even when the underlying equipment is identical. This situation illustrates how e-waste has no natural definition, and the e-waste problem is an indeterminate one (Wynne, 1987). With different definitions, the comparison and communication among different territories about their e-waste volumes, management measures, and disposal methods will be problematic. Without a unified e-waste definition, studies about comparison of e-waste volumes or management systems among different territories are difficult. Moreover, due to wide differences in the meaning of e-waste from one jurisdiction to another, no unified e-waste definition is found to be capable of presenting all the e-waste definitions from all over the world, and no type of e-waste is found to be qualified to represent e-waste as a whole.

CHAPTER 3. THE PATTERN OF THE GLOBAL TRADE OF E-WASTE

3.1 Introduction

This chapter investigates how the pattern of the global trade of e-waste has changed over time. A proxy data method using COMTRADE data (see section1.4.2 above) is chosen to conduct this research. The waste and scrap of primary batteries, electric accumulators, spent primary batteries and spent electric accumulators (WPBs) is chosen as the proxy for e-waste. These data are analyzed from three aspects: 1) the basic characteristics of the international trade of e-waste, 2) the pattern of this trade among different economic zones, and 3) different analytic stories this trade shows when different country classifications for developing and developed countries are used. For the third part, I conduct this analysis in two ways: using Basel Convention categories and using WTO categories. The results of these two categorizations are compared and contrasted. As discussed in detail below, the two categorization schemes result in quite different trends despite using the same underlying COMTRADE data. The implications of these differences are further discussed in Section 3.5 .

3.2 Technical Details about Obtaining and Processing Data

The COMTRADE data category used in this analysis is HS Code 854810. The importation data of this category as reported by countries around the world from 1996 to 2015 was downloaded from the UN COMTRADE Database for further calculation and analysis. China is the one exception to the use of import data. China reported zero importation of the WPBs after 2000, when it completely banned the importation of e-waste. However, other countries have still reported exporting WPBs to China in this same time period (For more details, see Section 4.2.2).

One possible reason for this contradictory data set is that the Chinese government purposely ignored data derived from illegal waste importation to cover its failure on banning e-waste importation. This study will apply importation data reported by the Chinese government from 1996 to 2000. After 2000, the study will rely on export data to China as reported by China's trade partners in the COMTRADE database.

In this thesis, two types of software, Microsoft Excel and MATLAB, are applied as tools to analyze the raw data. These data are calculated and visualized in Microsoft Excel, and are separated into different groups by MATLAB.

3.3 Basic Characteristics of the Global Trade of E-Waste

The international trading of WPBs has two basic characteristics: 1) the total amount of this trade is increasing, and 2) only a small number of trade transactions account for the bulk of total trade. I explore the details of these two general characteristics in the sections that follow.

3.3.1 The Total Trade of WPBs is Increasing

The international trade volume of WPBs has grown remarkably in the last 20 years. If data sets for all years are included, the annual average growth rate is 9.12%. If outlier years are excluded (1996 and 2011), this annual average growth rate is 11.35%. In 2015, the trade of WPBs increased to 1.4 million tonnes, which was 5.7 times the amount reported in 1997. The details of this increase are shown in Figure 3.1.

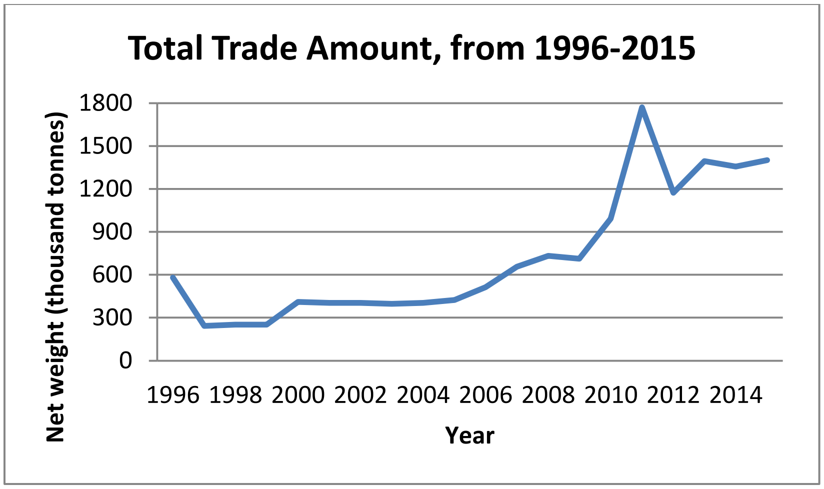

Figure 3.1 Total International Trade Amount of WPBs, from1996-2015
SOURCE: UN COMTRADE database (n.d.), calculations by the author.

3.3.2 A Small Number of Trade Transactions Account for the Bulk of Total Trade

The global trade of e-waste is made up of hundreds of single trades between different partners. However, the summation of only a few such trades accounts for the bulk of the total trade; around 10% of trades transactions account for more than 90% of the total. That is to say, of the 600-800 trades reported every year, around 60 of them account for 90% of the total trade. For example, in 2015, 807 trades were reported, yet only 64 of them account for 90% of the total trade volume. Moreover, the summation of the five biggest trades can account for more than 30% of the total. The share of the five biggest trades ('share' in this chapter means 'share of the total') of this sum rose gradually over the last 15 years. This proportion fluctuated from 1996-1999, and then rose continuously from 29% in 2000 to around 54% in 2015. That a relatively small number of trades account for a large portion of the total trade shows that, for purposes of controlling the international trade of e-waste, methods specifically focusing on larger trades will be more efficient than the ones accepted by every country equally.

3.4 Analysis of the Trade of WPBs among Different Continents

Economic zone is a concept widely applied in international trade research (Grant, 1994). This classification is also useful when analyzing the international trade of e-waste. Lepawsky and McNabb (2010), for example, divided all the countries in the world into continental categories (e.g., Africa, Americas, Asia, etc), with the purpose of analyzing the international trade patterns of e-waste. They showed that most trade occurs within, rather than between, these regions. In this thesis, I use the geographical categories of the World Trade Organization (WTO), which divides the world into seven parts: Africa, Asia-Pacific, Commonwealth of Independent States (CIS), Europe, Middle East, North America, and South and Central America (World Trade Organization, 2015). These classification groups are shown in Figure 3.2, with each area identified using a different color.

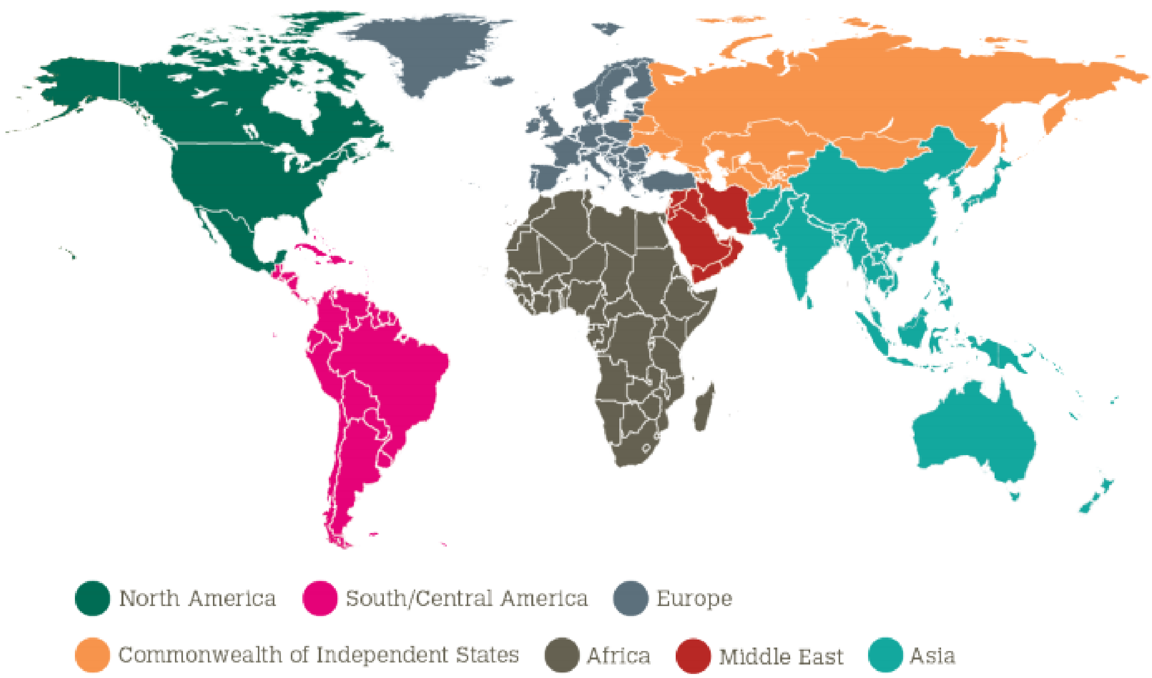

Figure 3.2 World map with different colors represent different classification groups
SOURCE: WTO 2015

Using the WTO classification, I confirmed Lepawsky's and McNabb's (2010) finding that a large amount of the international trades of the WPBs are intra-regional trades. The share of the entire intra-regional trading remained steady at around 80% from 1996 to 2015, with only four years falling below 80%.

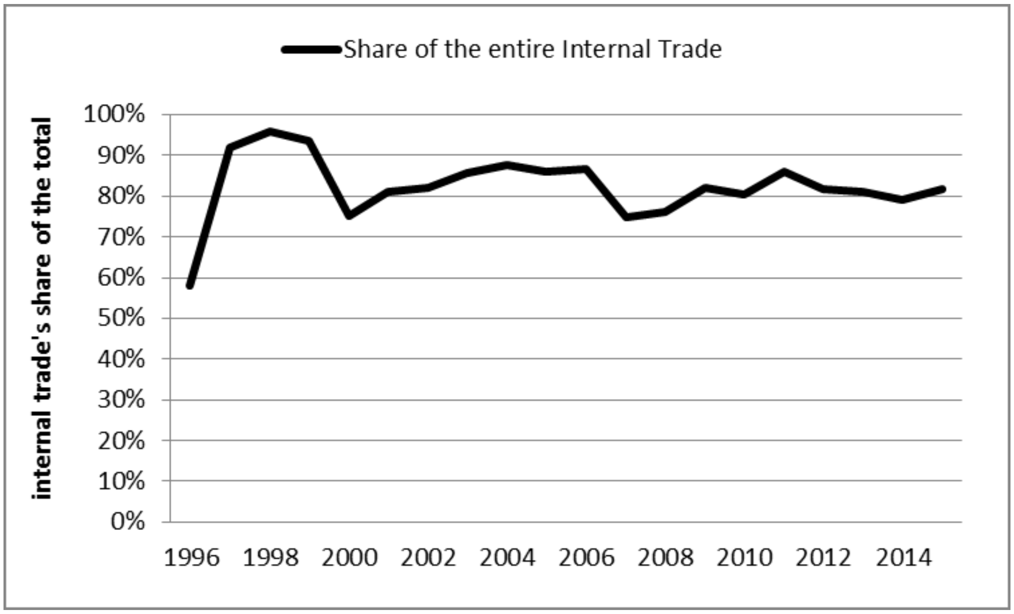

Figure 3.3 The share of the entire intra-regional trade of the total, 1996-2015
SOURCE: UN COMTRADE database (n.d.), calculations by the author

Some regions maintain high percentage of intra-regional trade, such as Asia-Pacific areas, Europe, and North America. These areas maintained a high percentage of intra-regional trade, with an average proportion of 93%, 95% and 83% over these years, during which the averages of the Asia-Pacific and European areas remained stable, while North America fluctuated more frequently. These three areas are the major contributors to this trade, accounting for more than 85% of the total.

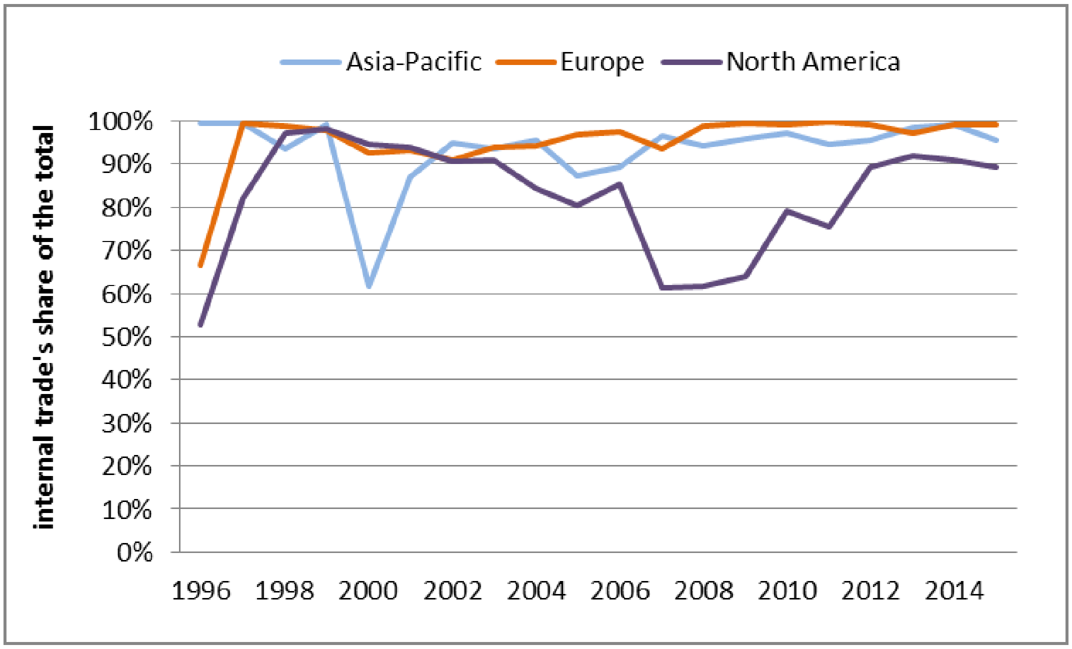

Figure 3.4 The share of the intra-regional trade in Asia-Pacific, Europe and North America, 1996-2015
SOURCE: UN COMTRADE database (n.d.), calculations by the author

Other regions show a shift in trade orientation over time, moving from internal orientation to external orientation. Both South/Central America and CIS experienced a reduction in intra-regional trade share since 2000. The percentage of intra-regional trade in South/Central America decreased continuously from more than 90% in 2000 to around 3% in 2015. While the proportion of intra-regional trade in CIS decreased from more than 90% in 2000 to 9% in 2010, and then increased to around 30% in 2015. Africa and the Middle East mainly trade WPBs with other regions and their average share of intra-regional trading is only 5% and 8%, respectively. Africa, South/Central America, CIS and the Middle East take a relatively small portion of the entire international trade of the WPBs. In most of the years from 1996 to 2015, the share of these four areas was less than 15%.

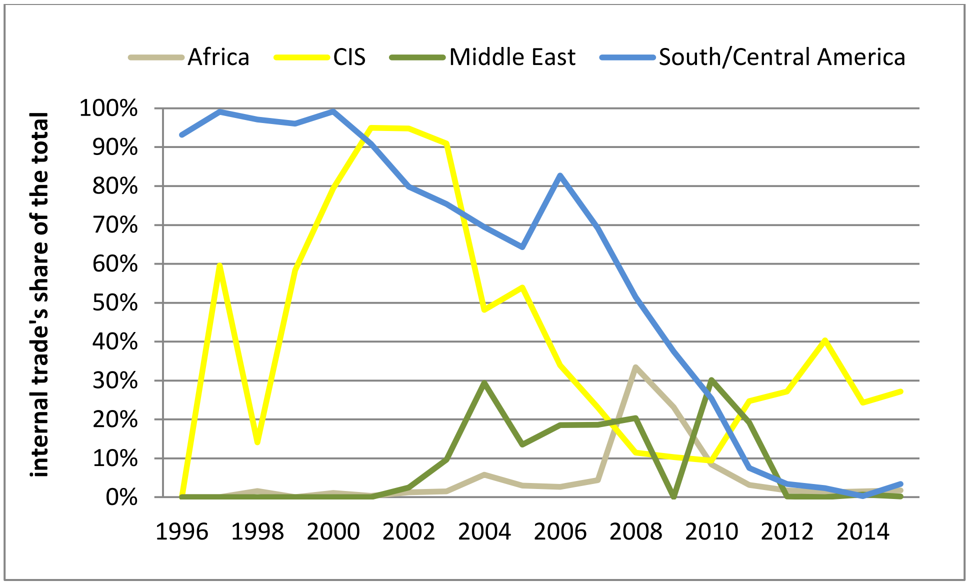

Figure 3.5 The share of the intra-regional trade in Africa, CIS, Middle East and South/Central America, 1996-2015
SOURCE: UN COMTRADE database (n.d.), calculations by the author

What these broad patterns of trade show is that some regions remain internally oriented over time, while other regions have become increasingly externally oriented. The organization of these trade patterns suggests that, for some regions, such as the Europe, North America and the Asia-Pacific area, policies concentrating on intra-regional transboundary movements of e-waste will be more effective. For other regions, such as Africa, CIS, Middle East, and South/Central America, policies concerning inter-regional transboundary movements may be more appropriate.

