Economic analysis of EPR policy in South Korea

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Executive summary

The EPR principle of OECD is still in a developing stage and has different interpretations. Due to this ambiguity, EPR tends to be used as a generic name of environmental policy in the field of waste management. Against this background the objective of this study is to clarify the economic reasons of EPR and the appropriate goal of EPR itself. Based on the clarified EPR principle, this study aims to examine whether this principle functions effectively in the EPR policy of Korea.

This study clarifies the critical features of OECD' EPR and its limitation. To summarize, the most critical feature of OECD's EPR is to promote producers to take waste management costs into consideration in manufacturing by imposing on them responsibility for waste management. Meanwhile, OECD's EPR may have a limitation because it depends on the producers' decision how to minimize waste management cost by either reducing it in the production phase or in the disposal phase.

This study examines the functions and limitations of EPR policy in practice based on three case studies of Korea. It suggests that EPR policy in Korea focuses on the disposal phase rather than the production phase, and may lead to different outcomes, i.e. reduction of producer's economic responsibility and transfer of negative externalities abroad against the intention of OECD's EPR.

Some of the key findings of this study are outlined as follows. (1) The EPR policy of Korea focuses on waste stream by promoting recycling of producers. At the same time it allows exports of collected waste as a legitimate recycling manner to curb the economic burden on producers. (2) Based on the waste volume generated in Korea, the collection rates of the five targeted WEEE are below 30% in 2009; 7% of air-conditioner, 15% of mobile phone, 26% of refrigerator, 23% of television and 28% of washing machine. (3) The recycling rate of metal packaging dropped from 59% in 2000 to 40% in 2011 and recycling volume dropped accordingly. (4) The cost-benefit incidence analysis of the metal packaging recycling program showed that net social benefits decreased by 2.8 billion won (2.5 million US dollars), while the net benefits to producers increased by 1.9 billion won under the EPR program compared with the WDR program. These changes in costs and benefits mainly resulted from a decrease in the amount of recycling, which ultimately increased costs for landfill disposal. (5) According to the cost-benefit incidence analysis of international recycling of used CRT computer monitors against domestic recycling, in total, the net benefits from international recycling are estimated as at most 785 KRW per unit. However, it implies that the larger concern is the health and environmental costs in Vietnam, the smaller net benefit generated from the international recycling program globally.

This dissertation unfolds as follows:

Chapter 1 presents the background, objectives and research questions of this study.

Chapter 2 explores the economic reasons of EPR based on reviews of economic arguments

and discussions by OECD. Additionally, features of Korea’s EPR policy are highlighted in comparison with the EPR policies of Germany and Japan.

Chapter 3 estimates the collection rates of WEEE based on the waste generation. The volume of WEEE generated in Korea was estimated with the population balance model.

In Chapter 4 collection rates of metal packaging were estimated with the governmental statistics. It shows the changes of cost burden of producer and society by EPR policy in comparison to the WDR program with the methodology of cost-benefit incidence analysis.

Chapter 5 clarifies the practice of international recycling with a case study of used computer monitors. This chapter shows the international recycling of Korea against domestic recycling brings economic benefits to the EPR producers and exporters, and ecological benefit to the Korean society. It is verified based on the estimates and analysis of the export rates of WEEE and the export destination from Korea, cost-benefit incidence analysis, and field research.

Chapter 6 comprehensively discusses the research findings of chapter 2-5, and in Chapter 7 main findings of this study are summarized as conclusion.

要約

本論文は、循環型社会を形成する上で重要な費用負担原理である拡大生産者責任(以下 EPR)についてその経済理論的根拠、目的及び限界を議論し、その実際を韓国の事例研究で検証したもので、7 章から構成される。

第 1 章では、研究目的と課題を論じている。研究目的は EPR の理論と実際の相違点を韓国の事例をもって議論し韓国 EPR の実際の機能と限界を示すことで、研究課題は 3 つあり、1 つ目は EPR の理論と韓国の EPR 政策との相違点を明らかにすること、2 つ目は韓国における EPR 政策の環境成果を検証すること、3 つ目は EPR 政策がもたらした社会費用便益の変化を検証することである。

第 2 章は OECD と経済学の議論における EPR の規範的根拠と目的を論じた上で韓国の EPR 政策の特徴を明らかにした。すなわち、経済学の議論における EPR の目的は廃棄物の発生抑制で、OECD の EPR は環境配慮設計による廃棄物削減で必ずしも廃棄物の発生を予防するようなものではない。韓国 EPR 政策はリサイクル促進の側面が強く環境配慮設計を促す政策手段の追加が望ましい。

第 3 章は 5 つの電子機器において EPR 政策による再活用率を推計した。その結果、特に 2006 年以降冷蔵庫以外の品目で若干の増加が見られた。この章では小幅ではあるが EPR 政策のリサイクル促進による廃棄物削減が示された。

第 4 章は金属缶の再活用率と費用便益を分析した。その結果、廃棄物預託金政策のときより EPR 政策のもとで再活用量と率ともに減少したことが分かった。その理由は、EPR 政策以降再活用実績の買取単価の高いアルミニウム缶の消費量が以前より増加したため、生産者は再活用量を以前より減少させ費用負担の増加を抑えているからである。この章では、EPR への制度変更を行ったにもかかわらず、実質的には生産者の費用負担の責任は拡大されず埋立地節約を含む社会便益が減ったことが示された。

第 5 章は有害性の高い中古パソコンモニタの輸出に関し、輸出率、輸出先及び輸出による韓国社会への費用便益を分析した。その結果、国内リサイクルと比べ輸出によって生産者、輸出業者、政府に純便益が生じていることが分かった。また、輸出による外部不経済の拡散の可能性が示唆された。

第 6 章では第 2 章の EPR 理論分析に照らし第 3～5 章の事例研究の検証結果を総合的に考察することによって、韓国の EPR 政策はリサイクル促進を重視するものの EPR にとって欠かせない特徴である環境配慮設計が弱いもので、輸出などを通して生産者の支払額の増加を避けており廃棄物に対する実質上の生産者の経済的責任は拡大されていない可能性が示唆された。

第 7 章の結論では本論文で明らかにした点と今後の課題をまとめている。

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Chapter 1 Introduction

1.1 Background

The industrialized economies have experienced an ever-increasing volume of solid wastes, and the early measure was the cheapest disposal such as landfill (Turner and Thomas, 1983). However, landfill sites have been rapidly running out of and the costs of disposal of these wastes have also escalated. Furthermore the widespread uneasiness over environmental hazards caused by bad landfill practices has led to strong resistance to the siting of waste management facilities. It has caused further cost increase due to the adoption of expensive environmental safeguards.

The government recognized gradually that the public waste management with general tax or with low charge has a limit to decrease waste volume because waste dischargers do not have economic incentives to reduce wastes (Ueta, 1999). Additionally the government awakened that a preventive policy is required rather than end-of-pipe strategies (Gunjima, 1995).

In this background, OECD started the project on EPR in 1994 and led dozens of publications including *EPR-guidance manual for governments* (OECD, 2001). Also, The OECD (2007) introduced the EPR policy as one of the tools for Environmentally Sound Management of Waste. As of 2014 most OECD countries are implementing EPR programs in key sectors (OECD and JMOE, 2014). Also, emerging economies in Asia, Africa and South America have also started to develop EPR program in recent years (Manomaivibool and Hong, 2014).

OECD defines EPR as an “environmental policy approach in which a producer’s responsibility for a product is extended to the post-consumer stage of a product’s life cycle” (OECD, 2001: 9). However, OECD gives little guide about which particular aspect of waste problem OECD’s EPR tries to remedy. OECD only states that “an effective EPR scheme is the establishment of clear policy goals and program objectives”(OECD, 2001: 28) and actually leaves it to governments to set a policy goal of their EPR scheme. EPR can be used as a generic name of waste management policy in which producers take some roles.

There are various points of view on EPR. Lindhqvist (2000) defined that EPR is to promote the improvement of the whole life cycle of product system. Especially Walls (2004) and Tojo (2008) focused the aspect of design for environment of products in production phase by EPR. In developing countries, EPR is often viewed as a waste reduction strategy focusing on waste stream to promote collection and recycling by target-based system (Manomaivibool, 2011).

Development of EPR in Korea

Faced with increasing waste generation and shortage of landfill sites, South Korea implemented the waste deposit recycling (WDR) policy in 1991. The WDR policy imposed a product charge on producers in proportion to their production output, and refunded part of the total deposit to producers once discarded metal packaging was recycled. The Korean government replaced the WDR policy with the EPR policy in 2003. The EPR policy requires mandatory recycling of producers with binding targets and fines for noncompliance.

There are mainly three factors which influenced on the policy shift from the WDR to EPR policy. Firstly, WDR policy was criticized by the industry with reasons of excessive cost-burden on producers, weakening of competitive power and inefficient use of ‘unreturned deposit’ by the government (Shin, 1995; Yu et al., 1998; Lee, 2010). As a result, the deposit rate was not able to set to high enough to obtain the noticeable recycling achievement. The deposit money of WDR program was averagely only below 25% of the actual collection and recycling cost on average (Chang et al, 1999). The WDR program was abolished in 2001 due to the lack of political consensus on cost allocation and insufficient recycling performance (Kim et al. 2006).

Secondly, due to the 1997 financial crisis of Korea, it became hard to maintain charge programs which were suspected to weaken business competitiveness. In early 2000s not only WDR but also many other charge programs on producers were criticized as well. In 2001 nine of charge programs were abolished and one of which was the WDR policy (KMOSF, 2002).

Thirdly, since the EPR policy got backing of OECD and was already implemented by many OECD countries, the government acquired easily a social agreement by appealing EPR as “a policy of developed countries” (KMOE, 2003a: 514) and a policy for strengthening environmental policy at OECD level (KMOE, 2003a: 7).

1.2 Research objective, questions and structure of the dissertation

OECD’s EPR principle can be variously interpreted and remains ambiguous whether EPR is focusing on the waste management, the production phase of products or a combination of these. The objective of this study is to clarify the economic reasons of EPR and the appropriate goal of EPR itself. Based on the clarified EPR principle, this study aims to examine whether this principle functions effectively in the EPR policy of Korea. In order to achieve this purposes, the study raises three research questions. At first it asks (1) how different is the EPR policy of Korea with the EPR of economic theory and the OECD’ EPR. Secondly it examines based on empirical studies (2) how much has the current EPR policy reduced waste and (3) how is the costs and benefits accrued from waste management changed after EPR policy.

With respect to the first research question, chapter 2 explores EPR theory in economic arguments and OECD’s discussion. Additionally features of the EPR policy in Germany, Japan and Korea are highlighted.

With respect to the second research question, chapter 3 estimates collection rates of WEEE based on the waste generation. The volume of WEEE generated in Korea is estimated with the population balance model. In chapter 4, collection rates of metal packaging are estimated with the governmental statistics. Additionally, chapter 5 estimates the export rate of used electronics.

With respect to the third research question, chapter 4 shows the changes of cost burden of the EPR producer and society by EPR policy in comparison to the WDR program with the methodology of cost-benefit incidence analysis. Additionally chapter 5 shows the additional economic costs and benefits of the international recycling to the Korean society against domestic recycling based on the cost-benefit incidence analysis.

Chapter 6 comprehensively discusses the research findings of Chapter 2-5 and in Chapter 7 main findings of this study are summarized as conclusion.

Chapter 2 Theory and practice of EPR

2.1 Introduction

OECD defines “EPR as an environmental policy approach in which a producer’s responsibility for a product is extended to the post-consumer stage of a product’s life cycle” (OECD, 2001: 9). Even though EPR is still in a developing stage as a policy measure (Ueta, 2004) and not clear, the number of countries which have adopted EPR policy is increasing and their EPR policies in action are largely different.

Because EPR is still not a definitive policy concept, various points of view on EPR are existing. Lindhqvist (2000) defined that EPR is to promote the improvement of the whole life cycle of product system. Ishikawa (2010) defined that the goal of EPR is to prevent waste generation caused by overconsumption and to redesign products for cost minimization of waste management. Walls (2004) and Tojo (2008) focused especially the aspect of design for environment of products. On the other hand, in developing countries, EPR is often regarded as a waste minimization strategy focusing on waste stream to promote collection and recycling by target-based system (Manomaivibool, 2011). Questions still remains what is the most decisive role for EPR and how it is possible to design tha EPR policy to play that role effectively.

This section aims to clarify the economic reasons of EPR in economic theoretical researches and OECD discussions by reviewing the previous researches. Furthermore actual EPR schemes in Germany, Japan and Korea are analyzed based on the EPR principle.

2.2 EPR in economic arguments

Based on some selected previous researches which are often cited in the EPR discussion, this section explores economic instruments for solving the waste problems and especially the economic reasons why producers are preferred as payer for the external costs.

For the policy goal to reduce the amount of municipal solid waste, Dinan (1993) examined virgin material tax, and an alternative policy. The alternative policy is a combination of landfill disposal tax on producers for their outputs and the subsidy to all end users of recovered materials in manufacture. It demonstrated that the alternative policy obtains the optimal resource allocation, i.e. the optimal production level. Additionally it demonstrated that this combined tax and subsidy is theoretically consistent with unit-based household charges, but is preferred because unit- based charges provide households incentives for illegal disposal and are practically difficult to administer.

Fullerton and Wu (1998) suggested five various policy sets combined with tax and subsidy, and one policy set combined with producer’s take-back requirement and a tax for negative externalities. Negative externalities includes aesthetic or health costs on neighbors by landfill disposal, air pollution and hazardous residue by incinerator, and noise, odor and litter by collection trucks etc.(Fullerton and Wu, 1998: 134). The reason why the tax for negative externalities is imposed on producers even in the producer’s take-back requirement is that the market price for garbage disposal does not account for all social costs of negative externalities

(Fullerton and Wu, 1998: 143).

The policy options by Fullerton and Wu presume a perfect separate collection of packaging garbage and products, and well-functioning recycling market, i.e. recyclability of a product designed by producer should be thoroughly recycled in the market. It means that transaction costs in recycling market are ignored in the model.

Calcott and Walls (2000) assume a recycling market in which transaction costs high. In order to solve this problem, Calcott and Walls (2000) impose two taxes on producers and a subsidy; a disposal tax for social cost of garbage, a product tax based on recyclability and a subsidy to recyclers to make up for transaction costs. The former taxes can be replaced with taxes on households. However Calcott and Walls recommended the taxes on producer due to illegal dumping of households (Calcott and Walls, 2000: 235).

Common characteristics of economic solutions

All the economic solutions reviewed in this section have two characteristics in common. The first common characteristics is that social costs composed of garbage disposal costs and costs for negative externalities are fully internalized by tax. It means that the primary payer of the social costs changes from the public sector to the private economic agents in the market. Through the internalization of all social costs, the quantity supplied of any good is determined with reflection of the social costs associated with waste disposal. It is noteworthy that it is not always producers to pay these whole social costs. In some model consumers or households pay this social costs of wastes disposal. Also, it is not always that the local governments have to stop the physical task of waste collection.

The second characteristics is the incentive mechanism for improvement of product’s recyclability. Tax and subsidy are applied directly to producers or consumers to create the price signals favorable to recyclability of products, e.g. if producers produce a product with high recyclability, they can save costs imposed by tax inversely proportional to recyclability. However, recyclability in the reviewed articles is a neutral concept because it is understood in the context of optimal resource allocation. Recyclability or recycling is not a goal itself.

Why producers?

The economic solutions reviewed above assume many idealistic conditions. Among them, producer’s take-back requirement by Fullerton and Wu (2000) is supported because it has fewer barriers in practice than other instruments in three aspects. Firstly households have no incentive for illegal dumping. Secondly, it does not require a complete recycling market and a thorough separate collection (packaging and product). Thirdly, it requires relatively small amount of information because only one tax for negative externalities is to be fixed, while other policy options require plural taxes and subsidies to be fixed.

2.3 OECD’s EPR

Background: the segmented decision making process creating mass waste producing society

OECD pays attention to the decision making process in the market as a fundamental cause to create the waste problem. It can be noticed with the sentence: “environmental degradation is not just an incidental and unwanted result of some minor deficiencies in the economic process. Rather, its roots may go as deep as the decision-making process mechanisms at work within the market (OECD, 2001: 17p)”. The cycle of products encompassing production, distribution, consumption and waste disposal is segmented and decided by different economic agents based on their own priority for profit maximization. This segmented decision making process creates a mass production and mass waste producing society and it led our society to a deviation of optimal production and pollution level.

> In each process of production, distribution, consumption and disposal, each economic agent makes decisions of their actions based on their own principles such as profit maximization (…). As long as the public sector does not make any interference with these decision-making processes, the adjustment by the market mechanism works to create a system where production, distribution, consumption and disposal are done without giving consideration to the waste management, thus establishing a socioeconomic system with mass waste production. (…) Let us call a society with such socioeconomic system a “Segmented Society”.” (Ueta, 2004:289)

Why producer?

In many cases, municipalities carry out separate collection in order to reduce wastes for landfill disposal. However, this public waste management system has limitation to prevent the mass production and mass waste producing society, because it is not capable to reduce waste at source. It is necessary to make producer to take waste management costs into consideration from the production phase.

In order to incentivize producer to consider waste management costs in the production phase, it is possible that the government intervenes in the market by means of economic instruments such as tax or charge. However, OECD believes that in reality price signals created by economic instruments of the government have limitation to achieve efficiency and administration costs of the government are excessive. Therefore in order to achieve efficiency of resource use, i.e. to prevent mass production and waste producing society, it is required to influence on producers explicitly.

> Some OECD governments believe that in practice the price signals (…) are not being transmitted effectively up and down the product chain. (…) the administration costs associated with targeting waste flows with different environmental impacts may be excessive due to the complex nature of household

waste (OECD, 2001: 21).

In the same context, OECD recommends EPR rather than a unit-based waste fee (OECD, 2001: 49). Because OECD believes that price signals created by the unit-based waste fee in the disposal phase are hardly transmitted to producers and will not lead to a change in production phase. In this regard, OECD defines producers who "are most able to alter products to prevent waste, minimize waste management costs" (OECD, 2001: 59) and "the greatest control over decisions relating to materials selection and product design (OECD, 2001: 12)".

What is EPR?: Producer's economic- and physical responsibility

OECD' EPR is to shift of responsibility for waste management upstream toward the producer away from municipalities (OECD, 2001). OECD suggests EPR as "a means towards the privatization of waste management" (OECD, 1998: 48). OECD claims that "the complete 'privatization' of the financing post-consumer product management would tend to maximize the private sector's incentives to reduce waste (OECD, 1998: 16)". It means that the government is recommended to stop financing the waste management from general tax, and to charge the full costs of waste management to private sector, because it more incentivize them to reduce wastes winding up in the landfill sites than under the traditional public waste management.

Even though OECD supports the "complete privatization of the full financing of post-consumer product management" (OECD, 1998: 16), in reality OECD does not insist that producers should take the full financing responsibility for the collection, recycling and disposal.

Producers' economical responsibility is divided into two types: "full financial responsibility" (OECD, 2001: 60) and partial financial responsibility. The full financial responsibility is a type that producers primarily bear the full costs of waste management. The partial financial responsibility is a type which producers and local government share the costs of waste management.

With regard to physical responsibility, OECD also does not insist on a scheme that producers take the whole physical responsibility of collection and recycling. OECD's EPR rather put emphasis on a recycling scheme based on sharing the responsibility, in which every concerned private agent shares the physical responsibility.

> The achievement of EPR objectives will require the collaboration of all of society. Because physical responsibility for the product at different moments in its life cycle is placed upon actors other than the producer (OECD, 1998: 10)

OECD emphasizes that "communication and co-ordination with all actors in the product chain is vitally important to the success of the EPR policy and program" (OECD, 2001:62). Additionally OECD recommends that a "communication strategy should be devised to inform all the actors in the product chain including consumers about the program and to enlist their support and co-operation" (OECD, 2001: 28). It implies that OECD's EPR policy does not depend on an economic mechanism which provides incentives transmitted by price signals to induce the individual economic agent to act the required behavior without a special coordination and communication strategy. In this regard, it is considered that OECD's EPR is closer to a direct regulation, rather than economic instruments.

2.4 Comparison between OECD's EPR and EPR in economic arguments

This section compares between producer's take-back requirement by Fullerton and Wu (1998) in economic arguments and OECD's EPR. There are mainly four different points. First, definition of social costs associated waste management is different. In the economic arguments, the social costs refer not only to collection, transport and processing of waste, but also all negative externalities such as "aesthetic or health costs on neighbors, an incinerator generates air pollution and hazardous residue, and collection trucks create noise, odor, and litter" (Fullerton and Wu, 1998: 134). This social costs are marked as the sum of A and B in the Figure 2.1. Meanwhile, the social costs in OECD's EPR cover only those costs which municipalities pay generally by tax (the circle A in the Figure 2.1).

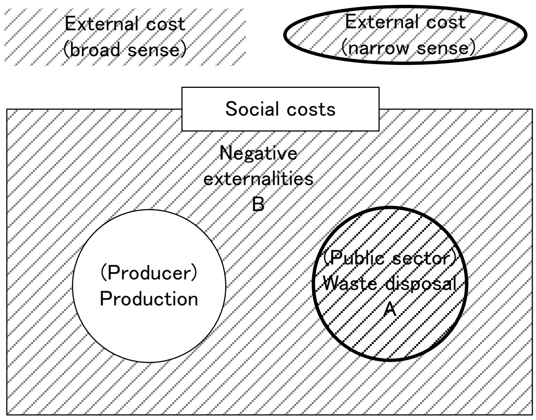

Fig. 2.1 External costs in economic arguments and OECD's EPR
Source: Author

Second, the degree of producer's payment is different. In the producer's take-back requirement, the social costs are fully internalized into the product price. Meanwhile, OECD's EPR covers the external costs in the narrow sense or a part of it.

Third, in the producer's take-back requirement, producers are imposed to pay the costs for negative externalities proportional to the production of ultimate waste and thus producers have incentive to reduce production scale of such products. Meanwhile, OECD's EPR require producers to manage wastes discarded and thus it depends on producers' decision whether they reduce production scale or manage after products discarded.

2.5 EPR in practice of Germany, Japan and Korea

This section outlined the EPR policy of Germany, Japan and Korea and highlighted the characteristics of the EPR policy of Korea (Table 2.1). Germany and Japan are selected because they represent the type of the full financial responsibility and the partial financial responsibility, respectively.

Table 2.1 EPR practices of packaging and containers in Germany, Japan and Korea

	Germany	Japan	Korea
Type of responsibility	Full cost	Partial cost	Recycling credit purchase
Collection financing	Producer	Municipality	Municipality and private collector
Recycling financing	Producer	Producer	Producer for designated volume
Target item	All packaging put into circulation in market	Glass, PET, Plastic, Paper packaging	Glass, PET, Plastic, and selected paper packaging, metal can
Duty	♦Recovery: 65% of all packaging ♦Reusable packaging: 80% of beverage container ♦Control over heavy metal concentration	-	♦Recovery: averagely 53% of EPR producer shipment
Export of collected waste	No prohibition	No export by PRO	Legitimate in case for recycling purpose

Source: JMETI (2006), GMOE (1998), KMOE (2012c)

Germany's EPR is physically and financially responsible for all packaging products put into the market. Producers contract out collection and recycling to Producer Responsibility Organization (PRO). It is noteworthy that Germany's EPR has a strategy for waste prevention by promoting producers to use reusable packaging with a binding target. Furthermore it prohibits circulation of packaging and container exceeding the prescribed heavy metal concentration to prevent negative externalities.

Japan's EPR is a partial financing type. Local authorities cover the cost of collecting packaging waste with general tax. Collected packaging wastes by local authorities are managed either by recycling companies contracted with local municipalities or PRO. Producers are obliged to finance the recycling for the collected packaging in PRO.

Korea's EPR is a type of recycling credit purchase. The government obliges producers to achieve recycling target assigned yearly based on EPR producer shipment. EPR producers mostly contract out this recycling task to PRO and PRO satisfies collectively the recycling duty of producers by purchasing recycling credits from reprocessing companies. The role and responsibility of local authorities are not specified and there is no legal system to be reimbursed for the expense of packaging waste collection from households.

With respect to export of the collected waste, PRO of Japan contracts out recycling of collected packaging and containers to domestic recyclers and does not carry out the export (JMOE, 2006: 18). However, municipalities prefer export of the collected waste to entrusting to PRO in cases if they can make a profit through export (Kurita, 2010). Germany does not prohibit export of the collected waste for the purpose of recycling (PRO EUROPE, 2009). Korea admits the export of collected waste for the purpose of recycling as legitimate recycling manner (KMOE, 2012c).

EPR has an aspect that stimulates export of waste, because exporting of the collected waste to developing countries is cheaper for producers than domestic recycling. Recently, in the UK EPR producers tend to satisfy the recycling duty through export due to the lower price (Francavilla, 2013). Also in EU, the representative body of recyclers clarified the opposition stance against the waste export due to the global environmental impact and unfair competition between domestic recyclers and recyclers in developing countries. It required a support of the local recycling treatment.

OECD recommends the government not to collect more wastes than that the domestic capacity can absorb (OECD, 2001. 21). Because “the dumping national surpluses (…) disrupts market and undercuts recycling efforts in other countries” (OECD, 2001: 70). Additionally OECD clarifies that “a subsidy aimed at the export of excess collected material would appear to be of the type prohibited by the Agreement on Subsidies and Countervailing Measures (ASCM)” (OECD, 2001: 71).

2.6 Conclusion

Many of the costs of using a product are not included in its price. One of those is the costs of collecting and safely disposing of the product after it is discarded. In order to correct this cost-pricing deficiency, many economic solutions suggested internalization of external costs regarding the waste through taxes. They achieved theoretically waste reduction at source. Among various economic models, producer’s take-back requirement is preferred from the practical reasons that it does not provide households incentives for illegal dumping, it does not require a complete recycling market and massive information for tax and subsidy rates.

Meanwhile, in the OECD discussion on EPR, EPR is preferred to other instruments, e.g. unit-based waste fee scheme. It is because OECD believes that price signals are not being transmitted upwards and downwards and that EPR can ensure a change in production to take waste management costs into consideration. Meanwhile, since OECD’s EPR only entrusts the responsibility for waste management to producers and does not influence directly to product price by tax, it depends on producers’ decision how to minimize the waste management costs either by reducing the costs through adjustment of production scale or by recycling waste efficiently in disposal phase. It is possible that EPR may not lead to any change in production phase against OECD’s expectation.

In the EPR policy of Korea, EPR producers have the financing responsibility only for the recycling of the assigned waste volume and thus relatively small economic responsibility. Furthermore, recycling duty can be satisfied not only by domestic recycling, but also by exporting of collected waste for the purpose of recycling. In this regard, EPR can be undermined in Korea because if producer’s responsibility can be cheaply satisfied through export, producers do not feel that investment for producing the more recyclable products is necessary.

Chapter 3 Estimating the amount of WEEE generated in South Korea by using the population balance model

3.1. Introduction

In 2003 South Korea instituted a mandatory recycling program for waste electrical and electronic equipment (WEEE) based on the principle of extended producer responsibility (EPR); (OECD, 2001). According to the Act on the Recycling of Electrical and Electronic Equipment and Vehicles (KMOE, 2008), producers have a duty to collect a minimum percentage of WEEE as determined by the government in proportion to the amount of new electrical and electronic equipment (EEE) shipped to the market in that year.

To assess the EPR policy properly, monitoring and meaningful targets are critical (Sheehan and Spiegelman, 2006), and reliable data on the amount of WEEE generated are essential. However, there are no official statistics for annual WEEE generation or collection in South Korea; thus, it is not obvious how much WEEE has actually been collected through this program, especially as a percentage of total amounts generated. In addition, uncertainties in the quantity of WEEE generated have also caused disputes about collection targets. More specifically, electronics manufacturers have suggested that collection targets should be set on the basis of the amount of WEEE generated and not on current product shipments (AEE, 2008). In the same context, the European Committee of Domestic Equipment Manufacturers (CECED, 2010) stated that the collection target of its WEEE Directive should be based on waste stream relevance because there are time differences between the products` placement on the market and its removal from service, depending on the particular characteristics of the product. The European Parliament and the Council of European Union agreed that the methodology for calculating collection rates based on WEEE generated should be developed in the near future (European Parliament and Council of EU, 2012). To have a realistic understanding of current collection performance and to set appropriate future performance goals, high-quality estimates of the amount of WEEE generated are necessary. In South Korea, there have been a few attempts to estimate the quantity of WEEE generated, but the methodologies used have been limited, as is discussed in Section 2.

The purposes of this study were to estimate the annual amount of WEEE generated in South Korea from 2000 to 2020 for eight products and to estimate the annual percentage of WEEE collected through the EPR recycling program from 2003 to 2009.