3.5 Comparison after Dividing all the Countries into Two Economic Groups

Using the same underlying COMTRADE data, this section will explore what happens when two different, but valid categories of countries are used in analyzing the international trade of e-waste. These two different classification criteria are designed to divide all the countries in the world into developed and developing countries.

One criterion is the Basel Convention's Annex VII and non-Annex VII countries, in which Annex VII countries stand for developed countries, and non-Annex VII countries stand for developing countries. The Basel Convention is one of the most influential international trade agreements focusing on preventing cross-border movement of hazardous waste (Basel Convention, 2016). This dividing criterion is from its Ban Amendment "by the third meeting of the Conference of the Parties in 1995 in its Decision III/1" (Basel Convention, 2016), which is still waiting to be ratified. If this Ban Amendment is ratified, under the Basel Convention system, "[each] party listed in Annex VII shall prohibit all transboundary movements of hazardous wastes to states not listed in Annex VII" (Basel Convention, 2017, p.14). This criterion is chosen because as one type of hazardous waste, the WPBs' international trade is mainly constrained by the Basel Convention, and will be significantly influenced by it if the Ban Amendment is ratified.

The other criterion is from the WTO, which is used to divide different countries into developed countries and developing ones. WTO uses the categories 'developed' and 'developing' countries, but provides no definition of this classification. Instead, members of WTO self-declare which group they belong to. In the WTO, the developing country status brings certain rights in the process of trading, such as technical assistance (WTO, n.d.b). The WTO standard is chosen because the WTO has 164 members as of 29 July 2016 (WTO, n.d.a). As such its classification criterion as well as WTO's published reports based on it will have great influence among its members in the field of international trading.

Both of these categories use developing countries and developed countries, but the countries classified are different. In the Basel scheme, the list is defined by an annex called Annex VII, which classifies developed countries as the OECD, the European Union (EU) and Liechtenstein (Basel Convention, 2017), and developing countries as other territories. In the WTO scheme, the developed economies include North America (except Mexico), the EU, the European Free Trade Association (EFTA, includes Iceland, Liechtenstein, Norway, and Switzerland), Australia, Japan and New Zealand, and developing economies refers to Africa, South and Central America and the Caribbean, Mexico, Europe (except the EU and EFTA), the Middle East and Asia (except Australia, Japan, and New Zealand) (World Trade Organization, 2015).

After dividing the countries in the world into two economic groups with these criteria, I re-examine patterns of interregional and intraregional trade by comparing and contrasting results obtained when Basel Convention Annex VII country classifications are used versus when WTO country classifications are used. As previewed in the introduction, the results from these two categories show different characteristics.

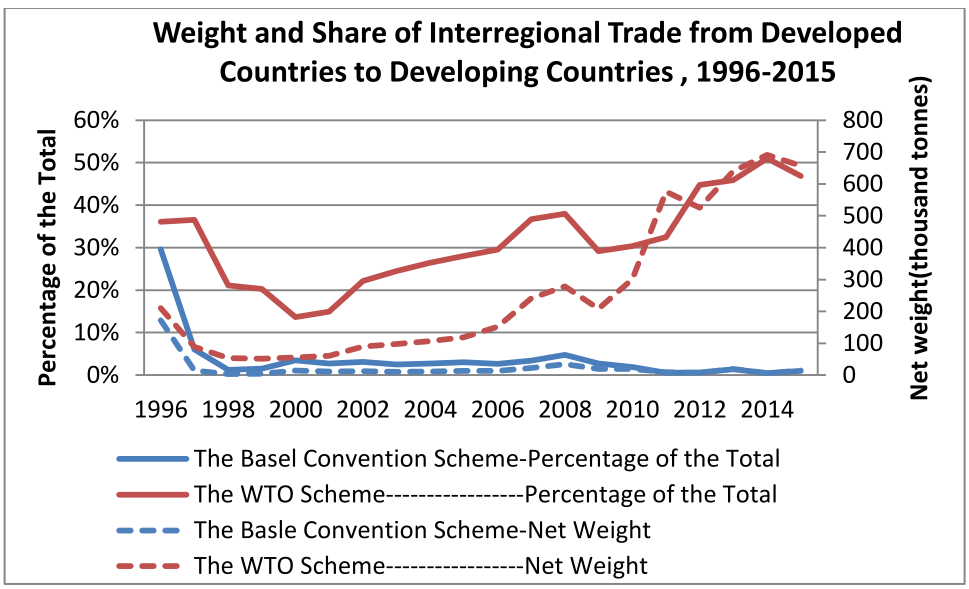

Figure 3.6 Comparison of Results from the Basel Convention Scheme and the WTO Scheme: Weight and Share of Interregional Trade from Developed Countries to Developing Countries, 1996-2015

SOURCE: UN COMTRADE database (n.d.), calculations by the author.

It is important to note, as shown in Figure 3.6, the interregional trade of WPBs from developed countries to developing countries show opposite trends when different classification criteria are used. Under the Basel Convention scheme, the trade from developed countries to developing countries stayed below 20,000 tonnes except for the year of 1996 and 2008. The majority stayed around 4% of total trade with a slight downward trend to 1% in 2015. In contrast, under the WTO Scheme, the WPBs are increasingly flowing from developed countries to developing ones. Under the WTO scheme, the share of the trade from developed countries to the developing ones increased from 20% in 2000 to around 50% in 2015, when the net weight was around 700,000 tonnes. These opposite trends tell us different stories. If we consider the transfer of WPBs from developed countries to developing ones as a problem, under the Basel Convention categorization scheme the problem is small or non-existent, while under the WTO categorization scheme the problem is large and growing.

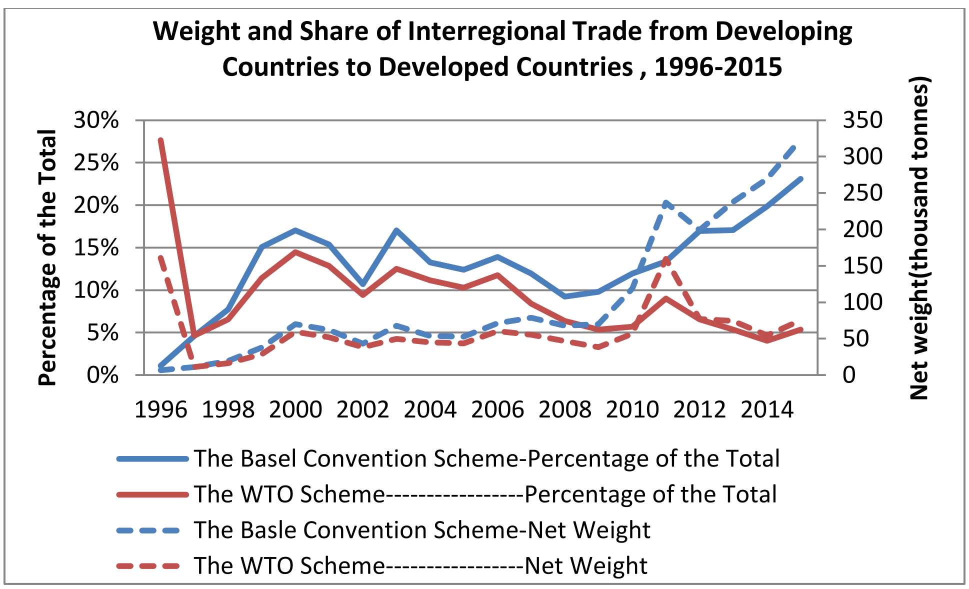

Figure 3.7 Comparison of Results from the Basel Convention Scheme and the WTO Scheme: Weight and Share of Interregional Trade from Developing Countries to Developed Countries, 1996-2015

SOURCE: UN COMTRADE database (n.d.), calculations by the author.

The interregional trade of the WPBs from developing countries to developed countries also shows opposite trends with these two classifications criteria. When using the Basel Convention criteria, both the weight and the share of the trade from developing countries to developed countries increased from 1996 to 2015. In 2015, this type of trade took 23% of the total, with a trading volume of 323,000 tonnes. When using the WTO criteria, the share of the trade of WPBs from developed countries to developing countries gradually reduced from 14% in 2000 to around 5% in 2015, when the net weight was 75,000 tonnes. Different stories are also shown in these opposite trends. Under the Basel Convention categorization scheme the volume of the trade from developing countries to developed countries was growing fast and had created a new phenomenon attracting attention from academia (Lepawsky, 2014), while under the other categorization scheme, the volume of the trade from developing countries to developed countries was small and decreasing.

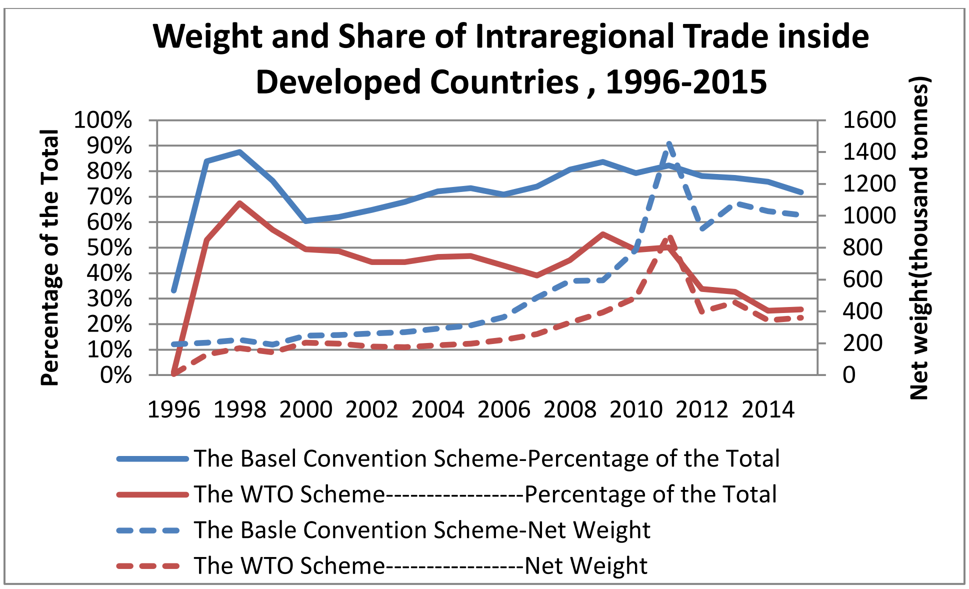

Figure 3.8 Comparison of Results from the Basel Convention Scheme and the WTO Scheme: Weight and Share of Intraregional Trade inside Developed Countries, 1996-2015
SOURCE: UN COMTRADE database (n.d.), calculations by the author.

The intraregional trade of the WPBs between developed countries also shows different features using different country classification criteria. Under the Basel Convention's dividing criterion, the intraregional trade of the WPBs between developed countries accounted for a large part of the total. From 2000 to 2015, this type of trade comprised more than 60% of total trade. In 2015, 72% of the trade is between developed countries. The net weight of this merchandise trading increased continuously from 193,000 tonnes in 1996 to 1,005,000 tonnes in 2015. Under the WTO's dividing criterion, the volume of WPBs flowing among developed countries takes a relatively small proportion and is decreasing. The share of this trade decreased from 67% in 1998 to around 25% in 2015. These opposite trends show different stories. Under the Basel Convention scheme, the international trade of the WPBs mostly occurs between developed countries, while under the WTO scheme this type of trading only takes a small proportion of the whole.

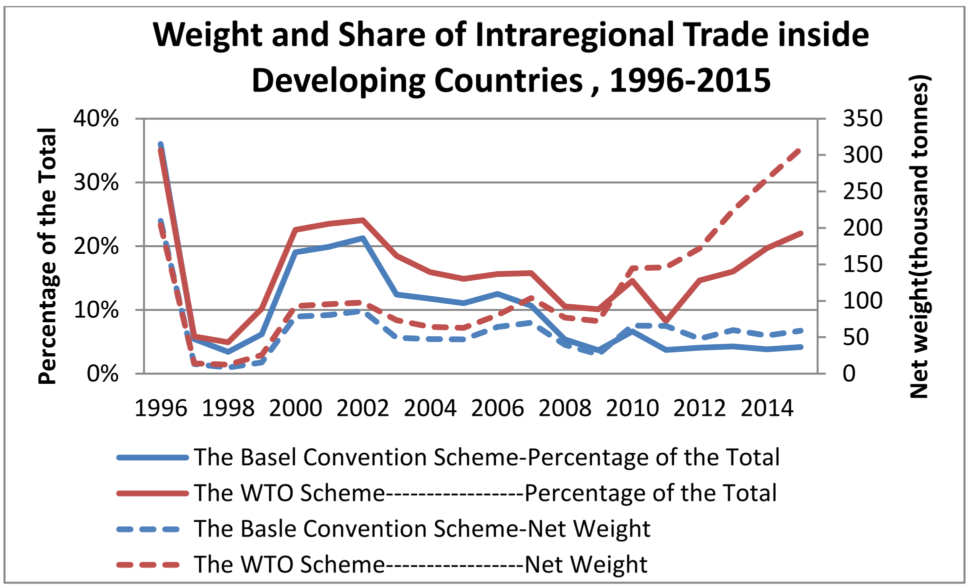

Figure 3.9 Comparison of Results from the Basel Convention Scheme and the WTO Scheme: Weight and Share of Intraregional Trade inside Developing Countries, 1996-2015
SOURCE: UN COMTRADE database (n.d.), calculations by the author.

The intraregional trade of the WPBs among developing countries also shows different characteristics under the different country classification criteria. Under the Basel Convention scheme, this type of trade makes up a very small proportion of total trade. The share of this trade greatly decreased from around 20% in 2000 to 4% in 2015, and its merchandise weight stayed around 50,000 tonnes with a slightly decreasing trend from 1996 to 2015. Under the WTO scheme, this type of trade takes a significant proportion of total trade and increased very fast in recent years. The share of this trade decreased with fluctuations from around 20% in 2000 to 10% in 2010 and then increased steadily to around 20% again in 2015. These opposite trends give us two different imaginations of the intraregional trade among developing countries. Under the Basel Convention scheme, this type of trade is almost invisible, but under the WTO scheme this type of trade is an important part of the whole story. It takes a bigger proportion than the trade from developing countries to developed countries.

After dividing all the countries into developing countries and developed countries with the two different classification criteria, two different stories about WPBs trading emerge. In one story, under the Basel Convention categorization scheme, developed countries are the main waste accepter as well as exporter in the international trade of the WPBs, whereas developing countries have been the recipients of only minor amounts of WPBs since 1996. From 1996 to 2015, more than 60% of the WPBs were traded between developed countries, classified according to the Basel scheme (in some years, like 2009, this percentage can be as high as 83%). Another 10 to 20 percent of trade flows to developed countries from developing countries under the Basel Convention scheme. In the other story, under the WTO classification standard, developed countries mostly act as the exporter and developing countries play the role of waste receiver. From 1996 to 2015, around 75% (its smallest value is 63% in 1997 and its biggest value is 90% in 2000) of the WPBs are exported by the developed countries. Meanwhile, developing countries accepted increasingly more WPBs from the developed countries. In 2012, developing countries surpassed developed countries as the main recipients of the international trade of WPBs. In 2015, 47% of the international trading of the WPBs was flowing from developed countries to developing ones.

The contrast of these two stories is interesting: on one hand, the Basel Convention is assumed to control the transfer of e-waste from the developed countries to the developing ones, but its categories show that such transfer amount to very small portions of overall trade. On the other hand, classifying countries as 'developed' or 'developing' using the WTO scheme tells the opposite story, yet the WTO framework, unlike the Basel Convention, is not about regulating transboundary hazardous waste flows.

Neither of these two data stories is right or wrong. They both describe a correct version of the international trade in e-waste and lead to opposite conclusions about the patterns of that trade. Yet, there is no non-arbitrary way to favour one country classification scheme over the other. The choice of this important system is arbitrary, and will have a very strong effect on what idea we have about the geographic characteristics of the international trade in e-waste. With different categorization, the economic group who take the responsibility of e-waste exportation, the economic group who suffer from the international transboundary movement of e-waste and the method that is efficient for controlling this trade are all different. That is to say, not only the category of the e-waste (more details, see Section 2.3.2) but also the categorization of the countries generate different analytical stories about the international trade of e-waste.

The importance of these findings in which different results can be obtained using the same data set but different country classifications, point to a broader problem than the specifics of either the WTO or the Basel Convention. It means the international trade of e-waste is a fundamentally indeterminate problem (more generally, see Wynne, 1987). It is because this indeterminate feature that there will be no non-arbitrary way to approach the international trade of e-waste as a research or policy problem, and that this trading will be poorly suited for standard method of risk analysis.