3.2. Previous estimates of WEEE generation in South Korea

We found seven previous studies of WEEE generation in South Korea in academic journals, reports from research institutions, and EEE producers' organizations (Table 3.1). Among the studies, KSWM (1998) and Lee et al. (2007) estimated WEEE generation from sales data and product lifespan information. This type of estimation model, the "delay model" (Van der Voet et al., 2002), has been widely applied to the estimation of WEEE generation. KSWM (1998) used the model to estimate the number of waste desktop PCs generated from 1998 to 2030 using an assumed lifespan, and Lee et al. (2007) used the model to estimate the amount of WEEE generated for four end-of-life household electronic appliances from 2000 to 2005 on the assumption that the average lifespan of the four items was about 10 years. In both cases, the lifespan was assumed, not derived from empirical data. AEE (2005, 2006) used the discard rate and number of households to estimate the quantity of WEEE generated. AEE conducted a questionnaire survey targeting the discard rate and household characteristics of approximately 1800 respondents. Some characteristics that could have an influence on discard rate, such as household income and number of household members, were not considered in the survey, and the report did not verify whether the questionnaire surveys were biased. Therefore, it is questionable whether the calculated WEEE discard rates are representative values for South Korea. KSWM (2007) calculated the amount of WEEE generated for four items by aggregating the amount collected through questionnaire surveys of WEEE collectors. Unfortunately, informal WEEE collectors were not included, and the estimated WEEE quantities may therefore be underestimated.

Jang and Kim (2010) estimated the number of end-of-life mobile phones generated from 2000 to 2007 by subtracting number of new subscribers from the number of phones purchased domestically in each year. On the basis of the results of a questionnaire survey, they assumed that 60% of the estimated number of end-of-life mobile phones were actually discarded and 40% were permanently stored at home by the user (i.e., they were “hibernating”). However, these hibernating mobile phones are almost certainly eventually discarded. Thus, Jang and Kim (2010) may have underestimated the actual amount of WEEE generated.

KEI (2009) calculated the amount of WEEE generated for six items from 2000 to 2015. The number of end-of-life mobile phones was estimated with the same methodology as Jang and Kim (2010). The amounts for the other five products were estimated based on the discard rate, which was assumed as the normal distribution. The discard rate was calculated simply by dividing the number of discarded products per product age through the total number of discarded products in the recycling centers. This estimation method is limited in that the average lifespan is affected by the number of products shipped in the corresponding shipment year (Oguchi et al., 2010). Therefore, the average lifespan reported by KEI (2009) may have been affected by the size of past shipments. In addition, future shipment volumes were assumed to maintain 2008 shipment levels.

Table 3.1 Previous estimates of WEEE generation in South Korea

Author	Year	Methodology	Estimation objects (years)
KSWM	1998	Outflow (t) = inflow (t-average lifespan), where t =year	Desktop PCs, televisions (1998–2030)
AEE	2005	Discard rate × number of households	Air conditioners, copiers, mobile phones, PCs, PC monitors, printers, refrigerators, washing machines (2005)
AEE	2006		
Lee et al.	2007	Outflow (t) = inflow (t-average lifespan)	Air conditioners, televisions, refrigerators, washing machines (2000–2005)
KSWM	2007	Aggregating the collected volume of WEEE through a questionnaire survey of WEEE collectors	Air conditioners, televisions, refrigerators, washing machines (2006)
KEI	2009	Σinflow (t – i) ×discard rate (i), where i=product age	Air conditioners, PCs, refrigerators, televisions, washing machines, [a]mobile phones (2000–2015)
Jang and Kim	2010	(shipment volume – number of new subscribers)×60%	Mobile phones (2000–2007)

[a]mobile phones was handled with the same methodology to Jang and Kim(2010)

Research on WEEE generation has different advantages and disadvantages depending on the estimation model used (Wen et al., 2009). In this study, we applied the population balance model (PBM), which has been applied in many academic studies (e.g., Kakudate et al., 2000; Tasaki et al., 2001, 2004; Daigo et al., 2005; Oguchi et al., 2006; Yamasue et al., 2009; Yoshida et al., 2009). The main reason for using PBM is that overestimation and underestimation of WEEE generation are less likely because the model draws on the mass balance principle of inflow (shipment volume), outflow (waste volume), and stock (ownership volume). Also, it is a time-series material flow analysis model so that it enables the estimation of past and future WEEE generation. However, PBM is facing limitations when estimating products of fast growth phase or decline stage on the market, because the parameters of lifespan distribution for those products might vary.

3.3. Methods and materials

3.3.1. Estimation objects

As of August 2011, the WEEE recycling program of South Korea included the following 11 items: air conditioners, copiers, computers (desktop and laptop), fax machines, mobile phones, printers, stereos, televisions (including flat-screen and cathode-ray-tube televisions), refrigerators, kimchi refrigerators, and washing machines. (A kimchi refrigerator is a product designed only for storing kimchi, a traditional Korean fermented vegetable product.) The recycling program is expected to gradually expand to include all types of EEE (KMOE, 2010a).

One of the purposes of this study was to estimate the collection rates of the recycling program based on the amount of WEEE generated for each product. Therefore, we targeted products included in the Korean recycling program. Some items with low rates of ownership in Korean households were excluded (e.g., fax machines, 0.02 unit/ household and copiers, 0.07 unit/ household) (KPE, 2009) because it would have been difficult to gather a sufficient amount of samples from the questionnaire survey of households without conducting a survey on a large scale. Desktop PCs were also excluded because some are assembled by PC stores. These desktop PCs circulated in the market (Lee, 2008) and are thus not included in the published shipment statistics. According to Lee (2008), the number of the assembled desktop PCs was equivalent to 20% of the total number of desktop PCs` shipment in 2008. However, as there is no further information available, the shipment volume for the other years could not be estimated. With the exception of desktop PCs, the assembled EEE were not reported in South Korea. We included microwave ovens and vacuum cleaners in the estimations because they have a high rate of household ownership (KPE, 2009) and are scheduled to be targets of the recycling program in the near future.

As a result, we performed estimations for the following eight products: (1) air conditioners, both window and wall types; (2) microwave ovens; (3) mobile phones; (4) televisions, including cathode-ray-tube and flat-screen televisions; (5) refrigerators; (6) kimchi refrigerators; (7) vacuum cleaners; and (8) washing machines.

3.3.2. Estimates of EEE lifespan distribution

3.3.2.1. Estimation procedure

To estimate the amount of WEEE generated, it is essential to know the product’s lifespan distribution. According to the review by Oguchi et al. (2010), there are four major methods of estimating a product’s lifespan distribution and they provide the same value of a lifespan if accurate data are available. We employed one that estimates the remaining rate distribution, which means the surviving rate of the commodities for each product age in the year t. The main equations used to analyze the lifespan distribution of each product are as follows:

$$F_t(i) = 1 - \left(N_{t,t-i} / P_{t-i}\right) \qquad (1)$$

$$W_t(y) = 1 - \exp\left\{-\left[y / y_{av}\right]^b \bullet \left[\Gamma(1 + 1/b)\right]^b\right\} \qquad (2)$$

For a given EEE item, $F_t(i)$ is the cumulative discard rate, which describes the percentage of the products of age i that has reached end-of-life from the time of shipment to the end of year t. $N_{t,t-i}$ is the number of products owned of age i at the end of year t. P_{t-i} is volume of domestic shipment in year $t - i$. $N_{t,t-i}$ $/P_{t-i}$ obtained usually fluctuated along lifespan. Thus they were smoothed twice and standardized with the average of $N_{t,t-i}$ $/P_{t-i}$ of recent years. $F_t(i)$ was expressed using the Weibull distribution as shown in Eq. (2). Whereas $F_t(i)$ in Eq. (1) is a discrete function, the Weibull function, $W(y)$, in Eq. (2) is a continuous function. y is product age adjusted by putting y in the middle of the year i (i.e., $y = i + 0.5$), y_{av} is average lifespan, b is a distribution shape parameter, and Γ is the gamma function. b and y_{av} values were calculated by approximating the remaining rate of EEE to the Weibull distribution.

We used the Weibull distribution for analyzing the lifespan distribution because through the researches of Gößling-Reisemann et al., (2009) and Mueller et al., (2007) it was verified that the lifespan distribution of appliances is better approached with the Weibull distribution than with the Gaussian distribution. On the other hand, there are some researches which used the Gaussian distribution (KEI, 2009; Müller et al., 2009).

The number of owned products for each product age ($N_{t,t-i}$) was calculated by multiplying the number of owned products of product age i per household by the number of households. The number of owned products for each product age per household was determined through our questionnaire survey, and the number of households was obtained from published government statistics (KOSIS,2005). The calculated remaining proportion of EEE relative to the shipment volume of the corresponding year was approximated by the Weibull distribution function, and the parameters of the distribution were obtained. See Tasaki and Oguchi (2006) for a more complete description of the estimation procedure.

There are various definitions of lifespan, and the definition is determined by the methodology and data used for estimation (Murakami et al., 2010; Oguchi et al., 2010). In this paper, lifespan is defined as the domestic service lifespan, which is the length of time from a product's shipment to its being discarded by the final owner. Therefore, the average lifespan of a product in this paper includes not only the use period but also any hibernation period after the product is no longer used but before it is discarded.

3.3.2.2. Questionnaire survey

To determine the number of items owned per household for each product age, a web-based questionnaire survey was conducted in February 2010. However, we did not conduct a pilot survey to test its reliability. Mizuho information & research institute (2004) conducted a web and mail based questionnaire on ownership of EEE in Japan. The result of the questionnaire showed that the number of PCs and fax machines owned by households was higher in the case of participants of the web-based questionnaire. On the other hand, there was only a small disparity shown for the other EEE. Therefore, it can be concluded that our survey which is based on a web questionnaire was not biased.

To collect representative samples, census data were broken down by number of household members (five categories) and population of different regions (four categories) as shown in Table 3.2. A survey company then randomly sent out the questionnaires to its own household-panel , and among the returned questionnaires, the first 1000 samples that matched our initial population and regional distribution conditions were used.

Table 3.2 Number of survey respondents selected by number of household members and residence area

		Location			
Number of household members	Metropolis	Prefectures	Provincial cities	Provincial counties	Total
1	43	49	89	19	200 (20.0%)
2	47	54	98	21	220 (22.2%)
3	45	51	93	20	209 (20.9%)
4	57	66	120	26	269 (27.0%)
5 and more	22	25	45	10	102 (10.0%)
Total	214 (20.8%)	245(25.8%)	445 (43.8%)	96 (9.5%)	1000

Metropolis: Seoul; prefectures: Busan, Daegu, Incheon, Kwangju, Daejeon, and Ulsan;
Provinces: Kyungi, Kangwon, Chungcheong, Cheonra, Kyungsang, and Jeju.
The proportion from the population census (KOSIS, 2005) is given in parentheses.

In the questionnaire, the number of products owned and the year of manufacture for each product were the main focus. We also asked about the number of hibernating products, that is, products that were still in the household but had not been used for more than one year. It was necessary to clarify the hibernating rate of the owned appliances and to modify the ownership data of Korea Power Exchange (KPE). We obtained the EEE ownership data by households from KPE. They did not count the products which had not been used for more than one year among owned appliances. In order to include those products which are not counted by KPE, we clarified the number of products which had not been used more than one year. In this paper, these products were defined as hibernating products.

3.3.3. Population Balance Model (PBM)

3.3.3.1 Estimation procedure

The estimates of the amount of WEEE generated were calculated following the PBM process designed by Tasaki et al. (2004). A brief explanation of the most the relevant equations is given below.

$$f_t(i) = F_t(i) - F_{t-1}(i-1) \quad (3)$$

$$N_t = P_t + \sum_{i=1} \left[P_{t-i} \bullet \{1 - F_t(i)\}\right] \quad (4)$$

$$G_t = \sum_{i=1} \{P_{t-i} \bullet f_t(i)\} \quad (5)$$

$$P_t = N_t - N_{t-1} + G_t \quad (6)$$

$f_t(i)$ is the discard rate, which describes the percentage of the products of age i that has reached end-of-life in the year t. N_t is the number of products owned at the end of year of t, which was calculated using the shipment volume and lifespan distribution as shown Eq. (4) in which F_t (0) and F_{t-1} (0) were preconditioned as 0. G_t is amount of WEEE generated. This process was repeated for each product type.

There are two unknown values in the cumulative lifespan distribution F_t (i): average lifespan (y_{av}) and the shape parameter (b). The shape parameter was obtained from the lifespan distribution analysis as explained in section 3.2.1. Average lifespan was calculated for each year with the given shape parameter b by approximating two sets of EEE ownership data as being the same. One of the sets was the ownership data calculated by Eq. (4), and the other was obtained from statistics provided by K P E (KPE 2006; KPE 2009). Using the calculated F_t (i) through the lifespan distribution analysis, the discard rate $f_t(i)$ was calculated with Eq. (3). The quantity of WEEE generated (G_t) was then calculated with Eq. (5). Shipment volume for future years was calculated by Eq. (6) and repeatedly substituted into Eq. (5) for the entire prediction period.

3.3.3.2 Input data

Shipment volume was defined as the sales volume in the South Korean domestic market and was calculated by subtracting exports from domestic production and then by adding in imports. The data were obtained from three statistical sources: the Report on Mining and Manufacturing Survey (KOSIS, 1980–2009), Statistics for Electronic Industries (KEA,1980–2001), and Global Trade Information (1996–2009).

The average number of EEE owned per household was obtained from KPE’s Survey on Electricity Consumption Characters of Home Appliances (Fig. 3.1), which investigated past and predicted future EEE ownership by using a biannual questionnaire survey of 4000 households on a national scale. The total number of EEE products owned by Korean households was calculated by multiplying the total number of households by the average number of EEE products owned per household.

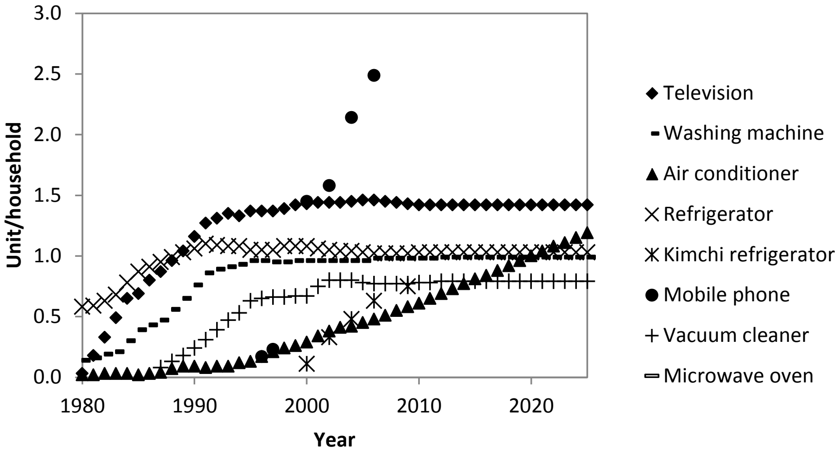

Fig.3.1. Average number of eight types of EEE owned per household (KPE, 2006; KPE, 2009).