3.6 Conclusion

Based on the analysis focusing on the basic characteristics of the international trade of e-waste, the pattern of this trade among different economic zones, and the pattern of this trade between developing and developed countries, the following conclusions can be drawn:

The total international trade volume of at least certain types of e-waste has grown remarkably in the last 20 years. Among the important findings of this chapter is that a few large trades of WPBs account for the bulk of total such trade. Furthermore, if all the countries in the world are divided into seven parts according to their geographic locations, we can find that, in most years, more than 80% of the international trade of the WPBs was intra-regional trade. The major contributors of this trade are Asia-Pacific areas, Europe, and North America. These areas maintained a high proportion of intra-regional trade. Other regions, namely Africa, CIS, Middle East, and South/Central America, show a shift in trade orientation over time from internal orientation to external orientation.

Two different category schemes are applied to divide countries all over the world into developing countries and developed ones. One criterion is from the Basel Convention and the other is from the WTO. Different results can be obtained using the same data set but with these two different country classification systems. Under the Basel Convention categorization scheme, WPBs are mostly traded between developed countries, the amount of the transfer of e-waste from developed countries to developing countries is very small, and the trading from developing countries to developed countries is thriving as a new phenomenon. Under the WTO classification standard, the amount of the transfer of e-waste from developed countries to developing countries is big and growing. These findings point to a broader problem than the specifics of either the Basel Convention or the WTO. It means not only the category of the e-waste but also the category of the countries make the international trade of e-waste a fundamentally indeterminate problem (more generally, see Wynne, 1987).

CHAPTER 4. CHINA'S E-WASTE PROBLEMS AND SOLUTIONS

4.1 Introduction

China plays a significant role in the international trade of waste as one of the largest recipient of exports from elsewhere. Its importance to the global organization of the waste management industry is highlighted by the recent announcement that China is filing with the World Trade Organization to ban the importation of some kinds of wastes, including various types of scrap metals and plastics by the end of 2017 (Staub, 2017). This action elicited different responses from trade interests. For example, the Institute of Scrap Recycling Industries marked this ban policy as having a "devastating impact" on "recycling on a global scale and in the U.S" (Staub, 2017). This policy will even "shape" the global metals markets (Paben, 2017). China's special status draws my attention to e-waste as a problem for the country.

This chapter will analyze China's e-waste problem and explore possible solutions. The first part of this chapter will analyze the volume of China's e-waste. This volume will be analyzed from two aspects: domestic generation and illegal importation. The general idea of the volume of China's domestic e-waste is obtained both from the published data of China's federal government reports and the estimated data from different researchers. The volume of e-waste imported by China is difficult to determine, but evidence for these imports can be found in three sources: COMTRADE data, research reports, and news articles. Drawing on these sources, the first part of the chapter provides a simple comparison of the volumes of e-waste that comes from domestic generation (i.e., from within China) versus that which is imported from abroad. The second part of this chapter will analyze legislation focusing on China's e-waste problem. This section will analyze these legislative control documents from three aspects: the ones focusing on China's domestic e-waste, the ones concentrating on banning the importation of e-waste, and the ones concerning e-waste already smuggled into China.

4.2 China's E-waste Problems

China's e-waste comes from two sources: domestic generation and importation. These two sources will both be analyzed in this section. To quantify the domestic generation of e-waste in China, data are available from China's government reports and academic research for wasted TVs, refrigerators, washing machines, air conditioners, and microcomputers (TRWACs). These five types of e-waste are chosen because they are the main regulatory objectives of China's e-waste policies. The COMTRADE data are available for WPBs and I use these data to approximate illegal importation in China. The COMTRADE data have limitations that I discussed in Section 1.4.2.

4.2.1 China's Domestic E-waste Generation

There are two approaches to get a general idea of the volume of China's domestically generated e-waste. The first one is the published data from China's federal government reports about the volume of different types of abandoned electrical and electronic products.[1] The data from this source are official data from the government. The second one is the estimated data from different researchers, which is also widely available. The data from these two approaches are sometimes different, and hence both of them are analyzed.

[1] The term "abandoned electrical and electronic products" is translated from China's report. In the following contents, terms like "electrical and electronic products", and "electronic products" are also used as translation from China's legal documents.

4.2.1.1 The Volume of E-waste According to China's Government Reports

Different departments of the Chinese government, like the National Development and Reform Commission and the Ministry of Commerce, publish reports about China's resource utilization and renewable resources recycling. Some of these reports include a section about e-waste, and provide data about the generation and disposal of China's domestic e-waste. Even though these data are not data from the statistical year books, they do represent official data from the Chinese government. A collection of these data about the volume of five different types of abandoned electrical and electronic products is shown in Table 4.1.

Two general conclusions can be derived from these data: 1) the volume of China's domestic e-waste generation is large. In 2010, even though the number of China's abandoned TVs and microcomputers per person are both only around 1/5 of the American value, the total volume of the abandoned TVs and microcomputers are both equal to the American value. In this year, China abandoned 24.6 million units of TVs (National development and reform Commission of the People's Republic of China, 2014), which is only slightly smaller than America's 28 million units (United States Environmental Protection Agency, 2011). In the same year, China abandoned 55.4 million microcomputers (National development and reform Commission of the People's Republic of China, 2014), which is even bigger than America's 51.9 million units. 2) This large volume of domestically generated e-waste in China is growing at a rate of 4% annually.

Table 4.1 The Volume of Five Types of Abandoned Electrical and Electronic Products, 2010-2015 (Million Units)

Year	TVs	Refrigerators	Washing Machines	Air Conditioners	Microcomputers	Summation
2010	24.6	11.0	15.1	17.2	55.4	123.2
2011	53.6	12.8	16.5	19.5	58.2	160.6
2012	18.5	9.3	10.6	17.8	26.5	82.6
2013	38.5	12.8	12.7	18.3	32.1	114.3
2014	58.6	13.3	14.2	19.6	30.1	135.8

2015	58.5	17.1	15.5	24.3	37.4	152.7

SOURCE: Annual report of comprehensive Utilization of Resources in China (2012); Annual report of comprehensive Utilization of Resources in China (2014); China's Renewable Resources Recycling Industry Development Report (2015); China's Renewable Resources Recycling Industry Development Report (2016). Calculation by the author.

4.2.1.2 Estimating the Volume of E-waste from the Research of the China Household Electrical Appliances Research Institute

Many studies have focused on estimating China's e-waste generation. One of the most influential one comes from the Chinese Household Electrical Appliances Research Institute (CHEARI). This institute is China's only national-level research-based institute focusing on household appliances (Chinese Household Electrical Appliances Research Institute, n.d.). CHEARI's Electrical Appliance Recycling Technology Center has conducted studies about the policies, regulations, technologies and standards related to e-waste since 1998 (Electrical Appliance Recycling Technology Center, n.d.).

Table 4.2 The Volume of Five Types of Abandoned Electrical and Electronic Products Estimated by the White Paper, 2009-2015. (Million Units)

	TVs	Refrigerators	Washing Machines	Air Conditioners	Microcomputers	Summation
2009	22	5.5	9.8	1	13.3	51.5
2010	23.8	6.5	10.5	1.2	16.5	58.5
2011	25.5	7.4	11.3	1.0	21.5	66.7
2012	27.7	8.7	12.6	1.5	25.3	75.9
2013	32.0	12.8	12.6	15.3	37.1	109.8
2014	30.5	14.7	14.2	20.3	34.1	113.8
2015	30.2	17.1	15.5	24.3	37.4	124.4
2016	30.6	21.4	14.7	23.6	21.8	112.1

SOURCE: CHEARI, 2016,2017

The results of the estimation from CHEARI research are shown in Table 4.2. Two similar conclusions can also be drawn in this estimation: 1) Even though the estimated volume in this estimation is slightly smaller than the data from the Chinese government's reports, the value is still large; and 2) Their value increased almost every year from 2009 to 2015, with an average growth rate is 15.8%, much bigger than the same rate calculated from the data in Section 4.2.1.1.

From the analysis above about the volume of China's e-waste generation, two conclusions can be drawn: 1) China's e-waste volume is large; and 2) It has kept increasing recently, and so may continue to increase in the near future. Moreover, the data collected above provide upper and lower range estimates of the amount of e-waste domestically generated in China which will be used to compare with the volume of e-waste that was illegally imported into China in Section 4.2.2.

4.2.2 E-waste Imported by China

In China, the importation of most types of e-waste is forbidden since 2000 (Environmental Protection Agency of China et al., 2000), and the importation of HS 854810 (WPBs, more details see Section 3.2 is banned since 2008 (Environmental Protection Agency of China et al., 2008). However, the formulation of these policies pertaining to e-waste does not mean that China's imported e-waste problem has been solved. Actually, multiple sources of evidence, from COMTRADE data, to research reports and news articles, show that China's importation of e-waste has never stopped, despite these trade bans.

One piece of evidence of the existence of China's e-waste importation problem is that the exportation of e-waste targeting China is reported by different countries every year. From 1996 to 2016, the international trading data of WPBs from the COMTRADE database shows that the exportation of the WPBs targeting China has never stopped. Even though this trading is illegal in China after 2000, and not reported by the Chinese government in the COMTRADE database since then, it is reported by more than ten of China's partner countries every year from 1996 to 2016. The volume of this export trade to China averages 5900 tonnes per year during this period, and reached its peak value of 21000 tonnes in 2007 (UN COMTRADE database, n.d.). These data are relatively small compared to China's domestic e-waste generation, but the COMTRADE data account for only a narrow range of e-waste types. This illegal importation accounts for a very small proportion of the total. However, if other sources of data for e-waste are considered, the volume of this problem is more significant.

Evidence of illegal imports of e-waste can also be found in a variety of different research reports. The Beijing Zhongse Institute of Secondary Metals estimated that, through Yangtze River Delta alone, around 700,000 tonnes of e-waste were imported to China in 2001 (Liu, Tanaka, and Matsui, 2006a). More recently, the Basel Action Network tracked the transfer of 205 used electronic devices, and found that 23.4% of the total ended in China: 37 of them ended in Hong Kong China, and 11 of them ended in Mainland China (BAN, 2016).

Different news about e-waste smuggled into China also provides evidence of this trade. In 2014, the Guangzhou Customs Anti-Smuggling Bureau found that criminals smuggled e-waste from Hong Kong to Guangdong province with a new route, and intercepted e-waste amounting to more than 72,000 tonnes (Gao, 2014). In 2017, Chinese Customs found 42 tonnes of e-waste hidden in ordinary storage containers (Cui, 2017).

The above evidence can show that even though the importation of e-waste was forbidden since 2000, a considerable amount of e-waste still flows into China every year. In the meantime, it is hard to determine the precise volume of this illegal trading from the existing materials. However, the sources discussed above provide data that can be used to generally estimate the e-waste imported by China. In the next section I will compare the estimates of domestic generation of e-waste in China with the estimates of illegal importation of e-waste into the country.

4.2.3 A Simple Comparison of the Volume of China's Domestic E-waste Generation and Illegal Importation

Based on the data and research results collected by this section (for more details, see Section 4.2.1 and Section 4.2.2), it is difficult to make an accurate comparison of the volume of China's domestic e-waste generation and its illegal e-waste importation for the following two reasons: 1) the proxy chosen for analyzing China's domestic e-waste generation is wasted TVs, refrigerators, washing machines, air conditioners, and microcomputers, while no international trading data related to these five types of e-waste can be found; and 2) The proxy chosen for investigating China's illegal imported e-waste is WPBs, while no data about Chinese domestically generated WPBs can be found either.

However, with several assumptions, a very rough and simple comparison can still be shown. For the domestic e-waste, the upper and lower range provided from Section 4.2.1 is applied. Two assumptions are made: 1) the weight of five types of e-waste, namely wasted TVs, refrigerators, washing machines, air conditioners, and microcomputers are assumed to be 25, 45, 30, 40 and 15 kg/unit, respectively. TVs are assumed to be 25 kg/unit because both LCD TVs and CRT TVs are included. Microcomputers are assumed to be 15 kg/unit because both laptops and desktops are included; and 2) The summary of the volume of these five types of e-waste covered 70% of the total amount of China's domestic e-waste (for more details about the category of China's e-waste, see Appendix I). The upper and lower range of the amount of domestically generated e-waste is shown in Figure 4.1. Over the five years between 2010 and 2015, a minimum total of 20 million tonnes and a maximum total of 29 million tonnes of e-waste was generated domestically in China.

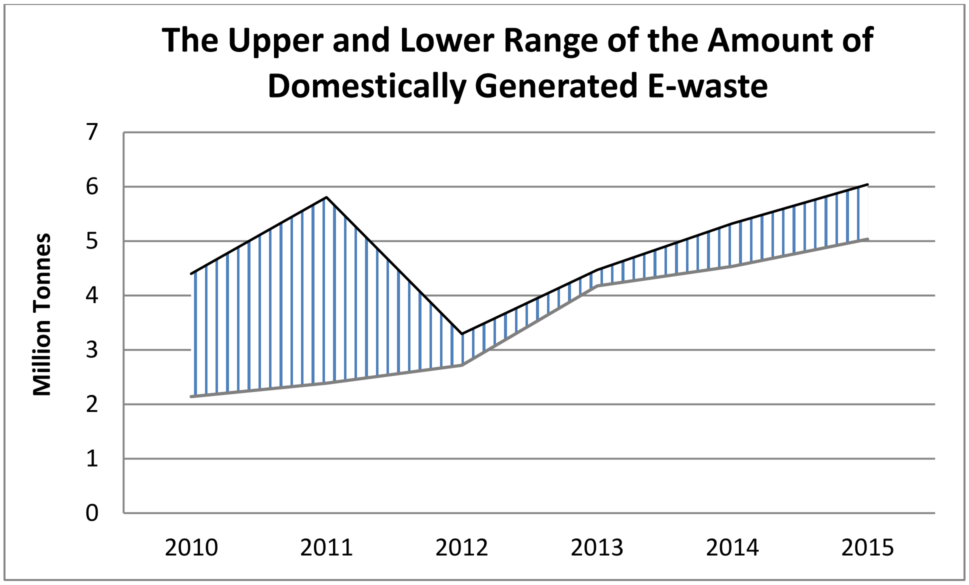

Figure 4.1 The upper and lower range of the amount of domestically generated e-waste, from 2010 to 2015[2]

The COMTRADE data show that, from 2010 to 2015, the total amount of China's WPBs importation is 19,000 tonnes. The real amount of the illegal e-waste importation of China may be much bigger than this number for two main reasons. First, the COMTRADE data only catch a narrow range of primary batteries and other electric accumulators (e.g., capacitors), and do not include most heavy types of e-waste. A large amount of China's illegally imported e-waste is wasted TVs, microcomputers, printers, and others (e.g. the Basel Action Network tracked 48 used electronic devices transferring from the U.S to China, 19 are printers, 3 are CRT monitors and 26 are LCD monitors; see BAN, 2016.). It is very likely that the primary batteries and electric accumulators are lighter than other types of e-waste. For example, a printer is normally around 10 kilograms. A game console battery can be around 100 grams, and other types of batteries like phone batteries are even lighter. A printer can be 100 times heavier than a game console battery. Even though the percentage of WPBs making up China's total e-waste importation

[2] The change between 2011 and 2012 was most likely a reflection of how data are collected as a consequence of policy changes as opposed to changes in the actual volume of e-waste being generated.

is unknown, considering that WPBs are only one type of e-waste among more than one hundred others, and that they are very light compared to other types of e-waste, it is reasonable to assume that the share of that trade represented by WPBs is very low.

Second, if only the trade of WPBs is considered, it is still very possible that the volume of this trading is underestimated. The COMTRADE data set misses all unreported trade. If illegal trade is a big problem for the government, it is very likely that a large amount of illegal trade is not reported. The true amount of China's importation of WPBs could be much higher than the data provided by this database, though this point is tempered by the fact that the COMTRADE data do show trade to China after 2000, which means at least some illegal trade is captured by these data. It remains reasonable to estimate that the true volume of WPBs imported by China is much larger than the data recorded by the COMTRADE database.

With the data limitations discussed above, I cannot judge for certain which source, domestic or imported, contributed larger amount of e-waste to China. It is very possible that the volume of the domestic e-waste is bigger than the volume of imported e-waste, while it is also reasonable that the volume of imported e-waste is larger than the domestic generation. However, with the data limitations I can still draw the conclusion that both the volumes of domestic e-waste and imported e-waste are big, and thus neither of them are problems which should be ignored by policy makers.

4.3 Legislative Control Concerning E-waste Problems in China

In response to its e-waste problems, China has promulgated many pieces of legislation. These legislative documents are focused on two different objects: domestically generated e-waste and imported e-waste. That is to say, China's e-waste legislation can be analyzed from three aspects: 1) legislation concerning the domestic e-waste problem, 2) legislation focusing on banning the importation of e-waste, and 3) policy responses concentrating on e-waste already smuggled into China. In this section, only the federal policy will be analyzed.

4.3.1 China's Legislation System Concerning Domestic E-waste Problem

To address its e-waste problem, the Chinese government has built an e-waste regulation system. As shown in Figure 4.2, this system is supported by different types of technical policies, administration measures, regulations, and other documents. Nearly every stage of the life cycle of e-waste, namely production & importation, consumption, collection, transportation and disposal, is regulated. In this system, different features are highlighted. They include:

1) Catalog. The catalog of e-waste that should be regulated by this system, as well as the name and code applied to the imported electrical and electronic products (General Administration of Customs of the People's Republic of China, 2012; National Development and Reform Commission of the People's Republic of China et al., 2015).
2) Multiple-channel Collection. The application of a multiple-channel collection system is encouraged to meet requirements from government agencies, organizations and households in the process of e-waste collection (Environmental Protection Agency of the People's Republic of China, 2006). Furthermore, rules for trading used electric products, and for packaging and storing e-waste to avoid the possible release of hazardous materials into the environment are also provided (Environmental Protection Agency of the People's Republic of China, 2006; Ministry of Commerce of the People's Republic of China, 2013).
3) Centralized Disposal. According to China's legislation, e-waste should be collected and disposed of by licensed companies with large disposal capacities. Many Chinese National Standards are issued to guide the disposal processes of these companies to make sure that their activities meet China's environmental standards. For example, there are requirements

provided by the Chinese National Standards for disposing of different types of e-waste, like desktop microcomputers, portable microcomputers, printers, copiers, plasma TVs, LCD TVs, and CRT TVs (China household electrical appliances research institute, 2016).

4) Planning. All the Chinese provincial level governments are required to develop plans for the e-waste disposal industry to supervise and support its development and prevent the potential environmental degradation it may cause (Ministry of Environmental Protection of the People's Republic of China, 2010e).

5) Licensing. E-waste disposal companies have to get a license to engage in the e-waste disposal industry. To get this license, a company should have several qualifications: 1) proper e-waste disposal workshops, storage sites, disassembling equipment, supporting information management system, and pollution control facilities; 2) equipment suitable for e-waste disposal: sorting and packing equipment, transport vehicles, handling equipment, compression packing equipment, special containers, central monitoring equipment, metering equipment, emergency response equipment, and other related equipment; 3) an environmental management system, including an alternate plan for e-waste that cannot be disposed of, along with another plan for environmental incidents; and 4) professional and technical personnel focusing on environmental quality, safety, and protection (Ministry of Environmental Protection of the People's Republic of China, 2010c).

6) Subsidy System. This subsidy system is based on the e-waste processing fund. This fund is collected from the producers and importers of new electrical and electronic products by the State Administration of Taxation of the People's Republic of China (State Administration of Taxation of the People's Republic of China, 2012). Moreover it is required to be used for 1) subsidizing the cost of disposing of e-waste, 2) building an information system

for e-waste collection and disposal, and 3) running this fund (State Administration of Taxation of the People's Republic of China, 2012).

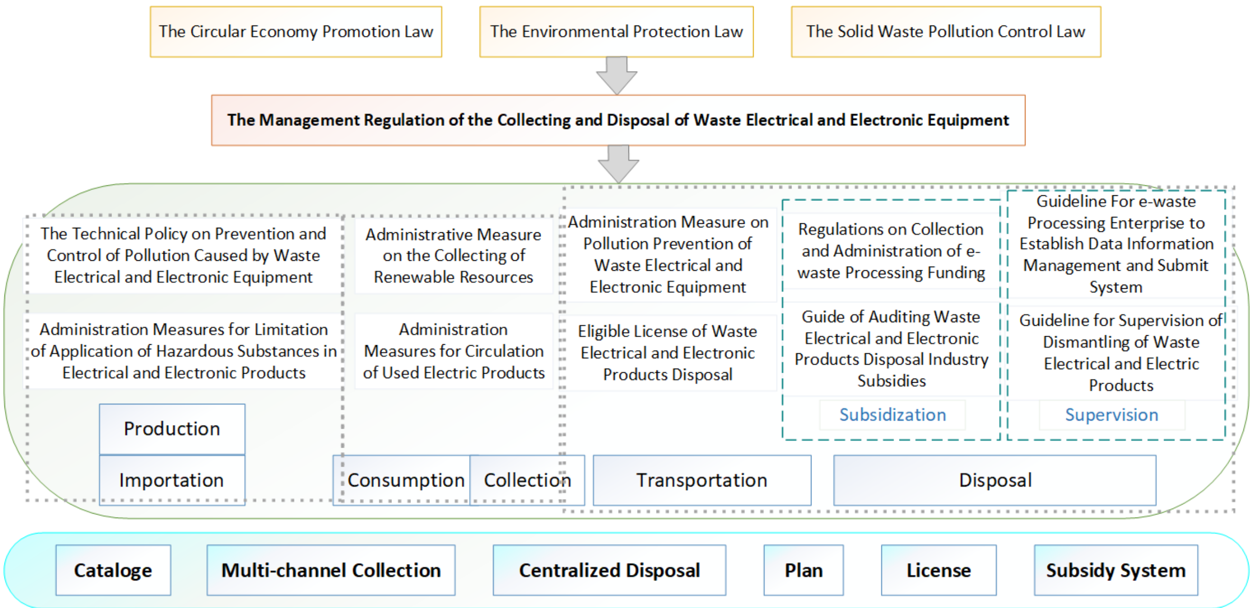

Figure 4.2 The System of China's E-waste Disposal Policies (Solid Waste Management Centre of Ministry of Environmental Protection of the People's Republic of China, 2013)

All licensed e-waste disposal companies have to establish an e-waste information collecting and submitting system to collect and report information about the collection, storage, disposal and environmental impact information of different types of e-waste (Ministry of Environmental Protection of the People's Republic of China, 2010a). On the other hand, the government is required to supervise the behavior of the e-waste disposal companies. The provincial level environmental protection departments are required to evaluate the companies' qualification, issue the e-waste disposal licenses to them (Ministry of Environmental Protection of the People's Republic of China, 2010c), and supervise their daily activities (Ministry of Environmental Protection of the People's Republic of China, 2015b). China's federal level environmental protection department and the provincial environmental protection departments are both required to audit the e-waste process fund to prevent fraud and false accounting (Ministry of Environmental Protection of the People's Republic of China, 2010d).

Under this e-waste disposal policy system, as of 2017, China has 109 licensed e-waste disposal companies (E-waste Disposal Information System of China, n.d.), whose disposal capacity is big enough to dispose of China's domestic e-waste formally. From 2013 to 2015, only five types of e-waste were regulated by the government, namely TVs, washing machines, refrigerators, microcomputers, and air conditioners. In 2013, 2014 and 2015, the disposal capacity of the formal disposal industry was 111.9, 133.5 and 140 million units, respectively (Ministry of Environmental Protection of the People's Republic of China, 2014; 2015a; 2016), while the e-waste generation was 114.3, 135.8 and 152.7 million units, respectively (Ministry of Commerce of the People's Republic of China, 2015; 2016). Therefore, if all the domestic e-waste was collected, 98%, 98% and 92% percent of the domestic e-waste could be disposed by government accepted methods in these three years, respectively.

In reality, this disposal capacity is not being fully utilized. In 2013, 2014 and 2015, 41.4, 70.4 and 76.2 million units of domestic e-waste are disposed of formally, respectively (Ministry of Environmental Protection of the People's Republic of China, 2014; 2015a; 2016), which only amount to 37%, 52.7% and 54.5% of China's formal e-waste disposal capacity in each year. These low collection rates result from the strong role of the informal e-waste collection and disposal sector (because they offer higher price or better service or other reasons) (Gu et al., 2016). Therefore, in China, the amount of e-waste handled formally is significantly below the formal disposal capacity, and the Chinese government has more than enough facilities to dispose of its domestic e-waste.

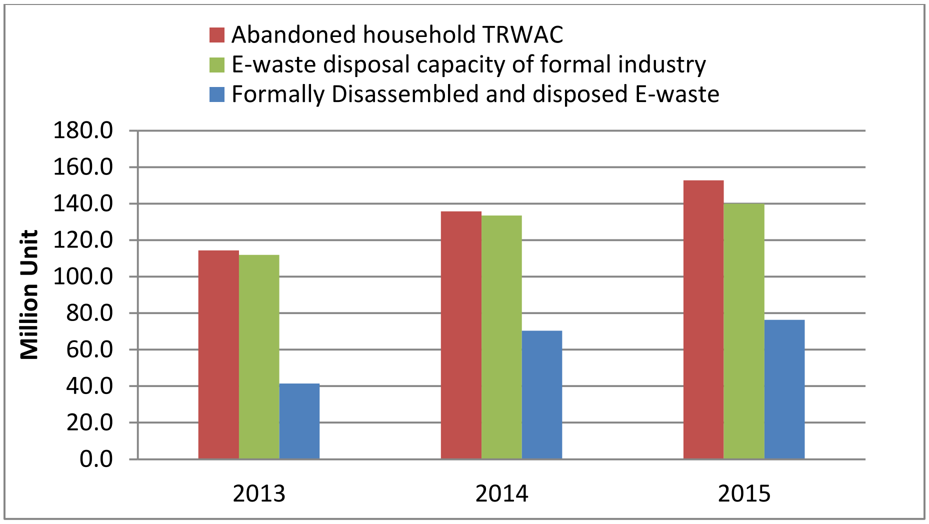

Figure 4.3 Comparison of China's abandoned house hold e-waste, formally disposed e-waste and capacity of formal e-waste disposal industry
SOURCE: Annual report of comprehensive Utilization of Resources in China (2012); Annual report of comprehensive Utilization of Resources in China (2014); China's Renewable Resources Recycling Industry Development Report (2015); China's Renewable Resources Recycling Industry Development Report (2016); National large and medium-sized municipal solid waste pollution prevention and control annual report (2014); National large and medium-sized municipal solid waste pollution prevention and control annual report (2015a); National large and medium-sized municipal solid waste pollution prevention and control annual report (2016); calculation by the author.

The analysis above illustrate that the Chinese government has already built a legislative system as well as enough facilities to dispose of its domestic e-waste. The behavior of nearly every stakeholder involved in the life cycle of e-waste, such as the producers, importers, retailers, the consumers, and the e-waste companies are all well regulated. Despite the fact that this system is not effective enough to solve its domestic e-waste problem (e.g., the percentage domestic e-waste disposed of formally is only around 50%), the Chinese government has made great effort trying to solve its domestically generated e-waste problem.

4.3.2 Legislative Control Focusing on Banning the Importation of E-waste

At the present time, the importation of e-waste is completely illegal in China. The Chinese government has been trying to control the importation of e-waste since 1994 (Environmental

Protection Agency of the People's Republic of China, 1994), and has forbidden its importation since 2000 (Environmental Protection Agency of the People's Republic of China et al., 2000). In 2008, the Chinese government published a catalog of e-waste forbidden from importing (Environmental Protection Agency of the People's Republic of China et al., 2008). This catalog was adjusted in 2009 (Ministry of Environmental Protection of the People's Republic of China et al., 2009), and remains in effect at the time of writing (see Table 4.3 and Ministry of Environmental Protection of the People's Republic of China et al., 2015).

Table 4.3 E-waste Listed in the "Catalog of Solid Waste Forbidden from Importing" (Ministry of Environmental Protection of the People's Republic of China et al., 2009)

Serial number	Trading Code	Name	Abbreviation
10. Waste Batteries			
67	8548100 000	Waste and Scrap of primary batteries and electric accumulators; spent primary cells, spent primary batteries and spent electric accumulators	Battery waste and waste batteries
11. Waste mechanical and electrical products and equipment; and their parts without sorting, demolition parts, broken pieces, smashed pieces			
68	8469-8473	Waste printers, copiers, fax machines, typewriters, computing machines, computers and other waste automatic data processing equipment and other waste office electrical and electronic products	Waste computer equipment, and waste office electrical and electronic products
69	8415, 8418, 8450, 8508-8510, 8516	Waste air conditioners, waste refrigerators and other refrigeration equipment, waste washing machines, waste washers, waste microwave ovens, waste rice cookers, waste vacuum cleaners, waste electric water heaters, waste carpet cleaners, waste electric knives, waste hairdressing machine, waste hair washing machine, waste brushing machine, waste shaving machine, waste massage equipment and other waste body care equipment, .	Waste Household Electrical Appliances
70	8517, 8518	Waste telephone, waste network communications equipment, waste microphones, waste speakers and other waste communications equipment	Waste communication equipment
71	8519-8531	Waste video equipment and waste radio and waste television equipment and waste signal devices, such as radio recorders, video recorders, laser disc players, camcorders, camcorders and digital cameras, radios, televisions, monitors, displayers, signaling devices	Waste audio-visual products, radio and television equipment, and signal devices
72	9504	Waste game consoles	Waste game consoles
73	8539	Waste fluorescent tubes; waste discharge tubes, including sodium and metal halide tubes; and other lighting equipment or lighting emission or control equipment	Waste lighting equipment
74	8532-8534, 8540-8542	Waste capacitors, waste printed circuit, waste hot tubes, waste CRT, waste cathode ray tube or photocathode, waste diodes, waste transistors and other waste semiconductor devices; integrated circuits and other waste electrical and electronic components	Waste electrical and electronic components
75	9018-9022	Waste medical equipment and waste ray equipment	Waste medical equipment and waste ray equipment
76	84、85、90	Other waste mechanical and electrical products and equipment	Other waste mechanical and electrical products and equipment

4.3.3 Managing E-waste Already Smuggled into China

The Chinese government has forbidden the importation of e-waste completely, but my research reveals that this policy of bans on imports appears not to be working well and that large amounts of e-waste are still smuggled into China every year (more details, see Section 4.2.2). Meanwhile, the Chinese government takes no action on managing waste already smuggled into China. In China's e-waste legislation system, e-waste already smuggled into China is largely ignored. There are only legal documents that forbid e-waste already smuggled into China to enter China's formal e-waste disposal system. For example, the "Administration Measures for Circulation of Used Electric Products" referred to smuggled e-waste with one sentence, where it "[forbids] the collecting of smuggled used electronic products" by formal collectors (Ministry of Commerce of the People's Republic of China et al., 2013).

However, the volume of the e-waste already smuggled into China is too large to be ignored. Actually, it may be equal to the amount of the domestic e-waste (for more details, see Section 4.2.3). Ignoring this segment of the e-waste stream makes it an environmental threat. Unlike e-waste generated in China, which is taken care of by a controlled system (for more details, see Section 4.3.1), every single piece of e-waste smuggled into China will go into an informal e-waste disposal industry. In this industry, some of the lucky ones will be refurbished and sold as fake new products, while a large amount of them will be processed for material recovery and disposed of by informal methods, such as open burning and acid melting, which causes substantial release of hazardous substances into the environment.

All the actions the Chinese government takes towards the smuggled e-waste is a ban, which has not been replaced for quite a long time (for more details, see Section 4.3.2). It is supported by evidence from different sources that this import ban policy is not working well (for more details, see Section 4.2.2). This ban policy appears to be only coverage for the government to say that it has worked on the e-waste importation problem to protect the environment. China will still suffer from environmental problems caused by the informal e-waste disposal. Since the e-waste has already being imported, China needs to do a better job of enforcing domestic environmental laws to manage e-waste that has already been smuggled into the country.

4.4 Conclusion

Based on the analysis about the volume of China's e-waste and the action the Chinese governments takes on it, I suggest that China's e-waste problem can be understood as two separate but related stories. One story is about China's domestically generated e-waste. The volume of this generation is large and growing. Over five years from 2010 to 2015, the summation of China's domestically generated e-waste ranged from 20 million tonnes to 29 million tonnes, with annual rates of increase ranging from 4% to 15.8%. However, the domestic e-waste is not uncontrollable. China has successfully built a regulation system to control it. Under this system, more than half of China's domestic e-waste is disposed of by methods that meet China's environmental standards. Moreover, if collected, China's formal e-waste disposal industry has the ability to dispose of more than 90% of its domestically generated e-waste. Even though problems still exist (e.g., low formal collection rates), we can still draw the conclusion that the Chinese government has put great efforts into trying to control its domestic e-waste problem, and that this problem is being addressed.