For past ownership data, the average numbers of products owned per household were fitted to a logistic curve as described below (Tasaki et al., 2001).

$$N_t = N_{\max} / \{1 - A \bullet \exp[-B(t - t_0)]\} \quad (7)$$

$$A = -\exp[B(t_{1/2} - t_o)] \quad (8)$$

For each product category, N_t is the average numbers of products owned per household in year t, and $N_{\max}$ is the maximum value of product ownership per household. t_0 is the first year of ownership, and $t_{1/2}$ is the year in which the value N_t is 1/2 of $N_{max.}$. The parameter B is a parameter that shows the rate for increase of product ownership per household. Parameters A and B were obtained so as to minimize the sum of the square of the distance of the KPE data from the logistic curve.

We also estimated the future ownership rates of mobile phones and kimchi refrigerators with a logistic curve because KPE offers only ownership data from the past and does not offer future predictions. We assumed the maximum ownership rate ($N_{max.}$) of kimchi refrigerators to be 0.76 unit per household because kimchi refrigerator ownership per household was 0.75 unit per household in 2009 (KPE, 2009), and the market for kimchi refrigerators is thought to be saturated (Kim, 2010). The maximum ownership rate of mobile phones was assumed to be 3.3 units per household because the average number of mobile subscribers per household has been estimated to 3.28 by the end of 2015 (ROA Holdings, 2011), and mobile phones have entered into the mature phase of the product life cycle (Lee, 2009). However, according to our questionnaire survey, 20% of the mobile phones owned by households could be classified as hibernating. Additionally, the KPE ownership rate data do not include hibernating mobile phones. Thus, to include these phones in the ownership rate, we predicted the ownership rate by fitting the KPE ownership ($N_{max.}$ 3.3) to a logistic curve and then increased it by 20% during the entire estimation period. As result, the

N_{max} increased 3.3 to 3.95 units per household.

The hibernating rates for the other appliances are maximum 3% per product owned by household. Thus it can be reasonably concluded that the hibernating rate for the other appliances can be ignored. The estimated parameters and the maximum value of ownership rate are shown in Table 3.3.

Table 3.3 The estimated parameters (*A* and *B*) and maximum ownership rate used to fit the logistic curve

Product	*A*	*B*	$N_{\max}$ (unit/household)
Air conditioner	–62.45	0.14	1.27
Kimchi refrigerator	–77.29	0.49	0.76
Microwave oven	–70.99	0.31	0.80
Mobile phone	–75.55	0.33	3.30
Refrigerator	–1.37	0.34	1.03
Television	–10.33	0.36	1.42
Vacuum cleaner	–51.94	0.29	0.85
Washing machine	–12.50	0.33	0.99

The KPE ownership rates do not include business ownership. However, many of the items listed in Table 3 can be owned by businesses. Resource Recycling R&D Center (2009) reported that 44% of end-of-life air conditioners (regardless of type and size) collected by WEEE collectors are from firms. We therefore modified the KPE ownership rate of air conditioners to include business ownership, but we did not modify the other items because of a lack of data. In addition, most of the other items could reasonably be considered to be primarily owned by households.

Our questionnaire survey indicated that 72% of air conditioners shipped to the market in 2009 were owned by households. The remaining 28% were most likely owned by businesses because air conditioners are not usually discarded in the first year of operation. We therefore assumed that the allocation of air conditioner ownership between households and business firms was 72% and 28% for the entire estimation period.

The ownership estimates for air conditioners and mobile phones are presented in Fig. 3.2.

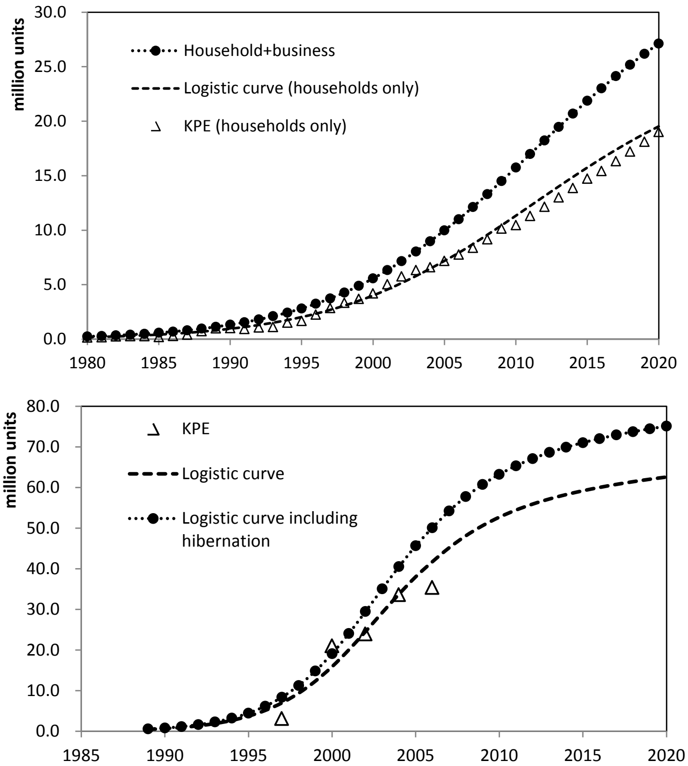

Fig. 3.2. Estimated ownership of (top) air conditioners and (bottom) mobile phones (KPE, 2006; KPE, 2009).

3.4. Results and discussion

3.4.1 Estimated lifespan distributions

To ascertain which respondent characteristics were the most influential in terms of EEE ownership per household, a correlation analysis was conducted between the number of products owned and respondents' characteristics, including monthly income, number of household members, place of permanent residence, and age of household head. The results of the analyses showed that monthly income and number of household members were highly correlated with ownership rate, whereas age of household head and place of residence were not (details of the correlation analyses are in the supplementary material).

Because we considered these characteristics in the survey design, the number of household members and region of residence were very representative of South Korea as a whole. We also needed to examine the distribution of monthly income of the respondents to determine whether the sample was biased, so we compared the distributions of average monthly income of the respondents with that of the entire population (KOSIS, 2009; Fig. 3.3).

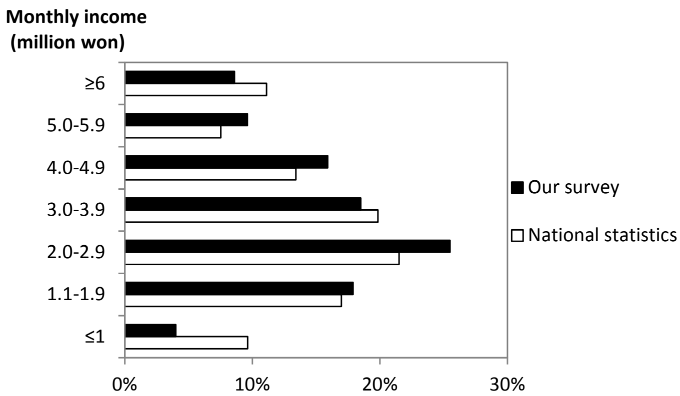

Fig. 3.3. Distribution of average monthly income for survey respondents and the South Korean population as a whole (KOSIS, 2009).

Overall, the distributions of monthly income distribution were similar, but the difference in the lowest income group was larger. We therefore considered the survey respondents to be representative of the larger population in terms of income distribution.

The estimated EEE lifespan distribution parameters are presented in Table 3.4, and the results of the regression analyses of the cumulative EEE lifespan distributions by the Weibull distribution function are shown in Fig. 3.4.

Table 3.4 Estimated lifespan distribution parameters, the coefficient of determination (R^{2}) and the coefficient of variation (CV)

	b	y_{av}	R^2	CV
Air conditioner	1.55	8.91	0.85	66%
Kimchi refrigerator	1.83	7.62	0.90	57%
Microwave oven	1.76	9.95	0.91	59%
Mobile phone	2.07	3.40	0.92	51%
Refrigerator	2.12	9.42	0.94	48%
Television	1.49	9.30	0.95	69%
Vacuum cleaner	1.60	6.38	0.97	64%
Washing machine	2.43	10.60	0.93	44%

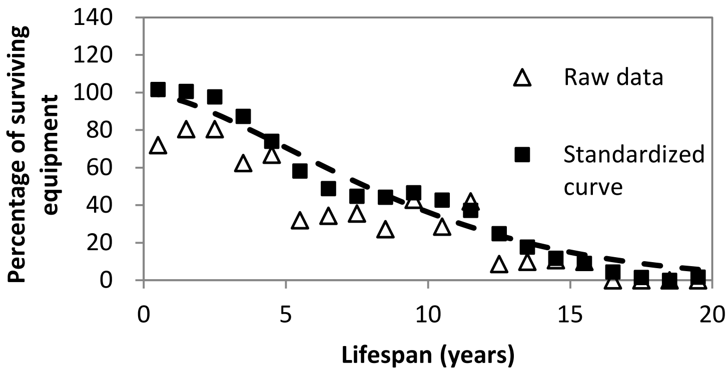

Fig.3.4 (a) Air conditioner

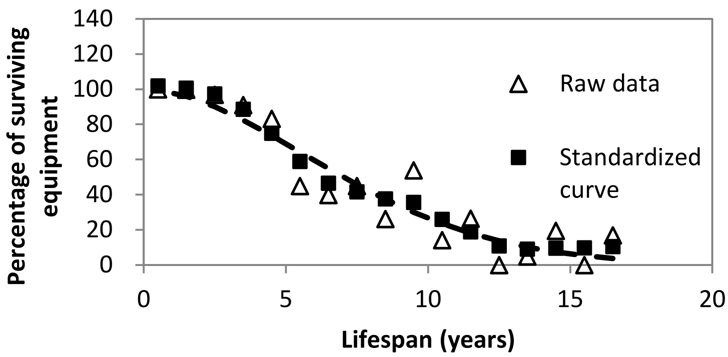

Fig.3.4 (b) Kimchi refrigerator

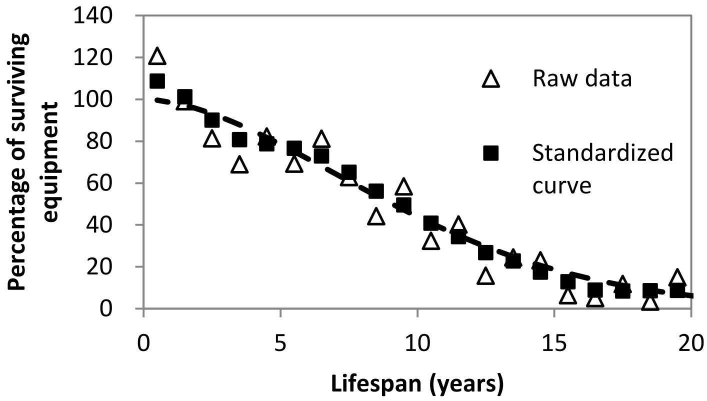

Fig.3.4 (c) Microwave oven

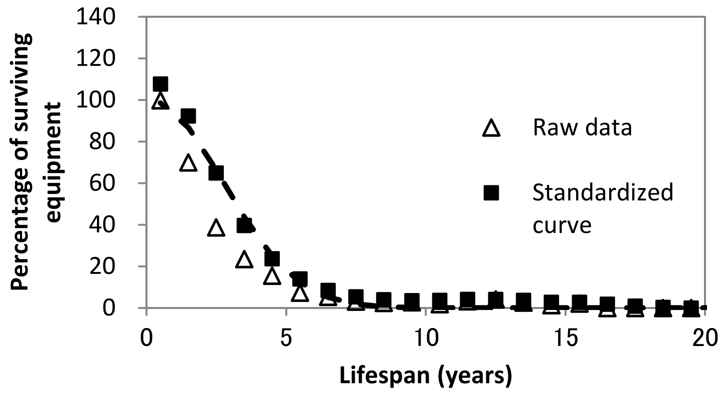

Fig.3.4 (d) Mobile phone

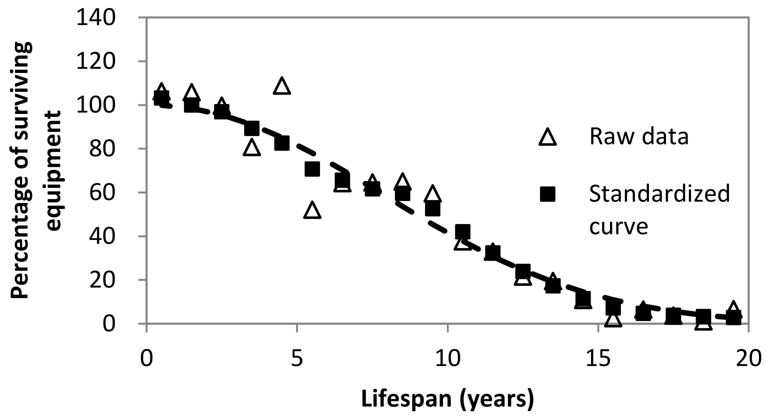

Fig.3.4 (e) Refrigerator

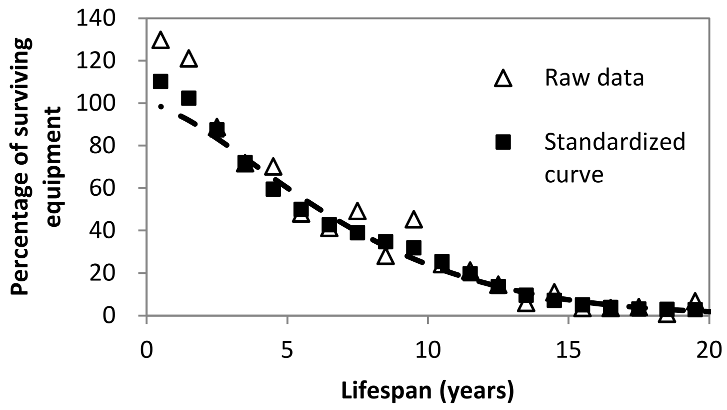

Fig.3.4 (f) Television

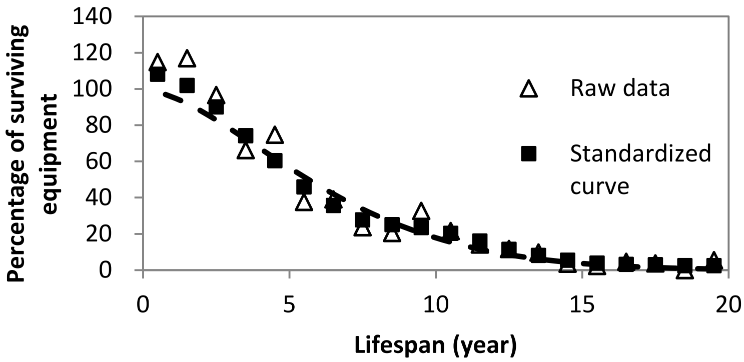

Fig.3.4 (g) Vacuum cleaner

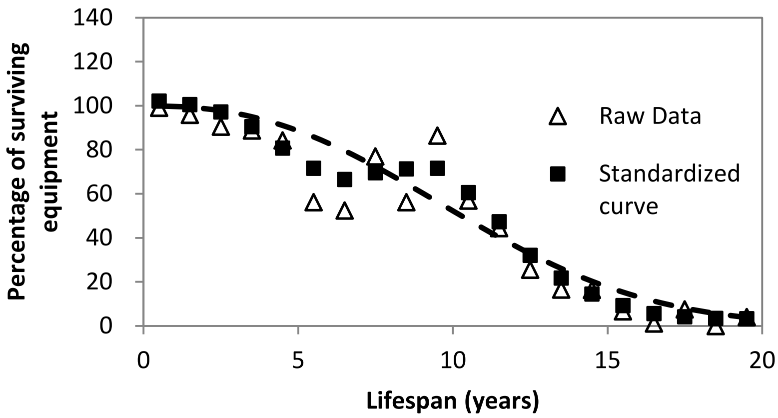

Fig.3.4 (h) Washing machine

Fig. 3.4. Regression analysis of the cumulative lifespan distributions for selected EEE products