The other story is about China's imported e-waste. The volume of e-waste already smuggled into China is very large and cannot be ignored. China's policy approach toward the importation of e-waste is a trade ban. The Chinese government has banned the importation of e-waste since 2000, and the catalog of e-waste being forbidden from importing is provided in 2008. This ban policy has not been replaced for nearly ten years, and even China's recent filing with the WTO has only mentioned e-plastic, but not e-waste more generally (Staub, 2017; Elliott, 2017). The ban policy appears to be not working well, which is supported by evidence coming from different sources. This smuggled e-waste is being forbidden to enter China's formal e-waste disposal system. As a consequence, every piece of e-waste already smuggled into China will end up in the informal e-waste disposal industry. In this industry, large amount of e-waste will be processed for material recovery and disposal using methods like open burning or acid melting and become threats both to the environment and to public health. It is possible that China's policy focusing on the imported e-waste can only succeed in the limited sense that the government can tell people that it has made effort to prevent the import of e-waste.

Comparing these two stories, we can see that, in China, the volumes of the e-waste coming from two different sources are both too big to be ignored. The Chinese government has put great efforts into solving its domestically generated e-waste problems. Meanwhile, in China, a large amount of imported e-waste is still out of control and being disposed of informally. Furthermore, the Chinese public as well as their government will still have to suffer environmental problems brought by both the formal and the informal e-waste disposal sectors. Therefore, the Chinese government still needs to do a better job to enforce its existing environmental laws.

CHAPTER 5. CONCLUSIONS

Along with the development of electronic technology, electrical and electronic equipment has infiltrated into every aspect of our lives, and created substantial waste problems. These problems have been popularized as e-waste and received increasing attention. This thesis examined three different aspects of the e-waste problems: 1) the differences in how e-waste is defined and the possible effects of those differences, 2) how the pattern of global trade of e-waste changed over time, especially the characteristics this pattern has demonstrated under different country categorization criteria, and 3) China's e-waste problems and policies.

In this chapter, I will summarize my analysis of the three different aspects of e-waste problems. Then, I will discuss the contribution of this thesis. The third section of this chapter will examine the limitations of this study. Drawing from the limitations, the fourth part of this chapter will provide suggestions for future research.

5.1 Summary and Contributions

This thesis can be divided into three parts. The first part is about the differences of e-waste definitions from different sources, and focuses on two research questions: what are the differences among these e-waste definitions? How do these differences of definition matter? To answer these questions, I searched e-waste definitions from legislative documents related to e-waste from territories all over the world. All such documents in English or Chinese were collected and analyzed from the StEP e-waste world map. Among these documents, some of them provide an explicit definition of e-waste, while others provide only an implicit definition. Among all of these documents, some 12 different types of e-waste definitions are found, ranging from definitions applied by multiple countries (e.g. the e-waste definitions from the EU) to definitions used by one Canadian province.

After examining the information from these legislative documents, especially the 12 different types of explicit e-waste definitions, I find that they are different in two aspects: 1) the approaches and restrictions to defining the covered equipment, and 2) the criteria to identify specific equipment as electronic waste. In addition, among all the e-waste definitions, there are three routes to defining their covered equipment: 1) through reference to the energy used by the equipment, 2) through a description of the components of this equipment, or 3) through a specific list of devices (e.g., TVs, air conditioners, or cell phones). Besides these three routes, many, but not all e-waste definitions set further restrictions on what counts as e-waste by distinguishing what systems equipment does or does not belong to (e.g., excluding part of end-of-life vehicles), through the size of equipment (e.g., excluding equipment with specified screen dimensions), or through the sources of the equipment (e.g., excluding medical devices). Moreover, different criteria are applied to determine when the covered equipment becomes waste. Some of the criteria are related to the conditions of the covered equipment, like whether an item loses its originally designed functionality, whether it is useful, or whether it is still accepted by the market. Some of the criteria are not related to the conditions of this covered equipment, like the consumer's action. Due to this great discrepancy, no unified e-waste definition is found to be capable of presenting all the e-waste definitions from all over the world, and no type of e-waste is found to be qualified to represent e-waste as a whole. Without a unified e-waste definition, studies about comparison of e-waste volumes or management systems among different territories will remain difficult. Therefore, I propose that any e-waste studies with multiple countries should pay attention to the differences of e-waste definitions from different countries.

Even though only three approaches are used to define the covered equipment, and several types of criteria to define when this equipment becomes waste, they provide a source of diversity on what should be considered as e-waste. The diversity in the e-waste definitions, even in the same area, lead to differences in the volumes and compositions of the e-waste issue. For example, a country considers refrigerators and washers as e-waste will face different e-waste problems if it does not consider these two types of waste equipment e-waste. On one hand, these differences will determine the nature of the e-waste issue, whether it is a serious problem with potential hazardous threats, or just a phenomenon with little effect on society. On the other hand, with these differences, the producers, sellers, and previous consumers of the covered equipment will all be different. The parties who should be responsible for this e-waste problem, who should be regulated to effectively collect e-waste, and who should be provided resources for e-waste disposal will all be different, depending on how e-waste is defined, the route(s) by which it is identified as waste, and any criteria used to include or exclude particular classes of equipment. In short, definitions matter in that they construe e-waste as a particular type of problem depending on what counts as such waste. Taken together, the wide variety in definitions of e-waste shows that e-waste, like other forms of waste, has no natural definition, and thus it presents policy makers with an indeterminate problem (Wynne, 1987).

The second part of this thesis examined the pattern of the global trade of e-waste concentrating on two research questions: 1) how has the pattern of global trade of e-waste changed over time, and 2) what characteristic trade patterns emerge under different country categorization methods? To answer these two questions, I applied a proxy data analysis method using data from the United Nation's COMTRADE database for waste and scrap of primary batteries, electric accumulators, spent primary batteries, and spent electric accumulators. Analyzing these data I found that the total international trade volume of at least certain types of e-waste has grown remarkably in the last 20 years, and a small number of trade transactions account for the bulk of total trade volume.

To investigate the characteristics of different economic zones shown in the process of international e-waste trade, I divided all the countries in the world into seven economic zones based on categories used by the World Trade Organization (WTO): Africa, Asia-Pacific, Commonwealth of Independent States (CIS), Europe, Middle East, North America, and South and Central America (World Trade Organization, 2015). After this division, it is demonstrated that, in most years, more than 80% of the international trade of the WPBs was intra-regional trade. Particularly, major contributors of this trading, namely Asia-Pacific areas, Europe, and North America, maintained a high proportion of intra-regional trade. Other regions, namely Africa, CIS, Middle East and South/Central America, show a shift in trade orientation over time from internal orientation to external orientation.

I also examined the effect on our understanding of the international trade in e-waste of using two different country classifications of developing and developed countries to organize the data. These two classification systems were that for the Basel Convention and for the World Trade Organization (WTO). In the Basel scheme, the list is defined by an annex called Annex VII, Annex VII classifies developed countries as the OECD, the EU and Liechtenstein (Basel Convention, 2017), and developing countries as the others. The WTO categories defined the developed economies as North America (except Mexico), the European Union, the European Free Trade Association (EFTA, includes Iceland, Liechtenstein, Norway, and Switzerland), Australia, Japan and New Zealand, and developing economies as others (World Trade Organization, 2015).

Different results can be obtained using the same data set but different country classifications. Under the Basel Convention categorization scheme, the WPBs is mostly traded between developed countries, the amount of the transfer of e-waste from developed countries to developing countries is very small, and the trading from developing countries to developed countries is thriving as a new phenomenon. Under the WTO classification standard, the amount of the transfer of e-waste from developing countries to developed countries is big and growing. These findings point to a broader problem than the specifics of either the Basel Convention or the WTO. It means not only the category of the e-waste but also the category of the countries make this e-waste problem another story, and that the international trade of e-waste is a fundamentally indeterminate problem (more generally, see Wynne, 1987).

The third part of this study is about China's e-waste problems and solutions. It considers the question of the relative importance e-waste from importation to China versus domestic generation, and whether the Chinese government's solutions to its e-waste problems are effective. To examine these issues, the volume of China's e-waste and China's e-waste policy were comprehensively analyzed. China's e-waste comes from two sources: domestic generation and importation. Using data for wasted TVs, refrigerators, washing machines, air conditioners and microcomputers, I found that the volume of China's domestic e-waste is large and growing. Over the five years between 2010 and 2015, a minimum total of 20 million tonnes and a maximum total of 29 million tonnes of e-waste were generated domestically in China. There are no precise data about China's e-waste importation, although I was able to make estimates by drawing on the COMTRADE data, research reports, and news articles. The COMTRADE data indicate that, from 2010 to 2015, the total amount of China's WPBs importation is 19,000 tonnes. Considering that the COMTRADE data set misses all unreported trade, and that these data ignores most types of China's illegal imported items (like wasted TVs), it is reasonable to assume that the actual size of the e-waste importation in China is also big. That is to say, imports of e-waste to China and domestically generated e-waste are both significant problems in China.

The legislation from the Chinese government is analyzed as China's solution to addressing its e-waste problems. China's provincial and lower level policies are made according to federal policy. Accordingly, only federal legislation was analyzed. My analysis shows that the Chinese government treats domestic e-waste and illegally imported e-waste as distinct problem. On one hand, China has successfully built a regulation system to control its domestically generated e-waste. The catalog of e-waste that should be controlled is provided. The e-waste listed in this catalog is required to be disposed of by industrial scale disposal companies. These companies are required to get a license to operate. A subsidy system is built to support the running of formal e-waste disposal companies. Different levels of Chinese government are required to supervise the system. Under this system, more than half of China's domestic e-waste is disposed of by methods that meet China's environmental standards. Moreover, if collected, China's formal e-waste disposal industry has the ability to dispose of more than 90% of its domestically generated e-waste. In other words, even though the formal system is operating below capacity, we can still draw the conclusion that the Chinese government has put great efforts into trying to control its domestic e-waste problem, and that this problem is being addressed. On the other hand, China's policy approach toward the illegal importation of e-waste is a trade ban. This ban policy has not been replaced for nearly ten years. Even the country's recent filing with the WTO to refuse imports of what it calls 'foreign garbage' have uncertain consequences for the import of e-waste since that filing covers some materials (particularly plastics) that relate to e-waste, but not e-waste itself. The smuggled e-waste is being forbidden to enter China's formal e-waste disposal system. As a consequence, every piece of e-waste already smuggled into China is out of the control of the government and will end up in the informal e-waste disposal industry. In this industry, a large amount of e-waste will be disposed of by methods like open burning or acid melting and become threats both to the environment and public health. Therefore, even with the great effort the Chinese government has made to solve its e-waste problems, China's environmental problems caused by e-waste still continue. This finding can give the Chinese government a new perspective to enhance its existing environmental laws, in which not only the domestically generated e-waste but also the smuggled e-waste should be considered.

5.2 Limitations of the Study

There are limitations on all three parts of this study. The analysis of the differences of the e-waste definitions is limited by the fact that there is no case study supporting it. I collected documents related to e-waste to analyze the differences of the e-waste definitions. Therefore, all the differences I find are based on literal analysis of the texts, and their influences are simply derived from the words of the documents. A case study of how these legislative documents are actually put into practice could more fully investigate the reason for the existence of the differences in e-waste definitions and the influence of these differences. Such a case study could answer questions such as the following: Where do the differences of e-waste definitions come from？ How significant is the e-waste problem deemed to be in jurisdictions with e-waste legislation? Whether the responsible parties and solutions to e-waste problems are different with different definitions; and whether the attitude of the government can influence the awareness of the public. Furthermore, this influence can also be analyzed in relation to their policy implementations.

The limitations of the study of the pattern of the global trade of e-waste mainly lie on the limitations of data quality. On one hand, only international trade data recorded by the

COMTRADE database are applied. Besides the trading recorded by the COMTRADE database, an unknown amount of e-waste trading is illegal and without any relevant statistical data. Therefore, the results of this thesis might only catch part of the whole story, and if the data about the illegal e-waste trading is considered, the results may be different. On the other hand, the WPBs data analysis presents only one type of e-waste. Different types of e-waste have different characteristics, as their weight, structure, and materials are all different. These different types of e-waste required different disposal methods, and accordingly, the reason for their international trading are also different. Therefore, the analysis provided by this thesis might only present the story of the international trade of e-waste from the aspect of WPBs rather than e-waste as a whole, and if other types of e-waste are included, this analysis might produce different results.

The limitations of the analysis of China's e-waste problems and solutions mainly lie on two points: 1) no data are available for the e-waste smuggled into China, and 2) this study fails to take the provincial and lower level policies into account. When analyzing the volume of e-waste already smuggled into China, I applied an estimation method. The e-waste data from the COMTRADE database are used as the basis for the estimation. Several general reasons are provided about why it is reasonable that the actual volume of this trading can be around 1000 times bigger than the volume of China's recorded importation of WPBs. These reasons are that the COMTRADE data misses all unreported trade of WPBs, and that other types of e-waste other than WPBs are not considered. Consequently, a very simple result is generated that the volume of the smuggled e-waste is as large as China's domestic e-waste. More detailed questions about this illegal importation are still waiting to be answered, like what accounts for the growth of trade in WPBs; what are the channels for the smuggling of e-waste into China; what are the potential explanations for the failure of China to ban the illegal import of e-waste. If data of e-waste already smuggled into China is available, this research can generate a more detailed recommendation to Chinese policy makers. Besides the limitation of insufficient data, this research is also limited by the scope of the analyzed policy. In this study, only federal legislation is analyzed for the reason that provincial and lower level policies are made according to the federal policy. However, when examining China's provincial and lower level e-waste policies, I find that many ordinances related to e-waste from local government, which should be made according to the federal documents, are actually violating them. If these ordinances are also included, this research will be enriched.

5.3 Suggestions for Future Research

This thesis suggests four possible directions for future research. First would be research based on a case study of how e-waste legislation is actually implemented and enforced combined with further investigation of the differences and influences of that e-waste definitions make. This case study could be conducted to investigate the reason and the influences of the differences of e-waste definitions mentioned in Section 2.3. The possible influences of the e-waste definition, namely the nature of the e-waste issue, the responsible parties, the possible solutions, and the attitude of the government as well as the public towards this issue could all be explored by the case study. Furthermore, the mechanism of how the e-waste definition influences the policy implementation could also be explored.

The second direction of possible future research is improving the data quality used in the analysis of the pattern of the global trade. There are two different ways to improve these data. The first way is to improve the data quality on the international trade of the WPBs. Mathematic modeling methods could be used to process the data from the COMTRADE database to improve the data accuracy, and a survey method could be applied to complement the information about illegal trading of WPBs that are not recorded by the COMTRADE database. The second way is finding ways to collect data about the international trade of other types of e-waste. When I conducted this research, I found that collecting appropriate data to demonstrate the international trade trends of e-waste was very difficult, and therefore only the data about the trading of WPBs were applied. If new methods of exploring data of international trade of other types of e-waste are developed, this scarce data problem could also be addressed.

The third direction of possible future research is conducting a case study in China. When examining China's e-waste problems and solutions, I find that many levels of local government published ordinances related to e-waste that violate the e-waste laws from the federal government. It is possible that this phenomenon developed because the informal e-waste disposal industries also creates jobs, thus the local government tries to protect them. A case study could further investigate the reasons and the results of this phenomenon, and explore features of ordinances related to e-waste from China's local government, which will enrich the analysis about policy approaches to e-waste in China investigated in this thesis. Moreover, the case study can also collect information about the volume of the e-waste already smuggled into China.

A fourth direction of possible future research is conducting similar research about e-plastic. China has banned the importation of some kinds of wastes, including e-plastics by the end of 2017 (Staub, 2017; Elliott, 2017). It is very possible that with the banning of the importation of e-plastic, the illegal importation will thrive, and the e-plastic will face a similar situation as e-waste. If this research was pursued, topics of possible future research could be a comparison of the volumes of smuggled e-plastic and China's domestic e-plastic, the analysis of China's policies concentrating on the e-plastic problems, and a case study about informal e-plastic industries.

REFERENCES

Agamuthu P, and Victor D, 2011. Policy trends of extended producer responsibility in Malaysia. *Waste Manage Res*, 29(9), 945-953.

Arensman, R., 2000. Ready for recycling?, *Electronic Business*,26(12), pp.108-115.

Australian/New Zealand Standard, 2013. Collection, Storage, Transport and Treatment of Used Electrical and Electronic Equipment, Available at:<https://shop.standards.govt.nz/catalog/5377:2013(AS%7CNZS)/scope?>[accessed 22 June 2017]

Babu B.R.., Parande A.K., and Basha C.A., 2007. Electrical and electronic waste: a global environmental problem. *Waste Manag Res*, 25, pp.307-318.

Basel Action Network, 2002. *Exporting Harm: The High-Tech Trashing of Asia*, [pdf] Basel Action Network. Available at: <http://archive.ban.org/e-waste/technotrashfinalcomp.pdf>[accessed 19 June 2016]

Basel Action Network, Silicon Valley Toxics Coalition, Toxics Link India, SCOPE (Pakistan), and Greenpeace China, 2002. Who get the trash? Available at:< https://globalizationstudies.sas.upenn.edu/node/757?size=_original>[accessed 22 June 2017]

Basel Convention Regional Centre for Asia and the Pacific, 2014. *Introduction of BCRC China*. Available at:<http://en.bcrc.cn/col/1257152702500/index.html> [accessed 12 May 2016] (in Chinese)

Basel Convention, 1998. Controlling transboundary movements of hazardous wastes and their disposal Basel Convention Annexes IX, Available at:<http://www.basel.int/Portals/4/Basel%20Convention/docs/text/BaselConventionText-c.pdf>[accessed 25May2017]

Basel Convention, 2011. technical guidelines on transboundary movements of e-waste, in particular regarding the distinction between waste and non-waste, [pdf]Basel Convention. Available at:<http://re.indiaenvironmentportal.org.in/files/file/basel%20convention6.pdf> [Accessed 21 March 2017]

Basel Convention, 2017. Controlling transboundary movements of hazardous wastes and their disposal, Available at:<http://www.basel.int/Portals/4/Basel%20Convention/docs/text/BaselConventionText-e.pdf> [accessed 25May2017]

Basel Convention, n.d.. Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal. [Online]Available at:<http://www.basel.int/Countries/StatusofRatifications/PartiesSignatories/tabid/4499/Default.aspx>[accessed, 9 March 2017] (in Chinese)

Basle Action Network, 2016. Scam Recycling e-Dumping on Asia by US Recyclers. [pdf] Available at:< http://wiki.ban.org/images/1/12/ScamRecyclingReport-web.pdf>

Bisschop L., 2012. Is it all going to waste? Illegal transports of e-waste in a European trade hub Crime. *Law and Social Change*, 58(3), pp.221-249.

Borthakur, A. and Singh, P., 2012. Electronic waste in India: Problems and policies. *International journal of environmental sciences*, 3(1), 353-362.

California State Legislature, 2003. *California Public Resources Code, Section 42463*. Available at:< http://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?lawCode=PRC&division=30.&title=&part=3.&chapter=8.5.&article=2.>[accessed 19 June 2016]

Cameron, J. and Gibson, K., 2005. Participatory action research in a poststructuralist vein. *Geoforum*, 36 (3), pp.315-331. doi:10.1016/j.geoforum.2004.06.006.

Cantin, P. and Bury, D., 2012. Inventory and Feasibility Assessment of Electronic waste recovery in the Northwest Territories, Available at:<http://120.52.72.43/www.enr.gov.nt.ca/c3pr90ntcsf0/sites/default/files/web_pdf_ed_wrr_inventory_feasibility_assessment_final_report_10_december_2012.pdf>[accessed 19 June 2016]

Chi, X., Streicher-porte, M., Wang, M.Y.L., and Reuter, M.A., 2011. Informal electronic waste recycling: a sector review with special focus on China. *Waste Manage*. 31(4), 731-742.

Chile National Environment Commission, 2010. Sustainable Management of Waste Computer Equipment. Available at:<http://www.residuoselectronicos.net/archivos/boletin/bol_18/documentos/Convenio_RAE_HP.pdf>[accessed 12 March 2017] (in Spanish)

China household electrical appliances research institute, 2016. *White Paper on WEEE recycling industry in China 2015*, [pdf]. Available at:<http://www.cheari.org/recyclingtech/%E7%99%BD%E7%9A%AE%E4%B9%A62015.pdf>[accessed 12 March 2017] (in Chinese)

China household electrical appliances research institute, 2017. *White Paper on WEEE recycling industry in China 2016*, [pdf]. Available at:< http://www.weee-epr.org/content.php?id=132#xiazai>[accessed 12 March 2017] (in Chinese)

China Resource Recycling Association, 2014. In 2013, the dismantling of waste electrical and electronic products reached 41 million units. *Resources Work Communication*, Available at:<http://www.crra.org.cn/html/2014/tongxun_0207/69.html>[accessed 22 June 2017] (in Chinese)

Chinese Household Electrical Appliances Research Institute, n.d.. *Institute introduction*. [on line] Available at:<http://www.cheari.org/AboutUs/Introduction.aspx>[accessed 22 June 2017]

Chung, S. and Zhang, C., 2011. An evaluation of legislative measures on electrical and electronic waste in the People's Republic of China. *Waste Management*. 31(12), pp. 2638-2646.

CNN, 2013. *China: The electronic wastebasket of the world*. [Online] Available at:<http://edition.cnn.com/2013/05/30/world/asia/china-electronic-waste-e-waste>[Accessed 25 May 2017]

COMTRADE, n.d. United Nations Commodity Trade and Statistics Database. Available at:<http://comtrade.un.org>[accessed 21June2017]

Council Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS) [2003] OJL037

Council Directive 2002/96/EC of the European parliament and of the council of 27 January 2003 on waste electrical and electronic equipment (WEEE)-joint declaration of the European parliament, the council and the commission relating to article 9[2003] OJL037:0024-39

Council Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE)[2012] OJL197

Cui, N., 2017. 42 Tonnes of Electronic Waste Hidding in Storage Container. Guangzhou Daily News, [online] 27 Febrary. Available at:<http://news.dayoo.com/guangzhou/201702/27/150079_50904263.htm>

Culver J, 2005. The life cycle of a CPU. [Online] Available at:<http://www.cpushack.net/life-cycle-of-cpu.html.> [accessed 5 December 2016].

DIRECTIVE 2008/98/EC the European parliament and of the council of 19 November 2008 on waste and repealing certain Directives[2008]OJL312

Dwivedy, M., and Mittal, R.K., 2010. Estimation of future outflows of e-waste in India. *Waste Management*. 30, pp.483–491.

Electrical Appliance Recycling technology Center, n.d.. *Introduction*. [on line] Available at:<http://www.cheari.org/recyclingtech/english/index.html>[accessed 22 June 2017]

Electronic Products Recycling Association, 2017. *Other programs in Canada*. [online] Available at:<http://epra.ca/provincial-programs>[accessed 12 March 2017]

Electronics product stewardship Canada and retail council of Canada, 2011. *Quebec product stewardship program for end-of-life electrical and electronic equipment*, Available at:<http://recyclemyelectronics.ca/qc/wp-content/uploads/2013/08/Quebec-Product-Stewardship-Program-Plan_Dec-9.pdf>[accessed 12 March 2017]

Elliott, B., 2017. *How China caused a global e-plastics dilemma*. [on line] Available at: <https://resource-recycling.com/e-scrap/2017/12/14/china-caused-global-e-plastics-dilemma/>[accessed 22 Oct. 2017]

Environmental Protection Agency of the People's Republic of China (Now is Ministry of Environmental Protection of the People's Republic of China), 2003. The circular on strengthening the environmental management of waste electrical and electronic equipment. Available at:<http://www.mep.gov.cn/gkml/zj/wj/200910/t20091022172222.htm>[accessed 5 December 2016](in Chinese)

Environmental Protection Agency of the People's Republic of China (Now is Ministry of Environmental Protection of the People's Republic of China), 2006. The Technical Policy for the Prevention of Pollution from Waste Electrical and Electronic Equipment, Available at:<http://kjs.mep.gov.cn/hjbhbz/bzwb/wrfzjszc/200607/t20060720_91676.htm>[accessed 5 December 2016](in Chinese)

Environmental Protection Agency of the People's Republic of China (Now is Ministry of Environmental Protection of the People's Republic of China), the Ministry of Commerce, the General Administration of Customs of the People's Republic of China, and the General Administration of Customs of the People's Republic of China, 2008. *Notice No. 11, on the publication of the "Catalog of Solid Waste Forbidden from Importing", the "list of limited imported solid wastes ", and" automatic licensing of raw materials that can be used as raw materials "*. Available at :< http://www.51wf.com/law/164815.html>(in Chinese)

Environmental Protection Agency of the People's Republic of China (Now is Ministry of Environmental Protection of the People's Republic of China), Ministry of Foreign Trade and Economic Cooperation(Now is the Ministry of Commerce of the People's Republic of China), General Administration of Customs of the People's Republic of China, Entry-Exit Inspection and Quarantine Bureau, 2000. *Notice on Relevant Issues Concerning Importing the 7th Class Waste*, Available at:<http://www.gsfzb.gov.cn/FLFG/Print.asp?ArticleID=32160>[accessed 3 October 2016] (in Chinese)

Environmental Protection Agency of the People's Republic of China (Now is Ministry of Environmental Protection of the People's Republic of China), Ministry of Foreign Trade and Economic Cooperation(Now is the Ministry of Commerce of the People's Republic of China), General Administration of Customs of the People's Republic of China, State Administration for Industry & Commerce of the People's Republic of China, General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, 1996. *Interim Provisions on the Environmental Protection of Waste Import*. Available at:<http://www.zhb.gov.cn/gkml/zj/wj/200910/t20091022_171872.htm>[accessed 3 October 2016] (in Chinese)

Environmental Protection Agency of the People's Republic of China (Now is Ministry of Environmental Protection of the People's Republic of China), 1994. *Interim Provisions on strict controls of imports from the EC*. Available at:<http://baike.baidu.com/item/%E5%85%B3%E4%BA%8E%E4%B8%A5%E6%A0%BC%E6%8E%A7%E5%88%B6%E4%BB%8E%E6%AC%A7%E5%85%B1%E4%BD%93%

E8%BF%9B%E5%8F%A3%E5%BA%9F%E7%89%A9%E7%9A%84%E6%9A%82%E8%A1%8C%E8%A7%84%E5%AE%9A> [accessed, 9 March 2017] (in Chinese)

e-Steward, 2017. *The e-Steward story*. [online] Available at:<http://e-stewards.org/about-us/the-e-stewards-story/>[accessed 12 March 2017]

e-Stewards, 2013. *Review version: e-Stewards Standard for Responsible Recycling and Reuse of Electronic Equipment*. [pdf] e-Stewards. Available at:< http://e-stewards.org/wp-content/uploads/2014/09/eStewards_Standard_Review_Version.pdf>[accessed 12 March 2017]

E-waste disposal information system of China, n.d.. *List of Companies*. [on line] Available at:<http://weee.mepscc.cn/Index.do?method=entpList>[accessed 22 June 2017]

Fu, J., Zhou, Q., Liu, J., Liu, Wang, T., Zhang, Q., and Jiang, G., 2008. High levels of heavy metals in rice (Oryza sativa L.) from a typical e-waste recycling area in southeast China and its potential risk to human health. *Chemosphere*, 71, pp.1269-1275

Gao, Y, 2014. Bypassing more than 6,000 kilometers to smuggle e-waste. Nandu, [online] 26 February. Available at:<http://epaper.oeeee.com/epaper/A/html/2014-02/26/content_2541601.htm?div=-1> (in Chinese)

General Administration of Customs of the People's Republic of China, 2012. *Name, Code and Collection Standards Applied to Imported Electrical and Electronic Products*. Available at:<http://www.customs.gov.cn/publish/portal0/tab518/info377606.htm>[accessed, 9 March 2017] (in Chinese)

Government of Saskatchewan, 2006. *Environmental Management and Protection Act, The waste electronic equipment regulations*. Available at:<http://www.publications.gov.sk.ca/details.cfm?p=489>[accessed 19 June 2016]

Grant, R., 1994. the geography of international trade. *human geography*, 18(3), pp. 298-312.

Greenpeace Philippines, 2015. *Zero waste groups back environmentally-sound management of waste electrical and electronic equipment*. [online] Available at:<http://www.greenpeace.org/seasia/ph/press/releases/Zero-waste-groups-back-environmentally-sound-management-of-waste-electrical-and-electronic-equipment/>[accessed 12 March 2017]

Greenpeace, 2008. *Toxic Tech: Not in our Backyard*, Available at: <http://www.greenpeace.org/raw/content/international/press/reports/not-in-our-backyard.pdf>[accessed 19 June 2008]

Gu, Y., Wu, Y., Xu, M., Wang, H., and Zuo, T., 2016. The Stability and Profitability of the Informal WEEE Collector in Developing Countries: A Case Study of China. *Resources, Conservation and Recycling,* 107: 18–26. https://doi.org/10.1016/j.resconrec.2015.12.004.

Guo Y, Huo X, Wu K, Liu J, Zhang Y, and Xu X., 2012. Carcinogenic polycyclic aromatic hydrocarbons in umbilical cord blood of human neonates from Guiyu, China. *Sci Total Environ*, 427, 35-40.

Han, G., Ding, G., Lou, X., Wang, X., Han, J., Shen, H., and Du, L., 2011. Correlations of PCBs, dioxin, and PBDE with TSH in children's blood in areas of computer e-waste recycling. *Biomed Environ Sci*, 24, pp.112-16.

Hicks C, Dietmar R, and Eugster M, 2005. The recycling and disposal of electrical and electronic waste in China—legislative and market responses. *Environmental Impact Assessment Review*. 25, pp.459-71.

HKEPD. Progress of Work in 2010, 2011. In The seventh working level conference on Waste transfer of the Mainland - Hong Kong. Environmental Protection Department Hong Kong SAR Government (HKEPD).

Hoornweg, D. and Bhada-Tata, P., 2012. What a waste-a global review of solid waste management. Available at:<http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf> [Accessed 21 March 2017]

I.C. Nnorom, and O. Osibanjo, 2008. Electronic waste (e-waste): Material flows and management practices in Nigeria. *Waste Management*, 28, pp.1472-1479.

I.C. Nnorom, and O.Osibanjo, 2008. Overview of electronic waste(e-waste) management practices and legislations, and their poor applications in the developing countries. *Resources,Conservation and Recycling*, 52, pp.843-858.

Japanese ministry of international trade and industry,1998. *Law for recycling of specified kinds of home appliances*. Available at:<http://www.meti.go.jp/policy/it_policy/kaden_recycle/index.html>[accessed 12 March 2017](in Japanese)

Kahhat, R. and Williams, E., 2012. Materials flow analysis of e-waste: Domestic flows and exports of used computers from the United States. *Resources, Conservation and Recycling*, 67, pp.67-74.

Kang, H.-Y., and Schoenung, J.M., 2006. Estimation of future outflows and infrastructure needed to recycle personal computer systems in California. *Journal of Hazardous Materials*, 137, pp.1165-1174.

Khetriwal, D.S., Widmer, R., Kuehr, R., and Huisman, J., 2011. One WEEE, many species: lessons from the European experience. *Waste Manag*. 29, 954–962. http://dx.doi.org/10.1177/0734242X11413327.

Korean Ministry of Environment, 2007a. *Korea waste control act*. Available at:<http://dinrac.nowpap.org/documents/law/Korea/Wastes_Control_Act_Korea.pdf>[accessed 19 June 2016]

Korean Ministry of Environment, 2007b. *Korean National Assembly, Act for Resource Recycling of Electrical and Electronic Equipment and Vehicles-Korea RoHS, WEEE & ELV*. Available at:<http://www.rsjtechnical.com/images/Documents/Korea_RoHS_ELV_April_2007_EcoFrontier.pdf>[accessed 19 June 2016]

Lawinfochina, 2017. Promotion Law of the People's Republic of China [Effective]. [Online] Available at:<http://www.lawinfochina.com/display.aspx?id=7025&lib=law>[accessed, 9 March 2017] .

Lepawsky J, and McNabb C., 2010. Mapping international flows of electronic waste. *Canadian Geographic*, 54, pp.177-195.

Lepawsky, J., 2012. Legal geographies of e-waste legislation in Canada and the US: Jurisdiction, responsibility and the taboo of production. *Geoforum*,43, pp.1194-1206.

Lepawsky, J., 2014. Are we living in a post-Basel world?. *Area*, 47(1), pp.7-15.

Lepawsky, J., 2015. The Changing Geography of Global Trade in Electronic Discards: Time to Rethink the e-Waste Problem. *The Geographical Journal*, 181 (2): 147–59. doi:10.1111/geoj.12077.

Li JH, Tian BG, and Liu TZ, 2006. Status quo of e-waste management in mainland China. *Journal of Material Cycles and Waste Management*, 8, pp.13–20.

Liboiron, M., 2014. 'Against Awareness, For Scale: Garbage Is Infrastructure, Not Behavior'. Discard Studies. January 23.

Lindhqvist T, 2000. Extended producer responsibility in cleaner production: policy principles to promote environmental improvements of product systems. PhD. Lund University.

Liu X., Tanaka M., and Matsui, Y., 2006a. Electrical and electronic waste management in China: progress and the barriers to overcome. *Waste Management and Research*, 24, pp. 92-101.

Liu, X., Tanaka, M., and Matsui, Y., 2006b. Generation amount prediction and material flow analysis of electronic waste: A case study in Beijing, China. *Waste Management and Research*, 24(5), pp.434-445.

Liu, Z., Xue, Y., and Huang H., 2016. Prediction of the quantities of waste electric and electronic products in Mainland China. *Huanjing Kexue Xuebao/Acta Scientiae Circumstantiae*, 36(5), pp. 1875-1882. (in Chinese).