The raw data for air conditioners show a relatively low first-year survival rate of 72%, but these numbers were not adjusted for business use, as previously discussed. Once business use was accounted for, the estimated average lifespan and distribution shape parameter were regarded to be valid for estimating the number of end-of-life air conditioners generated by both households and businesses. Using the same methodology as that used in this study, Oguchi et al. (2006) estimated the average lifespan of air conditioners in Japan to be 12.7 years, which is about 3.8 years longer than our average lifespan. The difference may be a result of the fact that air conditioners have only relatively recently come into wide use in South Korea. The ownership rate of air conditioners has grown markedly since 1995 and is still growing (Fig. 3). In Japan, the ownership rate per household was 2.6 units in 2006 and the penetration rate was 88% (ESRI, 2011), whereas in Korea, those rates were 0.5 and 45%, respectively, in 2006 (KPE, 2006). As air conditioners are not yet in the saturated phase in the market of South Korea, it is necessary to adjust the estimation of the number of end-of-life air conditioners by increasing the future

average lifespan in scenario, unlike the other products where the future average lifespan is regarded as stable. On the other hand, the average lifespan from the early stage of low saturation up to the present year (2009) is considered to be appropriate, because the lifespan of PBM up to 2009 is determined for each year based on the mass balance. Regarding the distribution shape parameter of air conditioners in this paper, there is possibly a limitation to apply a fixed shape parameter to the whole period of estimation, because the parameters can vary especially for the growth phase of a product in the market.
The average lifespan of mobile phones was estimated to be 1 year longer than the average replacement period (2.4 years) of Jang and Kim (2010); this difference is almost certainly a result of the different treatments of the hibernation periods in the studies.

The parameter *b* determines the shape of the EEE lifespan distribution, and it ranged from 1.49 for televisions to 2.43 for washing machines. The coefficient of variation indicates (CV) the width of the lifespan distribution, and it ranged from 44% (washing machines) to 69% (televisions). The lower CV theoretically indicates that products are more likely to be discarded around the age of the average lifespan. However, it was concluded that the lower CV result of television was not closely related to the discard behavior of people, because this study did not divide cathode-ray-tube and flat-screen television and took them into account as a single item.

It can be expected that the shape parameters of television vary in the transition from cathode-ray-tube to flat-screen television. Therefore the degree of accuracy for the estimated amount of end-of-life television might be limited. In order to acquire more exact parameters of lifespan distribution, it is necessary to classify the products by characteristics such as type, size or degree of growth phase in the market.

3.4.2 Amount of WEEE generated

The estimated amounts of WEEE generated in South Korea from 2000 to 2020 for the eight selected EEE items are shown in Fig. 5. Where available, the estimated results of KEI (2009) and Jang and Kim (2010) are also included in Fig. 5 for comparison. As the average lifespans of the estimated products have not shown a significant variation in recent years up to 2009, we assumed that the average lifespan of 2009 can be stable for the prediction period except for air conditioners. Therefore, we assumed that the previously discussed average lifespan and shape parameters for 2009 were constant for the entire prediction period (2010–2020). The future average lifespan of air conditioners was estimated based on a scenario that it would increase by 2.5% every year because air conditioners are still in the growth phase of ownership in South Korea (Fig. 3.1). As a result, the average lifespan of air conditioners reaches 11.6 years in 2020.

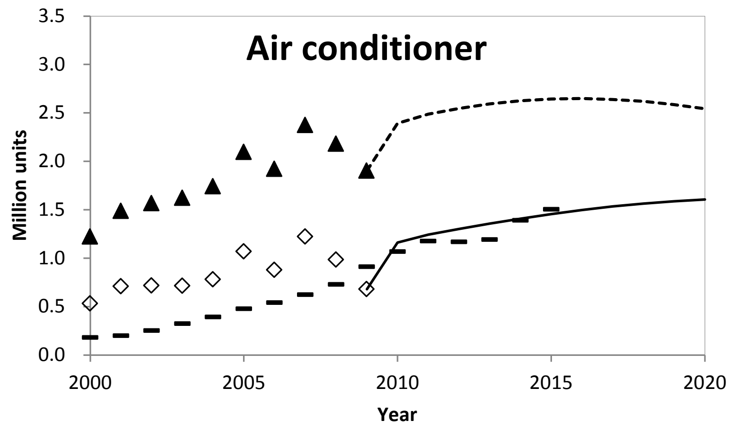

Fig.5 (a) Air conditioner

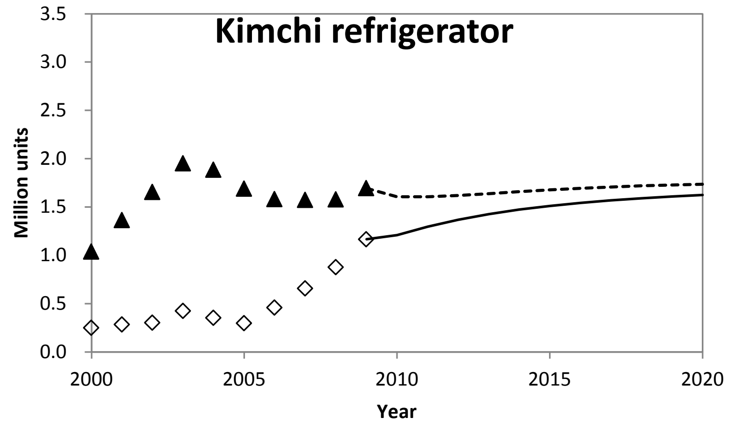

Fig.5 (b) Kimchi refrigerator

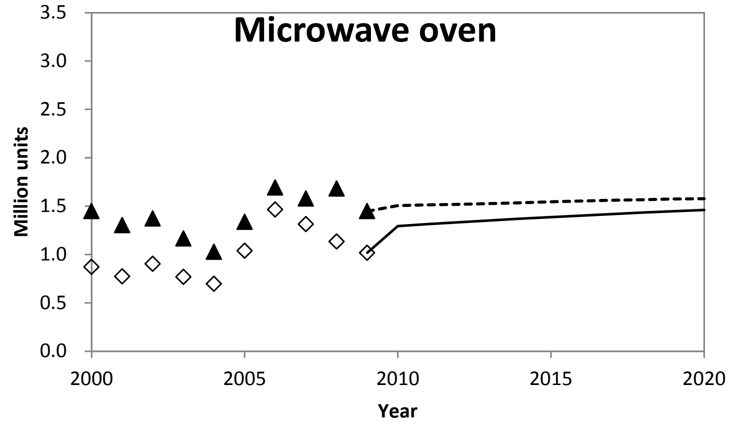

Fig.3.5 (c) Microwave oven

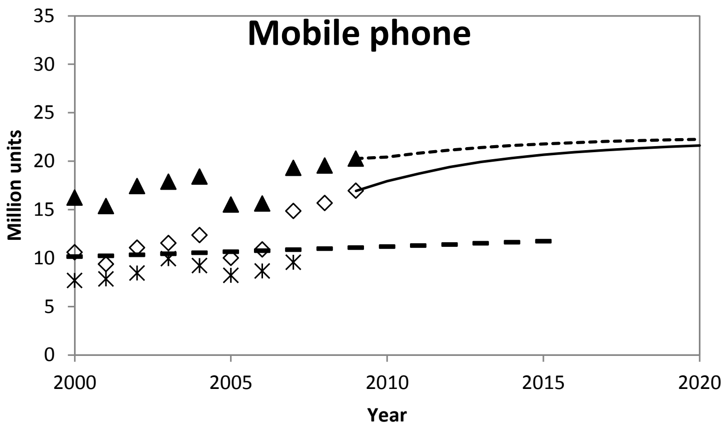

Fig.3.5 (d) Mobile phone

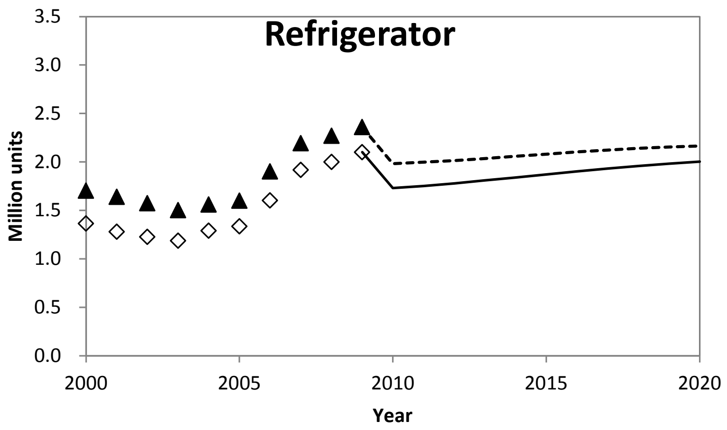

Fig.3.5 (e) Refrigerator

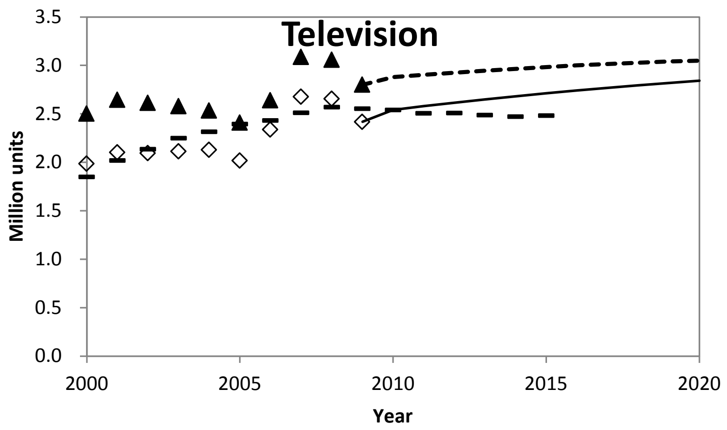

Fig.5 (f) Television

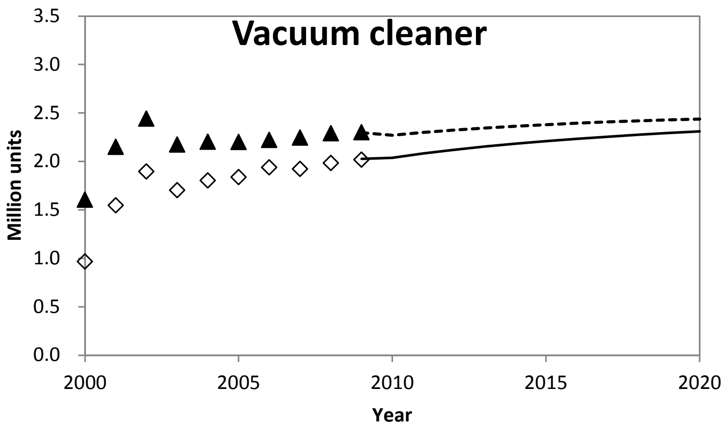

Fig.3.5 (g) Vacuum cleaner

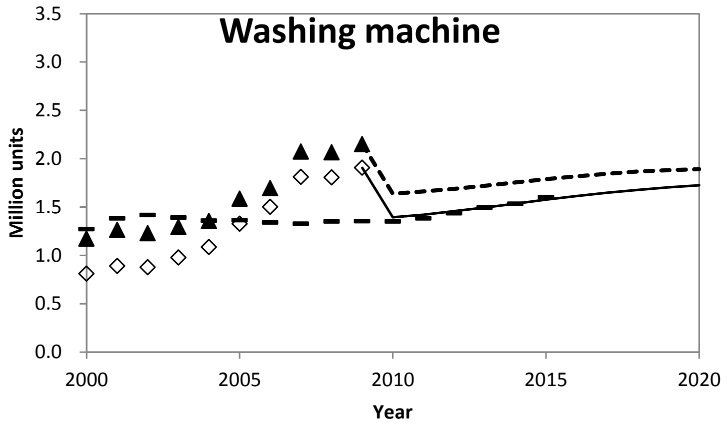

Fig.3.5 (h) Washing machine

▲	---	◇———	▬ ▬	✳
Shipment (statistics)	Shipment (predicted)	Waste estimated	KEI (2009)	Jang and Kim (2010)

Fig. 3.5. The amount of WEEE generated from 2000 to 2020 in South Korea for eight products. The estimated results of KEI (2009) and Jang and Kim (2010) are also included for selected products for comparison.

According to our estimates, 1.16 million air conditioners, 1.21 million kimchi refrigerators, 1.29 million microwave ovens, 17.02 million mobile phones, 1.73 million refrigerators, 2.54 million televisions, 2.04 million vacuum cleaners, and 1.40 million washing machines were generated as WEEE in South Korea in 2010.

There was a narrow gap between shipment volume and estimated quantity of end-of-life products for microwave ovens, refrigerators, televisions, vacuum cleaners, and washing machines. In large part, these items were saturated with regard to ownership per household during the study period (Fig. 3.1). Therefore, most units were purchased as a replacement of an existing older product, and the WEEE generated was similar to the shipment volume for these products. On the other hand, air conditioners, kimchi refrigerators, and mobile phones had a wider gap between the shipment volume and the amount of WEEE generated during parts of the study period. These items were not saturated with regard to ownership before 2009 (Fig. 3.1), and the gap represents first-time purchases of these items.

KEI (2009) assumed that the average lifespan of air conditioners (11.8) years was constant for the entire estimation period. As discussed previously, we gradually increased the lifespan from 8.9 years in 2009 and to 11.6 years in 2020. The discrepancy between the two sets of results from 2000 to 2007 most likely resulted from the different average lifespans used in the estimations.

Since 2007, our estimated numbers of end-of-life mobile phones differed from those of Jang and Kim (2010) and KEI (2009). These differences are probably the result of the previously discussed differences in the treatment of the hibernating stock of mobile phones.

Our results and those of KEI (2009) are similar for televisions, but KEI (2009) estimated that the number of end-of-life televisions would decrease slightly after 2009 and we predicted it would increase slightly. KEI (2009) assumed the shipment volume was constant since 2008. We estimated the future shipment volume using Eq. (6), which is based on mass balance, so it would increase if the ownership rate increases.

Concerning washing machines, a remarkable discrepancy between our results and those of KEI can be seen from 2007 to 2009. This difference can be attributed to the introduction of a new type of washing machine that was promoted through the use of financial incentives by major electronics producers since 2005 (Seo, 2005). Our estimated results were larger because our estimates were responsive to changes in shipment volume.

3.4.3. WEEE collection rates

The amount of WEEE collected in South Korea is increasing (KECO, 2010b). However, it must be considered that the amount of WEEE has risen too. Therefore, it needs to be investigated what percentage of the amount of WEEE has been collected.

Using our estimates for the amount of WEEE generated and the reported amounts of WEEE collected through the EPR recycling program (KECO, 2010b), we estimated the WEEE collection rates. Kimchi refrigerators and refrigerators were aggregated because there were no separate collection data available for these products. Microwave ovens and vacuum cleaners were excluded because these items are not currently covered by the recycling program. As a result, we estimated the collection rates of the five items shown in Fig.3.6 from 2003 to 2009. The collection rate of mobile phones was shown in the graph starting from 2005, because mobile phones have been included in the recycling program since 2005.

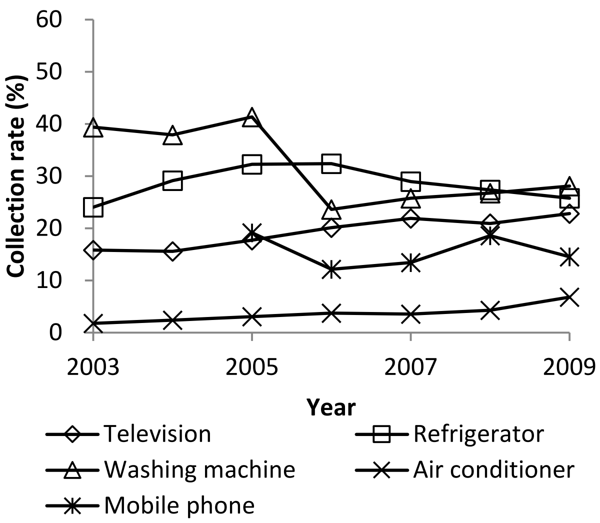

Fig. 3.6. Estimated WEEE collection rates for five EEE products from 2003 to 2010. Refrigerators include kimchi refrigerators.

The collection rate of air conditioners was clearly the lowest throughout the period, ranging from 2% to 7%. The rate for mobile phones was also low, from 13% to 19%. This rate is much lower than the 30% rate of Jang and Kim (2010) and KEI (2009), most likely because of the different treatment of the hibernating stock. The collection rate of televisions gradually increased until it reached 23% in 2009, and the collection rate of refrigerators ranged from 24% to 26%. KEI's (2009) collection rate of refrigerators fluctuated between 23% and 47% because they used the same estimated lifespan for both types of refrigerators and therefore probably underestimated the number of kimchi refrigerators that were discarded. The collection rate of washing machines was ranging from 24% to 28% during the study period.

In Japan, it was reported that 51% of the total WEEE amount of four home appliances were collected in 2005 (METI and JMOE, 2008). In the EU, 30-35% of the amount of WEEE were collected (Huisman, 2010) Furthermore, in the recast of WEEE directive, the EU agreed on the 65% collection target of EEE put on the market in the three preceding years, or alternatively 85% of waste generated by 2019 (European Parliament, 2012).

As nowadays WEEE is traded globally, it has become a new challenge to improve the collection rate and strengthen the producers` responsibility. Concerns about collection rate are raised with consideration of environmental and health risk due to inadequately treated products as well as illegal trade of WEEE (Huisman, et al., 2007; Sander, et al., 2010). In Japan, around 22% of total waste of home appliances were estimated to be exported to Asia and other regions in 2007 (Terazono and Yoshida, 2012). South Korea is possibly facing a similar situation. It is therefore necessary to explore the export flow of WEEE as a next task.

3.5. Conclusion

To have a realistic understanding of collection performance and to contribute to setting appropriate future performance goals, we estimated the quantity of WEEE generated for eight products from 2000 to 2020 by using PBM. This study is the first to apply PBM to estimate the quantity of WEEE generated in South Korea. As has already been shown, PBM is a frequently used model in academic papers. Therefore, this study can be globally compared to other studies using the same model. Furthermore, this study indicated how to deal with the problems of handling hibernating mobile phones and air conditioners of business firms.

The lifespan distributions of the eight items were also clarified through this research. We then used the WEEE estimates to estimate the collection rate of the EPR recycling program in South Korea for five products. Air conditioners had the lowest estimated WEEE collection rate in 2009, and the collection rate of mobile phones appears to have leveled off at a low rate during the study period.

Several limitations were encountered with respect to statistical data. First, many desktop PCs are locally assembled and are therefore not counted in the official shipment statistics. Second, the KPE ownership data of mobile phones only include the number of mobile phones in use, not those that are no longer in use but have not been discarded. Third, the statistics of air conditioner ownership rate only cover households, so we needed to adjust the data to include businesses to more accurately estimate the number of end-of-life air conditioners generated.

This research only determined the estimated collection rate of the official recycling program, but that program is not the only avenue for disposal of WEEE in Korea. There are three other possible flows: municipalities, private collectors, and exporters. In future studies, these types of flows need to be quantified to evaluate the official recycling program and increase the collection rate as a whole for South Korea.

Chapter 4 Revisiting the extended producer responsibility program for metal packaging in South Korea

4.1 Introduction

Faced with increasing waste generation, most OECD countries now implement extended producer responsibility (EPR) policies in key sectors (OECD and The Japanese Ministry of the Environment (JMOE), 2014). The OECD defines EPR as an environmental policy approach in which a producer’s responsibility for a product is extended to the post-consumer stage of a product’s life cycle (OECD, 2001). The OECD (2007) introduced EPR as one of the tools for Environmentally Sound Management of Waste. Emerging economies in Asia, Africa and South America have also started to develop EPR programs in recent years (Manomaivibool and Hong, 2014).

The original concept of EPR places emphasis on environmentally compatible product design as a way to minimize wastes at the source (Lindhqvist, 2000; Walls, 2006). Recycling itself is not treated as an objective. In developing countries, however, EPR is often viewed as a direct governmental intervention to promote recycling (Manomaivibool, 2011).

In 1991, South Korea implemented the waste deposit recycling (WDR) program as a system that imposed a charge for certain products. The WDR program was intended not only to finance waste management but also to divert certain materials from the mixed municipal waste stream. A shortage of landfill sites was the main driver of this initiative according to the South Korean Ministry of Environment (KMOE, 1992). The WDR program imposed a charge on packaging materials and household appliances (air conditioner, refrigerator, television, and washing machine). Producers of regulated packaging and products paid the charge in accordance with the products they sold in the previous year. A portion of the charge was refunded to producers of regulated packaging and products in accordance with the amount of recycling.

However, the WDR program has caused political hardship when the rates were raised (Shin, 1995). Producers of regulated packaging and products claimed that the product charges had weakened their competiveness (Kim et al., 2006) and that the government should be held accountable in its use of the revenues raised from product charges (Lee, 2010). The WDR program was evaluated as being effective in reducing waste from metal packaging and glass (Kim et al., 2006) but not home appliances (Manomaivibool and Hong, 2014). Opposition from industry and insufficient recycling performance for some products led the government to replace WDR program with the EPR program in 2003. The EPR program was backed by the OECD’s Recommendation of the Council on the Environmentally Sound Management of Waste (OECD, 2007). To date EPR is the leading instrument for packaging waste management in Korea.

In Korea, the EPR program requires mandatory recycling with binding targets and fines for noncompliance. The program’s objectives are waste reduction and cost minimization through recycling (Park, 2006).

In the years since the EPR program replaced the WDR program, a few comparative analyses between the programs have been conducted. However, these evaluations were qualitative and have not shown quantitatively whether the change has increased benefits.

Against this background, this paper aims to explore which program brings larger net benefits. A cost-benefit table is employed with landfill disposal taken as a baseline. Because of limited data availability, this paper focuses on metal packaging exclusively.

4.2. Previous research

Cost-benefit analysis (CBA) is a technique that compares the costs and benefits to society of providing a public good. Sturges (2003) advocated CBA as a tool for evaluating EPR programs. Smith (2005) constructed an analytical framework for the CBA of EPR programs.

There are two types of CBAs for waste management programs: financial and environmental assessment. Integrated financial and environmental assessments have been conducted by Bruvoll (1998), Eriksson et al. (2005), Hosoyamada et al.(2003), Ibenholt and Lindhjem (2003), Morris (2005), Nolan-ITU et al. (2001), RDC and Pira (2003), Reich (2005), and Vigsø (2004).

Other research has conducted either financial assessment (Begum et al., 2006; KECO, 2011; Leu and Li, 1998; Oh, 2003) or environmental assessment (Craighill and Powell, 1996).

The Korea Environment Corporation (KECO, 2011) conducted a financial assessment of Korea’s EPR program in comparison with landfill disposal during 2003-2011. KECO found the total benefits of the EPR program have outweighed the total costs since 2003. However, this study underestimated the costs, as it did not include collection costs.

Oh (2003) conducted a financial assessment on the waste management of plastic packaging in Seoul, and compared two EPR policy alternatives against the WDR program: One where producers pay the costs for the collection, transport, and recycling of plastic packaging, and one where producers pay for only transport and recycling costs. Oh found that the net benefits of the WDR program are positive for only the first policy option. However, these two policy options are quite different from the current EPR policy, and thus, do not hold practical implications for the current EPR program.

Lavee (2010) and Hosoyamada et al. (2003) conducted environmental assessments, but focused on only electricity consumption and CO_2 emissions, respectively. Others researchers have covered wider social impacts in their environmental assessments: traffic accidents, congestion, and noise (Nolan-ITU et al., 2001); disamenity of landfills (RDC and Pira, 2003); and time value spent by households sorting garbage (Ibenholt and Lindhjem, 2003).

In Korea, there has been no CBA of the EPR program based on environmental assessments. One reason is insufficient data on environmental impacts and economic valuation. Data on environmental impacts from the collection and transport of households refuse and recyclable wastes by municipalities are available (Oh et al., 2008) but do not cover final disposal such as landfill and incineration. With respect to the recycling stage, Gwak et al. (1998) conducted the only research that employs life cycle assessment of beverage cans throughout the whole lifecycle from manufacturing to recycling in comparison with landfill disposal. That study found climate change and ocean acidification to be the dominant environmental impacts. However, valuation of these environmental impacts is not available. Baek et al. (2011) evaluated the environmental impacts of the manufacturing stage of aluminum cans in which recovered material is used, but the recycling stage was not included.

Sturges (2003) has advocated CBA focused on environmental assessment. This is the only analytical framework that allows the optimal recycling level of a recycling program to be presented. However, this framework is difficult to apply in Korea because of the lack of data for defining the environmental impacts of the WDR and EPR programs in monetary terms. Meanwhile, Smith (2005) provided a framework for showing the performance of the EPR program against a counterfactual baseline. This is why the CBA framework of Smith (2005) is used in this paper, with a main focus on comparing financial assessments between the WDR and EPR programs, particularly the landfill savings targeted by these two policies.

4.3. Description of WDR and EPR programs

4.3.1.Theory

South Korea's WDR program for metal packaging differs from conventional deposit refund programs that place a surcharge on a product when purchased by consumers and issues a rebate when the packaging is returned. In South Korea, the government imposed a product charge on producers in proportion to their production output. The program had no mechanism to pass the refund from producers/retailers to consumers. Instead, producers received part of the total deposit from the government once discarded metal packaging was recycled.

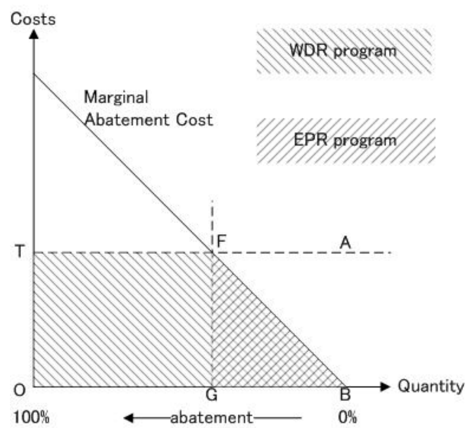

Fig.4. 1. Producers' recycling costs in the WDR and EPR programs

In Figure 4.1, if the deposit rate in the WDR program corresponds to line segment OT, producers should make a deposit to the government in advance; the deposit corresponds to the area enclosed by OTAB. When the deposit and refund rates correspond to line segment OT, producers recycle up to line segment BG, because BG is the recycling level where the cost incurred by producers becomes minimal. In this case, GFAB is returned to producers later.

However, producers eventually bear the cost of OTFB, given by the shaded area, because the area of triangle BFG is also part of the producers' costs for recycling. OTFG is unreturned and supposed to be used by the government to undertake environmental measures, including establishing recycling infrastructure (Lee, 2004). The government raised the deposit rate OT gradually in order to increase recycling volumes.

In the EPR programs, the government imposes a recycling quota on producers. If the quota is not met, a fine that is greater than the cost of implementing proper recycling is imposed on the producers (KECO, 2010a). Figure 4.1 shows that if the allocated recycling quota in the EPR program is BG, producers bear the cost only for the area of triangle BFG. In the EPR program, producers can save the cost OTFG if the recycling rates are BG in both programs. The government increases recycling by raising the recycling rate to BG annually.