Lu, C., Zhang, L., Zhong, Y., Ren, W., Tobias, M., Mu, Z., Ma, Z., Geng, Y., and Xue, B., 2015. An Overview of e-waste management in China. *J Mater Cycles Waste Manag*. 17, pp. 1-12. [online] Available at:<https://www.researchgate.net/profile/Bing_Xue/publication/270741854_An_Overview_of_e-wastes_Management_in_China/links/54b38f710cf220c63cd28540.pdf>[accessed 22 June 2017]

Maxianova, K., 2008. Shipments of electronic waste: providing the right incentives through regulation and enforcement. *Review of European Community and International Environmental Law*, 17 (3), pp.270–278.

Milovantseva, N., and Fitzpatrick, C., 2015. Barriers to electronics reuse of transboundary e-waste shipment regulations: An evaluation based on industry experiences. Resources. *Conservation and Recycling*, 102, pp.170-177.

Ministry of Commerce of the People’s Republic of China, 2007. *Administrative Measure on the Recovery of Renewable Resources*. Available at:<http://www.gov.cn/flfg/2007-03/30/content_566242.htm> [accessed, 9 March 2017] (in Chinese).

Ministry of Commerce of the People’s Republic of China, 2013. Order of Ministry of Commerce of the People’s Republic of China No.1 “Administration Measures for Circulation of Used Electric Products ”, Available at:<http://www.mofcom.gov.cn/article/b/d/201303/20130300062999.shtml> [accessed, 9 March 2017] (in Chinese)

Ministry of Commerce of the People’s Republic of China, 2015. *China’s Renewable Resources Recycling Industry Development Report (2015)*, Available at:< http://www.chinacace.org/news/view?id=5726>[accessed, 9 March 2017] (in Chinese)

Ministry of Commerce of the People’s Republic of China, 2016. *China’s Renewable Resources Recycling Industry Development Report (2016)*, Available at:< http://ltfzs.mofcom.gov.cn/article/af/201605/20160501325666.shtml >[accessed, 9 March 2017] (in Chinese)

Ministry of Environment and Forests of India, 2003. *Hazardous wastes (management and handling) amendment rules 2003*, [pdf] Ministry of Environment and Forests of India. Available at:<http://www.cseindia.org/dte-supplement/WASTES.PDF.>[accessed 12 March 2017]

Ministry of Environment and Forests of India, 2011. *e-waste (management and handling) Rules*. [pdf] Ministry of Environment and Forests of India. Available at:< http://www.moef.nic.in/downloads/rules-and-regulations/1035e_eng.pdf>[accessed 12 March 2017]

Ministry of Environment Protection of the People’s Republic of China, Ministry of Commerce of the People’s Republic of China, the National Development and Reform Commission of the People’s Republic of China, General Administration of Customs of the People’s Republic of China, and General Administration of Quality Supervision, Inspection and Quarantine of the People’s Republic of China, 2015. Notice about publishing ‘Catalog of importation waste (2015)’, Available at:<http://webcache.googleusercontent.com/search?q=cache:http://www.mep.gov.cn/gkml/hbb/bgg/201412/t20141231_293678.htm&gws_rd=cr&ei=k6vCWPfEHIvYjwT_upqACA>[accessed 3 October 2016] (in Chinese)

Ministry of Environment Protection of the People’s Republic of China, 2010a. *Notice of MEP about guideline for e-waste Processing Enterprises to Establish Data Information Management and Submit System*. Available at:<http://www.zhb.gov.cn/gkml/hbb/bgg/201011/t20101119_197728.htm>[accessed, 9 March 2017] (in Chinese)

Ministry of Environment, Forests and Climate Change of India, 2016. *GOVERNMENT OF INDIA MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE NOTIFICATION.* [pdf] Ministry of Environment, Forests and Climate Change of India. Available at:< http://envfor.nic.in/sites/default/files/EWM%20Rules%202016%20english%2023.03.2016.pdf>

Ministry of Environmental Protection of the People’s Republic of China, Ministry of Commerce of the People’s Republic of China, the National Development and Reform Commission of the People’s Republic of China, General Administration of Customs of the People’s Republic of China, and General Administration of Quality Supervision, Inspection and Quarantine of the People’s Republic of China, 2009. *Notice about adjusting the Catalog of importation waste*, Available at:<http://www3.customs.gov.cn/publish/portal0/tab49685/info434214.htm>(in Chinese)

Ministry of Environmental Protection of the People’s Republic of China, 2007. Administration of environmental pollution control and management of waste electrical and electric equipment. Available at:<http://www.mep.gov.cn/info/gw/juling/200709/t20070928 109698.html>[accessed 5 December 2016](in Chinese)

Ministry of Environmental Protection of the People’s Republic of China, 2009. Ordinance on the management of waste household electrical and electronic products. Available at:<http://www.sepa.gov.cn/law/fg/xzhg/200903/t20090305 134909.html>[accessed 5 December 2016](in Chinese)

Ministry of Environmental Protection of the People’s Republic of China, 2003. *The bulletin on strengthening the environmental management of waste electrical and electronic equipment*. Available at:<http://www.mep.gov.cn/gkml/zj/wj/200910/t20091022 172222.htm>[accessed 5 December 2016](in Chinese)

Ministry of Environmental Protection of the People’s Republic of China, 2014. National large and medium-sized municipal solid waste pollution prevention and control annual report(2014), [pdf] Ministry of Environmental Protection of the People’s Republic of China. Available at:<http://trhj.mep.gov.cn/gtfwhjgl/zhgl/201604/P020160424386477560289.pdf>[accessed 21June2017] (in Chinese)

Ministry of Environmental Protection of the People’s Republic of China, 2015a. National large and medium-sized municipal solid waste pollution prevention and control annual report(2015), [pdf] Ministry of Environmental Protection of the People's Republic of China. Available at:<http://trhj.mep.gov.cn/gtfwhjgl/zhgl/201604/P020160424386491215726.pdf>[accessed 21June2017] (in Chinese)

Ministry of Environmental Protection of the People's Republic of China, 2016. National large and medium-sized municipal solid waste pollution prevention and control annual report(2016), [pdf] Ministry of Environmental Protection of the People's Republic of China. Available at:<http://trhj.mep.gov.cn/gtfwhjgl/zhgl/201611/P020161123507795479700.pdf>[accessed 21June2017] (in Chinese)

Ministry of environmental protection of the people's republic of China, 2006. Waste household and electronic products pollution control technology policy, Available at:<http://kjs.mep.gov.cn/hjbhbz/bzwb/wrfzjszc/200607/t20060720_91676.htm>[accessed 19 June 2016](in Chinese)

Ministry of Environmental protection of the people's republic of China, 2010b. *Technical specifications of pollution control for processing waste electrical and electronic equipment*, Available at:<http://www.csres.com/sort/Chtype/z05_2.html>[accessed 19 June 2016](in Chinese)

Ministry of Environmental Protection of the people's republic of China, 2010c. Eligible License of Waste Electrical and Electronic Products disposal . Available at:<http://www.mep.gov.cn/gkml/hbb/bl/201012/t20101217_198804.htm>[accessed 19 June 2016](in Chinese)

Ministry of Environmental Protection of the people's republic of China, 2010d. *Guide of Waste Electrical and Electronic Products Disposal Industry Subsidies Audit*. Available at:<http://www.mep.gov.cn/gkml/hbb/bgg/201011/t20101119_197717.htm>[accessed 19 June 2016](in Chinese)

Ministry of Environmental Protection of the people's republic of China, 2015b. *Guidelines for supervision of dismantling of waste electrical and electronic products*. Available at:<http://www.zhb.gov.cn/gkml/hbb/bgg/201506/t20150608_303147.htm>[accessed, 9 March 2017] (in Chinese).

Ministry of Environmental Protection of the people's republic of China, 2010e. *Guidelines of Waste Electrical and Electronic Products Development Planning*. of the people's republic of China <http://www.mep.gov.cn/gkml/hbb/bgg/201011/t20101116_197563.htm>[accessed, 9 March 2017] (in Chinese).

Ministry of Foreign Trade and Economic Cooperation of the People's Republic of China, General Administration of Customs of the People's Republic of China, and Environmental Protection Agency of the People's Republic of China (Now is Ministry of Environmental Protection of the People's Republic of China), 2002. *Announcement No.25 of 2002:Announcement of the Catalog of Prohibited Imported Goods (Fourth and Fifth)*, Available at:<http://www.customs.gov.cn/publish/portal0/tab515/info10600.htm>(in Chinese)

Ministry of Industry and Information Technology, 2006. *Administration Measures of Pollution Control of Electronic Information Products*. Available at:<http://www.gov.cn/flfg/2006-03/06/content_219447.htm> [accessed, 9 March 2017] (in Chinese)

Ministry of Industry and Information Technology, the National Development and Reform Commission of the People's Republic of China, Ministry of Science and Technology of the People's Republic of China, State Administration of Taxation of the People's Republic of China, Ministry of Environmental Protection of the People's Republic of China, Ministry of Commerce of the People's Republic of China, General Administration of Customs of the People's Republic of China, and General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China 2016. *Administration Measures for limitation of application of hazardous substances in electrical and electronic products*, Available at:<http://www.miit.gov.cn/n1146285/n1146352/n3054355/n3057254/n3057260/c4608532/content.html>[accessed, 9 March 2017] (in Chinese)

Ministry of Natural Resources & Environment of Malaysian, 2010. *Guidelines for the Classification of Used Electrical and Electronic Equipment in Malaysia*. Available at:<https://www.doe.gov.my/portalv1/wpcontent/uploads/2010/07/ECTRICAL_AND_ELECTRONIC_EQUIPMENTIN_MALAYSIA.pdf>[accessed 19 June 2016]

Montenegro, 2012. *Management of Waste Electrical and Electronic Equipment (WEEE)*, Available at:<http://www.sluzbenilist.me/PravniAktDetalji.aspx?tag={713A8ACA-B2D3-4136-969D-001B0E5CAB19} >[accessed 19 June 2016](in Crnogorski jezik)

Mundada, M.N., Kumar, S., and Shekdar, A.V., 2004. e-waste: a new challenge for waste management in India. *International Journal of Environmental Studies*, 61, pp.265-279.

National Bureau of Statistics of the People's Republic of China, 2016. *China Statistical Yearbook 2016*. Available at:<http://www.stats.gov.cn/tjsj/ndsj/2016/indexch.htm>[Accessed 21 March 2017] (In Chinese)

National Bureau of Statistics of the People's Republic of China, 2015. *China Statistical Yearbook 2015*. Available at:<http://www.stats.gov.cn/tjsj/ndsj/2015/indexch.htm <Access 2017/03/21>[Accessed 21 March 2017] (In Chinese)

National Bureau of Statistics of the People's Republic of China, 2014. *China Statistical Yearbook 2014*. Available at:<http://www.stats.gov.cn/tjsj/ndsj/2014/indexch.htm<Access 2017/03/21><In Chinese>

National Bureau of Statistics of the People's Republic of China, *China Statistical Yearbook 2013*. Available at:<http://www.stats.gov.cn/tjsj/ndsj/2013/indexch.htm>[Accessed 21 March 2017] (In Chinese)

National Bureau of Statistics of the People's Republic of China, 2012. *China Statistical Yearbook 2012*. Available at:<http://www.stats.gov.cn/tjsj/ndsj/2012/indexch.htm>[Accessed 21 March 2017] (In Chinese)

National Bureau of Statistics of the People's Republic of China, 2011. *China Statistical Yearbook 2011*. Available at:<http://www.stats.gov.cn/tjsj/ndsj/2011/indexch.htm>[Accessed 21 March 2017] (In Chinese)

National Bureau of Statistics of the People's Republic of China, 2010. *China Statistical Yearbook 2010*. Available at:<http://www.stats.gov.cn/tjsj/ndsj/2010/indexch.htm>[Accessed 21 March 2017] (In Chinese)

National Bureau of Statistics of the People's Republic of China, 2009. *China Statistical Yearbook 2009*. Available at:<http://www.stats.gov.cn/tjsj/ndsj/2009/indexch.htm>[Accessed 21 March 2017] (In Chinese)

National Bureau of Statistics of the People's Republic of China, 2008. *China Statistical Yearbook 2008*. Available at:<http://www.stats.gov.cn/tjsj/ndsj/2008/indexch.htm>[Accessed 21 March 2017] (In Chinese)

National Bureau of Statistics of the People's Republic of China, 2007. *China Statistical Yearbook 2007*. Available at:<http://www.stats.gov.cn/tjsj/ndsj/2007/indexch.htm>[Accessed 21 March 2017] (In Chinese)

National Bureau of Statistics of the People's Republic of China, 2006. *China Statistical Yearbook 2006*. Available at:<http://www.stats.gov.cn/tjsj/ndsj/2006/indexch.htm>[Accessed 21 March 2017] (In Chinese)

National Bureau of Statistics of the People's Republic of China, 2005. *China Statistical Yearbook 2005*. Available at:<http://www.stats.gov.cn/tjsj/ndsj/2005/indexch.htm>[Accessed 21 March 2017] (In Chinese)

National Bureau of Statistics of the People's Republic of China, 2004. *China Statistical Yearbook 2004*. Available at:<http://www.stats.gov.cn/tjsj/ndsj/yb2004-c/indexch.htm>[Accessed 21 March 2017] (In Chinese)

National Bureau of Statistics of the People's Republic of China, 2003. *China Statistical Yearbook 2003*. Available at:<http://www.stats.gov.cn/tjsj/ndsj/yearbook2003_c.pdf>[Accessed 21 March 2017] (In Chinese)

National Bureau of Statistics of the People's Republic of China, 2002. *China Statistical Yearbook 2002*. Available at:<http://www.stats.gov.cn/yearbook2001/indexC.htm>[Accessed 21 March 2017] (In Chinese)

National Development and Reform Commission of the People's Republic of China, Ministry of Environmental Protection of the People's Republic of China, Ministry of Industry and Information Technology of the People's Republic of China, Ministry of Commerce of the People's Republic of China, General Administration of Customs of the People's Republic of China and State Administration of Taxation of the People's Republic of China, 2015. Catalogue of Waste Electrical and Electronic Products for Disposal in China (II). No.5 Announcement. Available at:<http://www.sdpc.gov.cn/zcfb/zcfbgg/201502/t20150213_664456.html>[Accessed 21 March 2017] (In Chinese)

National development and reform commission of the People's Republic of China, 2012. *Annual report of comprehensive Utilization of Resources in China (2012)*, Available at:<http://www.ndrc.gov.cn/xwzx/xwfb/201304/t20130408_536294.html>[accessed, 9 March 2017] (in Chinese)

National development and reform commission of the People's Republic of China, 2014. *Annual report of comprehensive Utilization of Resources in China (2014)*,[pdf] National development and reform commission. Available at:<http://www.ndrc.gov.cn/gzdt/201410/W020141009609718583202.pdf>[accessed, 9 March 2017] (in Chinese)

National People's Congress of the People's Republic of China, 1989. *General Environmental Law*. Available at:<http://www.gov.cn/zhengce/2014-04/25/content_2666434.htm>[accessed, 9 March 2017] (in Chinese)

National People's Congress of the People's Republic of China, 1995. *Solid Waste Pollution Control Law*. Available at:<http://www.gov.cn/flfg/2005-06/21/content_8289.htm>[accessed, 9 March 2017] (in Chinese)

National People's Congress of the People's Republic of China, 2002. *Clean Production Promotion Law of the People's Republic of China*. Available at:<http://www.gov.cn/flfg/2012-03/01/content_2079732.htm>[accessed, 9 March 2017] (in Chinese)

National People's Congress of the People's Republic of China,2008. *Circular Economy Promotion Law of the People's Republic of China*. Available at:<http://www.gov.cn/flfg/2008-08/29/content_1084355.htm>[accessed, 9 March 2017] (in Chinese)

New York State Department of Environmental Conservations, 2010. *Electronic Equipment Recycling and Reuse*, Available at:<http://www.dec.ny.gov/docs/materials_minerals_pdf/ewastelaw2.pdf>[accessed 19 June 2016]

New Zealand Ministry for the environment, 2015. e-waste product stewardship framework for New Zealand Final Report, [online] Available at:<http://www.mfe.govt.nz/sites/default/files/media/Waste/e-waste-product-stewardship-framework.pdf>[accessed 22 June 2017]

Newfoundland and Labrador House of Assembly, 2012. *Newfoundland and Labrador regulation 85/12, Environmental Protection Act*, Available at:<http://www.assembly.nl.ca/legislation/sr/annualregs/2012/nr120085.htm>[accessed 19 June 2016]

Nnorom I. C. and Osibanjo O., 2008. Overview of electronic waste (e-waste) management practices and legislations, and their poor applications in the developing countries. *Resources, Conservation and Recycling*, 52, pp.843–858.