4.3.2. Recycling structure of metal packaging

The characteristics of the two programs are outlined in Table 4.1. Targeted producers in the WDR and EPR programs are those using metal packaging for their products. A key difference between the two programs is that the EPR program targets only producers who meet the following two criteria: (a) having more than 1.0 billion won in domestic sales or 300 million won of imports in the previous year, and (b) having more than 4 tons of domestic production shipments or 1 ton of imports in the previous year (GOK, 2011a). Producers that do not meet either criterion are exempted from the recycling duty.

Table 4.1. Characteristics of the WDR and EPR programs

	WDR program (1991–2002)	EPR program (2003–)
Costs	Producers	Producers above minimum production level
Regulatory measure	–	Recycling quota and fines for noncompliance
Economic instrument	Product charges and partial refunds transferred between producers and government	

The basic recycling scheme in both systems is collective recycling by a third party, namely, the Korea Metal Cans Resources Association (KMCRA, interview, July 5, 2013). Producers have contracted out recycling tasks of metal packaging to the KMCRA since 1994.

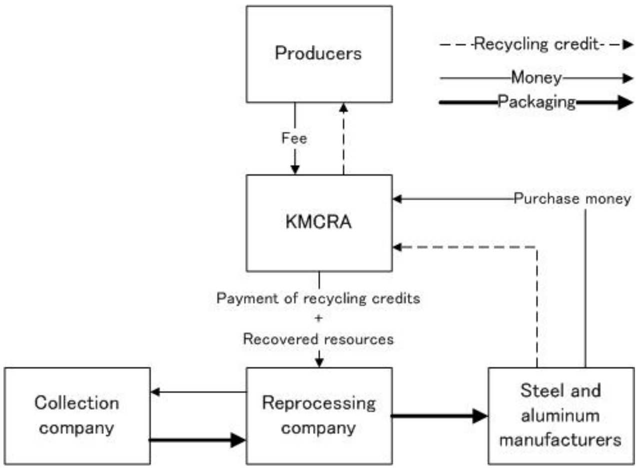

Fig. 4.2. Recycling operations of the KMCRA in the WDR and EPR programs
Source: Author compilation based on an interview with the KMCRA on July 5, 2013

The flows of money, recycling credits, and metal packaging are presented in Fig. 4.2. Producers who contract out recycling to the KMCRA pay a fee to the KMCRA. This fee is determined uniformly based on the size of production output. The KMCRA buys recycling credits from scrap metal reprocessing companies based on the report of steel and aluminum manufacturers. The contracted reprocessing companies make payments to procure the discarded metal packaging, and provide the scrap metal to steel and aluminum manufacturers as determined by the KMCRA. These manufacturers then report the weight of the scrap metal and collectively pay the KMCRA for the purchase of scrap metal. Then, the KMCRA passes on moneys from the sales to reprocessing companies, as well as to make payments for recycling credits. The price of recycling credits is financed by a producer fee. This price is annually determined by a committee composed of the KMCRA, reprocessing companies, producers, and experts (KMCRA, interview, July 5, 2013).

4.4 Materials and methods

4.4.1 Recycling rate

The WDR and EPR programs define recycling as the process of changing discarded metal packaging into new metal products (GOK, 2002a; GOK, 2011b). One difference between the programs is that under the EPR program, it is possible to include the volume of exports for recycling when determining EPR recycling credits. However, in 2011, 90% of recycling under the EPR program was processed domestically through the KMCRA (KMCRA, 2012). For this reason, this paper disregards the possibility of recycling via exports and regards all recycling in the EPR program as being conducted in Korea only.

The recycling volume under the WDR program must be estimated because it is not available as a tonnage figure, while the amount of recycling in the EPR program can be derived from data from the MOE (2013). Due to limitations in the data, only the amount of recycling for the year 2000 was calculated. WDR recycling volume was estimated from the following: the refund total in 2000 was 9.7 billion won (8.6 million US dollars) (KMOE, 2001); the refund amounts for steel and aluminum packaging were 46,000 and 111,000 won per ton, respectively (Chang et al., 1999); and the generation ratio of used steel and aluminum packaging was 95% and 5% by weight, respectively (Chang et al., 1999). Thus, the equations can be expressed as follows:

$$(x \text{ ton} \times 46 \text{ thousand won}) + (y \text{ ton} \times 111 \text{ thousand won}) = 9{,}679{,}963 \text{ thousand wons.} \quad (1)$$

$$x \text{ ton} = (x \text{ ton} + y \text{ ton}) \times 95\%, \quad (2)$$

where x stands for the amount of recovered steel packaging and y stands for the amount of recovered aluminum packaging.

In order to estimate the recycling rates, we must have a common denominator for the analyzed period. The shipment volumes of the targeted producers in the WDR and EPR programs are not appropriate as a common denominator because the range of producers is narrower in the EPR program than in WDR programs. The exemption standards for producers were introduced only with the start of the EPR program (GOK, 2002b). The most appropriate indicator is the amount of annual metal packaging consumed in South Korea. However, such data are not available. Instead, this paper uses data on the generation of metal packaging (KMOE, 2012d). It is noted that these data represent the amount of production for domestic steel and aluminum packaging, which excludes imported products.

4.4.2 Social costs and benefits of WDR and EPR programs

4.4.2.1 Social costs and benefits

To compare the costs and benefits of the WDR and the EPR programs, we estimate the costs and benefits of the recycling programs in the years 2000 and 2011. The year 2000 is the final year when the WDR program began to be phased out, and the year 2011 is the most recent year of available data under the current EPR program.

Table 4.2. CBA framework

		Content
Cost	Producers	Administrative expenses of KMCRA Recycling credits of recyclers
	Recyclers	Collection, transport, and recycling of metal packaging
Benefit	Recyclers	Income from sales of recovered resources Recycling credits
	Society	Prevention of social costs that usually accompany landfill disposal (landfill disposal of incombustible wastes)

Table 4.2 shows our analytical framework, which is a modification of Smith's CBA framework and clarifies the incidence of costs and benefits. Costs consist of KMCRA administration, payment of recycling credits, and recycling costs incurred by reprocessing companies. Producers bear the costs of KMCRA administration and payment for recycling credits. The actual collection, transport, and recycling costs are counted as recyclers' costs. Benefits consist of revenues of reprocessing companies and savings of landfill space and disposal. Producer payments for recycling credits that are provided to reprocessing companies are included in the benefits to recyclers.

Studies by the Korea Environment Institute (KEI, 2002) and Choi et al. (2007) provide possible estimates of the cost per ton for collection and recycling. This paper uses the estimate in KEI (2002), as it is based on an actual area that was representative of dwelling patterns in Korea. KEI (2002) seems to come closer to actual cost compared to Choi et al. (2007), which assumed a uniform dwelling pattern.

In addition, the social benefits of recycling are estimated on the assumption that discarded metal packaging would otherwise be channeled to one disposal route, landfilling, if not recycled under the WDR or EPR program. The unit price for this calculation is based on the previous research by Mok (2005). To date, this is the only research that estimates the average cost related to landfill disposal at the national level in South Korea. The landfill disposal costs by Mok (2005) are composed of four components; land use for 50 years, and construction, operation, and post management for 15 years. The post management includes the costs of leachate and gaseous emissions. The estimated value by Mok (2005) is about 34% higher than the landfill tax for incombustible wastes in the capital area (CLC, 2013).

Smith (2005) counted the reduced external costs of landfill disposal and the saved production of virgin materials as social benefits of a recycling program. Regarding the former, the external cost components of landfill disposal are considered to be already covered by the data of Mok (2005). Regarding the latter, we use sales of recovered scrap metal as a substitute for saved production of virgin material. For the price of recovered scrap metal, we use the average market price of middle grade scrap metal materials during the past 5 years (2008–2012) based on statistics from the report Market Trend of Recovered Resources put out by the Korean Statistical Information Service (KOSIS, 2013c). The costs and benefits per ton used in our analysis are shown in Table 4.3.

Table 4.3. Costs and benefits per ton for recycling and landfill disposal

	Content	Material	Price/ton (Thousands of won)
Cost	Separate collection, sorting, storage	Steel	199
		Aluminum	1,005
	Transport	Steel	33
		Alum.	72
	treatment (compress and shred)	Steel	68
		Alum.	161
Benefit	Sales of recovered resource	Steel	254
		Aluminum	1,211
	Collection, transport, landfill	Incombustible	161

Source: KEI (2002), Mok (2005) and Kosis (2013c)

As Table 4.3 shows, the transport and treatment costs per ton are higher for aluminum packaging than for steel packaging. Aluminum packaging is lighter than steel packaging of the same size. As a result, for a given weight of aluminum packaging, a volume of metal several times larger must be transported and treated compared with steel packaging.

To express the value of money on the same basis, we adjusted all relevant values to 2011 values by using the GDP deflator (KOSIS, 2013a). For the sake of international discussion some values are expressed in both won and US dollars by using the average US dollar–won exchange rate for 2011 (1 US dollar = 1,131 won) (KOSIS, 2013b).

4.4.2.2 Producers' costs

Producers' costs in the WDR program in the year 2000 (WC) can be calculated using the following equations:

WC = Deposit - Refund + Recycling cost, (3)

Deposit = Refund / 83.4%, (4)

Refund = Q × T, (5)

Recycling cost = KMCRA administration + Payment of recycling credits, (6)

KMCRA administration = Refund × 17% (Steel:Aluminum = 95%:5%), and (7)

Payment of recycling credits = Refund × 73% (Steel:Aluminum = 95%:5%), (8)

where WC, Q, and T stand for producers' costs, recycling amount, and per ton refund in WDR program, respectively. Per ton refund (T) was 46,000 won for steel packaging and 111,000 won for aluminum packaging (Chang et al., 1999). The refund rate was 83.4% of the total amount of deposit in 2000 (KMOE, 2003a: 176). The recycling costs under the WDR program are mainly composed of two elements: the KMCRA administrative cost, and the payment of recycling credits to reprocessing companies. Of the total refund amount, 17% was spent on KMCRA administration and 73% on the payment of recycling credits (Chang et al., 1999). Based on this information, producers' costs in the year 2000 were estimated and then multiplied by 1.32 to adjust to 2011 values (KOSIS, 2013a).

The cost for producers in the EPR program (EC) is composed of KMCRA administrative cost and payment for recycling credits. They can be expressed as follows:

$EC = P / 87\%,$ (9)

$P = PT \times R,$ *and* (10)

$A = EC - P,$ (11)

where EC, P, PT, R, and A stand for producers' costs, payment of recycling credits, per ton price of recycling credit, recycling amount, and administrative costs of the KMCRA, respectively. In 2011, around 87% of producers' costs were used for payment of recycling credits (KMCRA, 2012). The per ton prices of recycling credits (PT) for steel and aluminum packaging were 60,000 won and 110,000 won, respectively (KMCRA, interview, July 5, 2013). The recycling amount (R) was 97,132 tons for steel packaging and 42,490 tons for aluminum packaging (KMOE, 2013). Administrative costs (A) are calculated by subtracting the payment of recycling credits (P) from the total costs of producers (EC). Administrative costs are around 2 billion won (KMCRA, interview, June 17, 2013)

4.5. Results

4.5.1 Recycling rate

The recycling amount of steel and aluminum packaging are estimated to be 186,721 tons and 9,827 tons respectively in 2000. Although limited data availability prevents calculation of the amount of recycling in other years, it can be safely assumed that recycling rates increased under the WDR program because the refund rate of deposits increased over time (KMOE, 2003a: 176). The estimated percentage of recycling amount in generation of metal packaging waste (the recycling rates) is shown in Figure 4.3.

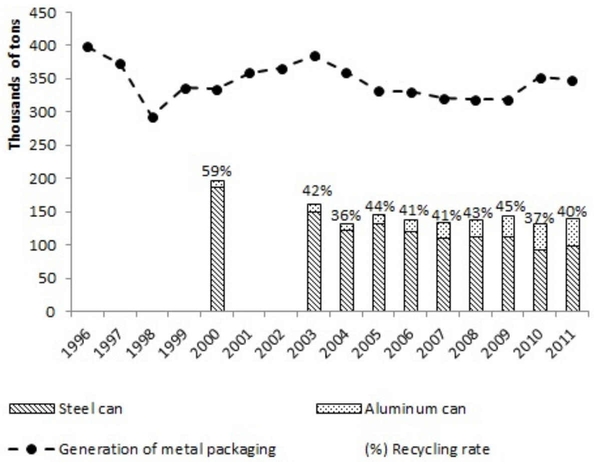

Fig. 4.3. Recycling rate for metal packaging (2000–2011)

Source: Author compilation based on MOE (2012, 2013)

A drastic decline in the generation of metal packaging in the year 1998 can be attributed to the Asian financial crisis. After 2003 another decline occurred, which was followed by a period of stagnation. This change can be attributed to the increasing preference for plastic packaging and light aluminum packaging in the market (KMCRA, 2009). In 2011, the generation ratio of discarded steel and aluminum packaging was 70% and 30%, respectively (KMOE, 2013).

Since the EPR programs started, the recycling rates have stayed below 45% and have not exceeded the recycling rate achieved under the WDR program in the year 2000. The primary reason for this reduction is the exemption of small- and medium-size producers from mandatory recycling under the EPR program.

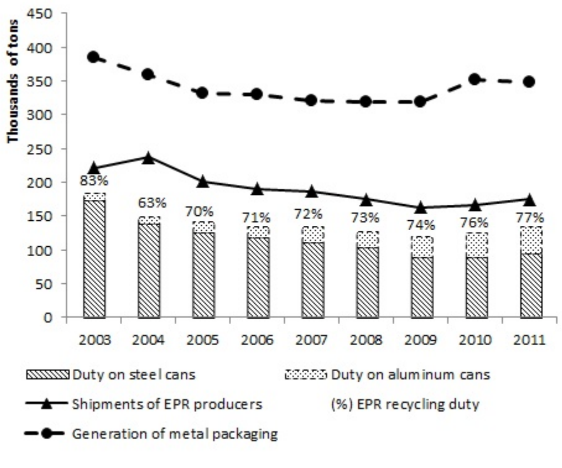

Fig. 4.4. Mandatory recycling rate of EPR producers

Source: Author compilation based on MOE (2012, 2013)

Figure 4.4 shows that the volume of shipments from producers covered under the EPR accounts for only 50% of the overall generation of metal packaging in 2011. The percentage of the mandatory recycling volume in the shipment volume of EPR producers (the mandatory recycling rate) appears to have been increasing gradually since 2005. However, the actual mandatory recycling rate by definition is much lower than the mandatory recycling rate presented. This is because 77% of the mandatory recycling rate for EPR producers in the year 2011 corresponds to only 39% of the total generation of metal packaging. The 39% is far below the previous level of 59% that the government required producers to achieve in the year 2000 under the WDR program.