OECD, 2001. *Extended producer responsibility: a guidance manual for governments*. Paris: OECD.

Ogunseitan OA., 2013. The Basel Convention and e-waste: translation of scientific uncertainty to protective policy. *The Lancet Global Health*, [e-journal]1(6),313–314. doi: 10.1016/S2214-109X(13)70110-4.

Ongondo, F.O., Williams, I.D., and Cherrett, T.J., 2011. How are WEEE doing? A global review of the management of electrical and electronic wastes. *Waste Manag*. 31, pp.714-730.

Ongondo, FO., Willianms, ID., and Cherrett TJ. , 2011. How are WEEE doing? A global review of the management of electrical and electronic wastes. *Waste Management*, 31, pp.714-730.

Paben, J., 2017. *How China import policy could shape metals markets*. [on line] Available at: <https://resource-recycling.com/e-scrap/2017/09/28/china-import-policy-shape-metals-markets/>[accessed 22 Oct. 2017]

Pater, L.R. and Cristea, S.L., 2016. Systemic Definitions of Sustainability, Durability and Longevity. *Social and Behavioral Sciences*, 221(7), pp.362-371.

Peralta, G.L., and Fontanos, P.M., 2006. e-waste issues and measures in the Philippines. *Journal of Material Cycles and Waste Management*, 8, pp.34–39.

Province of Alberta, 2014. Environmental protection and enhancement act, Electronics designation regulation. Available at:<http://www.qp.alberta.ca/documents/Regs/2004_094.pdf>[accessed 12 March 2017]

Puckett J., and Smith T., 2002. Exporting harm: the high-tech trashing of Asia. [pdf] The Basel Action Network and Silicon Valley Toxics Coalition. Available at:<http://www.greenpeace.org/eastasia/Global/eastasia/publications/reports/toxics/2006/exporting-harm-the-high-tech-trashing-asia.pdf>[accessed, 9 March 2017]

Puckett, J. and L. Byster, 2002. Exporting Harm: The High-Tech Trashing of Asia, Available at:<http://svtc.org/wp-content/uploads/technotrash.pdf> [accessed 9 September 2016]

Radioactive and Hazardous materials committee, 2005. *A Joint Memorial Requesting the Secretary of Environment to Appoint a Task Force to Assess the problem of Electronic Waste and*

Make Recommendations for Recycling and Disposal. Available at:<https://www.env.nm.gov/swb/doc/EGS%20Final1.doc>[accessed 19 June 2016]

Republic of the Philippines department of environment and natural resources, 2015. *Guidelines on the environmentally sound management (ESM) of waste electrical and electronic equipment (WEEE)*. Available at:<http://www.emb.gov.ph/portal/Portals/25/Draft%20TechGuidelines%20on%20ESM%20of%20WEEE.pdf>[accessed 19 June 2016]

Robinson, B.H., 2009. e-waste: an assessment of global production and environmental impacts. *Science of the Total Environment*,408, pp.183–191.

Schwarzer, S., De Bono, A., Giuliani, G., Kluser, S., and Peduzzi, P., 2005. *E-waste, the hidden side of IT equipment's manufacturing and use*. [pdf] United Nations Environment Programme. Available at:<https://archive-ouverte.unige.ch/unige:23132>[accessed 19 June 2017]

Schwarzer, S., De Bono, A., Giuliani, G., Kluser, S., and Peduzzi, P., 2005. E-waste, the Hidden Side of IT Equipment's Manufacturing and Use. Available at:< http://www.grid.unep.ch/products/3_Reports/ew_ewaste.en.pdf> [accessed 5 December 2016].

SERI, 2013. The responsible recycling("R2") Standard for electronics recyclers. [pdf]SERI. Available at:<https://sustainableelectronics.org/sites/default/files/R2-2013%20Standard%20%5BENGLISH%5D.pdf>[accessed 19 June 2016]

SERI, n.d.. *About SERI*. [online] Available at:<https://sustainableelectronics.org/about>[accessed 19 June 2016]

Setp, n.d.. *StEP e-waste world map,* Available at:< http://www.-initiative.org/step-e-waste-world-map.html>[accessed 19 June 2016]

Sierra Club, 2014. *ZERO WASTE – PRODUCER RESPONSIBILITY*. [Online] Available at:<https://content.sierraclub.org/grassrootsnetwork/teams/zero-waste-producer-responsibility> [accessed 5 December 2016].

Singapore national environment agency, n.d.. *National Recycling Programme.* [online] Available at:<http://www.nea.gov.sg/energy-waste/3rs/national-recycling-programme>[accessed 19 June 2016]

Solid Waste Management Centre of Ministry of Environmental Protection of the People's Republic of China, 2013. *Management points of waste electrical and electronic products*. [on line] Available at:< https://max.book118.com/html/2016/0121/33733856.shtm>[accessed 22 June 2017]

Song, Q., Li, J., Liu, L., Dong, Q., Yang, J., Liang, Y., and Zhang, C., 2016. Measuring the generation and management status of waste office equipment in China: A case study of waste printers. *Journal of Cleaner Production*, 112, pp.4461-4468.

State Administration of Taxation of the People's Republic of China, 2012. *Notice about "Regulations on Collection and Administration of the e-waste Processing Fund"*. Available at:<http://www.chinatax.gov.cn/n810341/n810765/n812151/n812401/c1082760/content.html>[accessed, 9 March 2017] (in Chinese)

Staub, C., 2017. *Electronics not named in China's imports ban*. [on line] Available at: < https://resource-recycling.com/e-scrap/2017/07/20/electronics-not-named-chinas-imports-ban/?>[accessed 22 Oct. 2017]

StEP, 2005. *Solving the e-waste problem: a synthetic approach (StEP), Draft Project Document*. Available at:<http://step.ewaste.ch.>[accessed 5 December 2016].

StEP, 2014. One Global Definition of e-waste. *Solving the e-waste Problem (Step)* White Paper,[pdf]Setp. Available at:<http://www.stepinitiative.org/files/step/_documents/StEP_WP_One%20Global%20Definition%20of%20e-waste_20140603_amended.pdf>[accessed 19 June 2016]

StEP, 2016. *United States of America overview of e-waste related information*, Available at:<http://www.step-initiative.org/Overview_USA.html>[accessed 19 June 2016]

StEP, n.d. *StEP e-waste world map*. Available at: <http://www.step-initiative.org/step-e-waste-world-map.html> [accessed 25May2017]

StEP, n.d..World overview of e-waste related information. Available at :<http://www.step-initiative.org/overview-world.html>[Accessed 21 March 2017]

Sustainable Electronics Initiative, 2010. Summary of U.S. State Laws on Electronic Waste and Disposal Bans. Available at:<https://www.ideals.illinois.edu/bitstream/handle/2142/16301/State%20Legislation_May09.pdf?sequence=2>[accessed 19 June 2016]

The General Assembly of State of Colorado, 2012. Senate Bill 12-133, Available at:< http://www.leg.state.co.us/clics/clics2012a/csl.nsf/fsbillcont/BE40677619E5656187257981007F374C?Open&file=133_eng.pdf>[accessed 22 June 2017]

The General Assembly of the State of Indiana, 2007. *Indiana Administrative Code, Electronic Waste Management Regulations*. Available at:<www.in.gov/legislative/iac/T03290/A00160.PDF>[accessed 12 March 2017]

The General Assembly of the State of Indiana, 2009. House enrolled act No. 1589. [pdf] Available at:< http://www.in.gov/legislative/bills/2009/PDF/HE/HE1589.1.pdf >

The ministry of commerce of the people's republic of China, 2006. *Administrative Measures on the Collecting of Renewable Resources*. Available at:<http://file.mofcom.gov.cn/article/gkml/200804/20080494612114.shtml>[accessed 19 June 2016]

The state Council Information Office of the People's Republic of China, 2011. *Legal system with Chinese Socialism characteristics*. Available at:<http://www.gov.cn/zwgk/2011-10/27/content_1979526.htm>[accessed, 9 March 2017] (in Chinese).

The state Council of the People's Republic of China, 2009. *Regulation on the Administration of the Recovery and Disposal of Waste Electrical and Electronic Products [Effective]*. Available at:<http://www.gov.cn/zwgk/2009-03/04/content_1250419.htm >[accessed, 9 March 2017] (in Chinese).

Tong, X. and Wang, J., 2004. Transnational Flows of e-waste and Spatial Patterns of Recycling in China. *Eurasian Geography and Economics*, 45(8), pp.608-621.

Townsend, TG., 2011. Environmental Issues and Management Strategies for Waste Electronic and Electrical Equipment. *Journal of the Air & Waste Management Association*, 61(6), pp.587-610. DOI: 10.3155/1047-3289.61.6.587

U.S. International Trade Commission, 2013. Used electronic products: an examination of U.S. exports, [pdf] Washington, DC. Available at:<https://www.usitc.gov/publications/332/pub4379.pdf>[accessed 19 June 2016]

United Nations University and Institute for the Advanced Study of Sustainability, 2015. E-waste Statustics Guidelines on Classification, Reporting and Indicators. [pdf] Available at :< http://i.unu.edu/media/unu.edu/news/49515/E-waste-Guidelines_Partnership_2015.pdf>

United States Environmental Protection Agency, 2011. Electronics Waste Management in the United States Through 2009, EPA 530-R-11-002. [pdf] Available at:<http://www.epa.gov/wastes/conserve/materials/ecycling/docs/fullbaselinereport2011.pdf>

Uniter States Environmental Protection Agency, 2017. *Certified Electronics Recyclers*. [online] Available at:<http://www.epa.gov/smm-electronics/certified-electronics-recyclers>[accessed 12 March 2017]

Vermont Department of Environmental Conservation, 2010. No. 79 An act relating to the recycling and disposal of electronic waste. Available at:<http://www.leg.state.vt.us/docs/2010/Acts/ACT079.pdf>[accessed 19 June 2016]

Wang, F., Huisman, J., Stevels, A., and Baldé, C., 2013. Enhancing e-waste estimates: Improving data quality by multivariate Input–Output Analysis. *Waste Management*. 33(11), pp.2397-2407.

Washington Department of Ecology, 2006. *Electronic Product Recycling Law*. Available at:<http://apps.leg.wa.gov/Rcw/default.aspx?cite=70.95N&full=true#70.95N.020>[accessed 19 June 2016]

Wasswa,J., Uganda Cleaner Production Centre, Kampala/Uganda Mathias Schluep, Empa, and St.Gallen/Switzerland, 2008. *e-waste Assessment in Uganda*. Available at:<http://www.unido.org/fileadmin/user_media/Services/PSD/ICT/E_Waste_Study.pdf>[accessed 19 June 2016]

Wei, L. and Liu, Y., 2012. Present Status of e-waste Disposal and Recycling in China. *Procedia environmental science*, 16, pp. 506-514.

Widmer, R., Oswald-Krapf, H., Sinha-Khetriwal, D., Schnellmann, Max., and Böni, H., 2005. Globalperspective on e-waste. *Environmental Impact Assessment Review*, 25, pp.436-458.

World Trade Organization, n.d.a. *Members and Observers*. [on line] Available at:< https://www.wto.org/english/thewto_e/whatis_e/tif_e/org6_e.htm>[accessed 22 June 2017]

World Trade Organization, n.d.b. *Who are the developing countries in the WTO*. [on line] Available at:<https://www.wto.org/english/tratop_e/devel_e/d1who_e.htm>[accessed 22 May 2018]

World Trade Organization,2015. *International Trade Statistics 2015*, Available at:< https://www.wto.org/english/res_e/statis_e/its2015_e/its2015_e.pdf Access 2/24/2017>[accessed 24Februry2017]

Wynne, B., 1987. Risk Management and Hazardous Waste. Berlin: Springer-Verlag.

X. Zhu, R. Lane and T.T. Werner., 2017. Modelling in-use stocks and spatial distributions of household electronic devices and their contained metals based on household survey data. *Resources, Conservation and Recycling*, 120, pp. 27-37.

Yang, J.X., Lu, B., and Xu, C., 2008. WEEE flow and mitigating measures in China. *Waste Management*, 28 (9), pp.1589–1597.

Yang, W.H., 2008. Regulating electrical and electronic wastes in China. *Review of European Community and International Environmental Law*,17 (3), pp.337–346.

Yoshida A, Tasaki T, and Terazono A, 2009. Material flow analysis of used personal computers in Japan. *Waste Management*, 29, pp.1602-14.

Yu, H., Zhou, B., Ju, H., Li, S., Zheng, Y., and Wang, J., 2006. Study on Catalog of Imported Waste. *Journal of Environmental Engineering Technology*, 1, pp.85-89.

Yu, J., Williams, E., Ju, M., and Shao, C., 2010. Managing e-waste in China: Policies, pilot projects and alternative approaches. *Resources, Conservation and Recycling*, 54(11), pp.991-999.

Zeng, X., Duan, H., Wang, F., and Li, J., 2017. Examining environmental management of e-waste: China's experience and lessons. *Renewable and Sustainable Energy Reviews*, 72(1), pp.1076-1082.

Zeng, X., Gong, R., Chen, WQ., and Li, J., 2016. Uncovering the Recycling Potential of "new" WEEE in China. *Environmental Science and Technology*, 50(3), pp.1347-1358.

Zhang, S., Ding, Y., Liu, B., Pan, D., Chang, C., and Volinsky, A., 2015. Challenges in legislation, recycling system and technical system of waste electrical and electronic equipment in China. *Waste Management.* 45, pp. 361-373.

Zheng G, Xu X, Li B, Wu K, Yekeen TA, and Huo X., 2013. Association between lung function in school children and exposure to three transition metals from an e-waste recycling area. *J Expo Sci Environ Epidemiol*, 23, pp.67–72.

Zhou, L., and Xu, Z., 2012. Response to waste electrical and electronic equipments in China: Legislation, recycling system, and advanced integrated process. *Environmental Science and Technology*. 46(9), pp. 4713-4724.

APPENDIX I

Catalogue of Waste Electrical and Electronic Products for Disposal in China (National Development and Reform Commission of the People's Republic of China, 2014) (translated)

No.	Category	Product Range
1	Refrigerator	Refrigerator-freezers (cabinet), freezers (cabinet), refrigerated box (cabinet) and other cold insulation boxes consumpting energy for refrigeration system.(Volum≤800L)
2	Air Conditioners	Overall air conditioner (window unit, wall type, .), split air conditioners (split wall, split unite, .), multi-split air conditioner and other air conditioner with cooling capacity less than 14000W.
3	Range Hood	Deep suction and exhaust hood, European tower suction hood, side suction suction hood and other electric appliances installed in the upper part of the stove forcollecting and disposal of contaminated air.
4	Washing Machine	Loading washing machine, drum type washing machine, stirring type washing machine, dryer and other appliances rely on the mechanical action to wash clothes (including drying function, and drying volume ≤10Kg) .
5	Electronic Water Heater	Storage type electric water heaters, fast heat water heaters and other appliances that convert electrical energy into heat energy and transfer heat energy to water to produce water at a certain temperature (capacity ≤500 liters).
6	Gas Water Heater	Transfer the heat to the cold water through the heat exchanger by means of combustion heating to achieve the purpose of producing hot water (heat load ≤ 70kw).
7	Printer	Laser printers, inkjet printers, dot matrix printers, thermal printers, and other devices that work online with computers or use cloud printing platforms to convert digital information into text and images and output them in hardcopy, including print-based mathineswith other functions(printing format <A2, printing

		speed ≤ 80 / min).
8	Copyer	Electrostatic copiers, inkjet copiers and other equipment that produces copies using a variety of different imaging processes, including copy-based equipment with other functions (print format <A2, printing speed ≤80 sheets / min).
9	Fax Machine	Applying of scanning and photoelectric conversion technologies, the communication terminal equipment convert the text, graphics, photos and other still images into electrical signals and sent out; and receive electrical signals and convert back into a copy, including fax-based devices with other functions .
10	TV Set	Cathode ray tube (black and white, color) TV, Plasma TV, LCD TV, OLEDTV, rear projection TV, mobile TV receiving terminal and other terminal equipment for receiving the signal and restore the image and sound.
11	Monitor	Image output devicewhich apply the display device as the core(excluding the tuner), like cathode ray tube (black and white, color) monitors, LCD monitors, .
12	Microcomputer	Desktop microcomputer (all in one PC included) and portable microcomputers (including PDAs) and other information transaction processing entity.
13	Mobile Communication Handset	Devicessend or receive sound or image signals between two locations through the cellular network of electromagnetic waves, like GSM handsets, CDMA handsets, SCDMA handsets, 3G handsets, 4G handsets, PHS and other handheld.
14	Telephone	PSTN ordinary telephone, Internet telephone (IP telephone), special telephone and other communications equipment Which canconvert sound energy and electronic energy.