4.5.2 Social costs and benefits of the WDR and EPR programs

The results of the cost-benefit analysis in 2000 and 2011 are shown in Table 4.4. Limited data availability prevents estimates of cost-benefits in other years. The net social benefit of both programs is positive. However, our analysis also reveals that the net social benefit in 2011 is smaller than in 2000. This comes mainly from a decrease in recycling amounts, which led to the reduction in benefits from increased use of landfill disposal.

Table 4.4. Social costs and benefits matrix of metal packaging recycling in 2000 and 2011 (billions of won)

		Incidence	Content	2000	2011
Cost		Producers	Total	14.0	12.1 – 12.5
			(Steel)	13.1	6.7
			(Aluminum)	0.9	5.4
			KMCRA administration	2.2	1.6 – 2.0
			Recycling credit	9.3	10.5
			Unreturned deposit	2.5	—
		Recyclers	Collection and recycling	68.1	81.7
	Subtotal			82.1	93.8 – 94.2
Benefit		Recyclers	Total	68.6	86.6
			recovered resource	59.3	76.1
			Recycling credit	9.3	10.5
		Society	Landfill of incombustible wastes	31.6	22.5
			Unreturned deposit	0 – 2.5	—
	Subtotal			100.2 – 102.7	109.1
Net benefit				18.1 – 20.6	14.9 – 15.3

Producers' costs totaled 14.0 billion won (12.4 million US dollars) in 2000 and 12.1 – 12.5 billion won (10.7 – 11.1 million US dollars) in 2011. Producers' costs decreased by 1.9 billion won (1.7 million US dollars) from 2000 to 2011 at a maximum. The policy shift from the WDR program to the EPR program allowed producers to save 2.5 billion won (2.2 million US dollars) in the "unreturned deposit" component. However, due to an increase in the payment of recycling credits and a decrease in the administrative costs of the KMCRA, producers ultimately saved 1.9 billion won in practice at a maximum.

Producers' costs for steel packaging in 2011 amounts to only half of the costs compared to 2000. By contrast, for aluminum packaging costs for producers in 2011 increased six times compared with the 2000 level. This result reflects the change in the amount of recycling for steel and aluminum packaging between 2000 and 2011.

Despite the decrease in the amount of recycling in 2011, the overall cost for recyclers increased, reflecting the higher average cost of collection and reprocessing of aluminum packaging. The recent increase in the consumption of aluminum packaging results in higher costs for recyclers as well. In the meantime, this enables them to earn higher revenue, because the higher price of recycled aluminum packaging brings higher economic profits. Because of this, benefits to recyclers in 2011 exceeded the benefits in 2000 by 18 billion won (16 million US dollars) in total.

Benefits to society are estimated at 31.6 billion (27.9 million US dollars) and 22.5 billion won (19.9 million US dollars) in 2000 and 2011, respectively, a decrease of 9.1 billion won (8.0 million US dollars) over that period. This decrease results from the smaller cost savings of landfill disposal.

The net benefits of the programs are estimated at 18.1 billion won (16.0 million US dollars) in 2000. If we assume that the government spent 2.5 billion won of "unreturned deposit" on the establishment of recycling infrastructure in 2000, the net benefits in the year 2000 are within a range of 18.1 – 20.6 billion won (16.0 – 18.2 million US dollars). The net benefits in 2011 are within a range of 14.9 – 15.3 billion won (13.2 – 13.5 million US dollars).

4.6. Discussion

The WDR program was replaced with the EPR program with the aim to increase recycling rates by increasing the economic responsibility of producers. However, our estimation clarified that the recycling rate of metal packaging dropped from 59% in 2000 to 40% in 2011, and recycling volume dropped accordingly. Despite the decrease in total recycling volume and rate in 2011, producers' cost of recycling credits increased than that in 2000. This is because of the increased recycling volume and the higher unit price of recycling credit for aluminum packaging compared with steel packaging. Our estimation suggests that since the EPR program began, the recycling volume and rate of metal packaging have decreased, due to the increased cost burden of producers accrued from aluminum packaging. In addition producers that use aluminum packaging now face a higher cost burden under the EPR program than under the WDR programs because small- and medium-size producers are exempted from the mandatory recycling requirement. In order to set an ambitious recycling target, it is necessary to mitigate this unequal treatment.

Also worth noting is that this research does not cover the environmental assessment because of the lack of data for defining the environmental impacts of the WDR and EPR programs in monetary terms in Korea. Craighill and Powell (1996), Vigsø (2004), and Lavee (2010) showed in their environmental assessments that among various types of packaging, aluminum packaging brought the highest net benefits from recycling. This is because of the enormous amount of electricity required to convert bauxite into aluminum ingot and thus able to be saved by using recovered aluminum in the production stage. It is a future challenge to make an integrated financial and environmental assessment of the WDR and EPR programs.

4.7. Conclusion

The Korean government replaced the WDR program with the EPR program in 2003. The original purposes of this policy change were the reduction of waste and the minimization of costs.

Regarding the recycling rate, we found that recycling rate has not exceeded the rate from the year 2000. This paper estimates that the rate dropped from 59% in 2000 to 40% in 2011 and recycling volume dropped accordingly. This decrease implies that municipalities and society have to bear increasing external costs associated with landfill disposal, although data constraints preclude an investigation of the size of this increase.

Cost-benefit incidence analysis shows that net social benefits decreased by 2.8 billion won (2.5 million US dollars) at a minimum, while the net benefits to producers increased by 1.9 billion won (1.7 million US dollars) at a maximum under the EPR program compared with the WDR program. These changes in costs and benefits mainly resulted from a decrease in the amount of recycling, which ultimately increased costs for landfill disposal.

As theoretical explanations suggest, the EPR program can achieve a higher recycling rate and greater net social benefits. To realize such improvements, the government of South Korea should tighten program standards and narrow the scope of the exemption given to small- and medium-size producers.

Acknowledgements

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Chapter 5 International Recycling by South Korea

5.1. Introduction

The Seoul Initiative was adopted at the 5th Ministerial Conference on Environment and Development in Asia and the Pacific (MCED-5) in 2005 with the aim of addressing major policy issues pertaining to green growth and encouraged an international discussion on green growth. Maximizing social benefit while minimizing ecological impact is regarded as a basic principle of green growth (UNESCAP, 2008).

Faced with the global economic recession that was at its worst in late 2008, President Myung Bak Lee of South Korea laid out a “Low Carbon, Green Growth” strategy as a new means of domestic economic development and set the ambitious goal of 7% growth per annum (Cho, 2010). The Low Carbon, Green Growth strategy defines its goals as “growth achieved by saving and using energy and resources efficiently to reduce climate change and damage to the environment, securing new growth engines through research and development of green technology, creating new job opportunities, and achieving harmony between the economy and environment” (KPMO, 2010, art. 2).

One of the important characteristics of South Korean green growth is that the aim is to ensure that resources are more used efficiently across the whole economy. Toward this end, resource productivity has been adopted as a key policy indicator for green growth (GGK, 2009). Resource productivity refers to the monetary yield per unit resource of domestic material consumption.

South Korea implemented the Extended Producer Responsibility (EPR) program as one of the main policy tools for green growth. This program is expected to increase the efficiency of resource use and eco-production. The EPR program focuses on two aspects: implementing a mandatory domestic recycling system, and reducing the amount of toxic material used in production (KMOE, 2010b). EPR is a policy concept recommended by OECD in 2001 (OECD, 2001) and advocated as a tool for environmentally sound management of waste (OECD, 2007). OECD defines EPR as “an environmental policy approach in which a producer’s responsibility for a product is extended to the post-consumer stage of a product`s life cycle” (OECD, 2001: 9). EPR aims at internalizing the negative externalities accrued from the whole life cycle of a product as a means of improving overall social welfare (Walls, 2004). Most OECD countries are implementing EPR programs in key sectors (OECD and JMOE, 2014).

The resource productivity of developed countries tends to increase with economic globalization. This is attributed to a gradual change in the structure of economic activity from resource-based and labor-intensive production to skill- and capital-intensive production (Alcorta, 2012). This structural change additionally increases the export of recyclable and hazardous waste from developed countries to developing countries (Taketoshi, 2009), which can result in increasing the resource productivity of developed countries simultaneously with increasing the negative externalities in developing countries. Rauscher (2001) asserted that, theoretically, international trade of hazardous waste is beneficial to the exporting countries, with the benefits increased by environmental laxity in the importing countries. When there is insufficient regulatory oversight in the waste disposal and processing industries, negative gains may be accrued to the importing countries, and this may cause welfare losses for the world as a whole. Therefore, to achieve global green growth, policies need to be implemented that will avoid the transfer of negative externalities from developed countries to developing countries.

In recent years, large amounts of waste of electrical and electronic equipment (WEEE) have been exported to developing countries. WEEE includes hazardous substances that can damage the environment and human health if not properly handled. International trade of WEEE can lead to welfare losses in developing countries where environmental governance is not sufficient to internalize the negative externalities. International trade of hazardous waste is regulated by the Basel Convention. However, there is no internationally unified regulatory framework for the international trade of used products. As a consequence, a great amount of WEEE was brought into non-OECD countries in the guise of used products intended for reuse (Nnorom et al., 2011).

As of 2009, in South Korea, WEEE regulated by the EPR program is collected at a rate of only 23–28% for televisions, washing machines, and refrigerators, and 7% for air conditioners (Kim et al., 2013). The flow of WEEE that is not collected under the EPR program has not been published. Accurate data on illegal exports of used electronics is not publicly available. However, according to the Japan China Commodities Inspection Company, only 28 cases of exports of used electronics from South Korea to China were found to be illegal in 2005 (Ahn, 2006). The reasons for those rejections were mixing of unsanitary or forbidden waste, falsification of export permits, and failing to undergo a preliminary inspection before shipment (Ahn, 2006). It is known that there were ship-backs of illegally exported used electronics disguised as products intended for reuse (KMOE, 2012a).

Against this background, this chapter first explores features of WEEE management in South Korea to focus on the institutions involved in the export of used electronics. The export rates of five types of goods are estimated and the export destinations of used cathode ray tube (CRT) computer monitors are identified. CRT monitors are chosen because they contain a very high concentration of toxic metals because of the lead included in the CRT glass (Oguchi et al., 2013). Field research in Nhat Tao market in Ho Chi Minh City, Vietnam, was used to create a cost–benefit incidence analysis in order to show how the benefits and costs of the export of CRT computer monitors are allocated under South Korea’s international recycling program.

5.2 Features of EPR programs for WEEE management

WEEE management in South Korea is the same as that in the European Union (EU) and Japan in that it focuses on mandatory recycling systems and the restriction of the use of certain hazardous substances (RoHS) in manufacturing covered by the EPR program. In South Korea, a mandatory recycling system for producers was implemented in January 2003 under the Act on the Promotion of Saving and Recycling of Resources. This law was superseded by the Act for Resource Circulation of Electrical and Electronic Equipment and Vehicles (ARCEEEV) in

February 2008; ARCEEEV encompasses both recycling and RoHS. As of 2014, 26 types of electronics are regulated by the law.

Table 5.1. Institutions of WEEE management in South Korea, the EU, and Japan (as of 2014).

	South Korea	EU	Japan
Definition of Producer	Manufacturers and importers[1] above standard[2]	Manufacturers and importers[1]	
Regulated items	Household appliances,[3] IT equipment,[4] etc. (26 types of EEE)	(102 types of EEE)	(8 types of EEE)
Collection (recycling) target (min.)	6 kg per inhabitant per year, in proportion to the shipment share of EPR producers in total domestic shipments by 2016	45% of average weight of EEE placed on the market in the prior three years, from 2016	—
Recovery rate (min.)	65–80%	50–80%	50–70% (laptop computer: 20%)
RoHS (max. level)	Lead (0.1%), Mercury (0.1%), Hexavalent chromium (0.1%), PBB (0.1%), PBDE (0.1%), and Cadmium (0.01%)		
Targeted item of RoHS	All of regulated items	All of regulated items	Regulated items and microwaves
RoHS penalty	Prohibition of sale and a fine below 30 million KRW	Prohibition of sale	Sale with a disconfirming mark
Export of used electronics	Approval of the export of used computer monitors for reuse as legitimate recycling	Monitoring duty / Cost of monitoring on producers / Burden of proof on exporters of used electronics	Specification of Harmonized System (HS) code for used household appliances and display / Prior consultation

Notes: [1]Any person or firm that, under its own brand name, manufactures and sells, or resells, or imports and sells the final electronics.

[2]More than 1 billion KRW of total sales in previous year, or more than 0.3 billion KRW of import amount in previous year.

[3]Air conditioners, clothes dryers, freezers, refrigerators, televisions, and washing machines.

[4]Computers (laptop and desktop) and computer displays (CRT and flat screen).

Source: EU (RoHS Recast, 2011; WEEE Recast, 2012), Japan (JISC0950, 2008; JOP, 2008; JOP, 2014), South Korea (KMOE, 2012b; KMOE, 2014a; KMOE, 2014b; KMOE, 2014c).

South Korea has three unique features in comparison with the EU and Japan. First, South Korea exempts certain manufacturers and importers (producers) of regulated electronics from recycling duty on the basis of their production size (KMOE, 2014b, art. 14–15).

Second, a producer's duty in the EPR program is different from that of a producer in the EU or Japan. The South Korean recycling program assigns EPR producers both a minimum recovery target per unit and a quota for the recycling of targeted electronics. Recycling refers to the whole process of changing WEEE into recovered materials in facilities approved for that purpose (KMOE, 2012b). If the quota is not met, a fine that is set to greater than the cost of implementing proper recycling for the missing volume is imposed upon the EPR producers (KMOE, 2014a, art. 18). The recycling target of EPR producers is 6 kg per inhabitant per year, adjusted to reflect their share of total domestic shipment, by 2016 (KMOE, 2014c). In the EU, collection targets refer to the separately collected volume by producers, distributors, and collection facilities (including municipal facilities), but there is no penalty to producers for not achieving this failure. Japan does not impose a collection or recycling target on producers, but it requires producers of regulated electronics to achieve a minimum recovery target per unit.

Third, by determining the volume of recycling conducted by EPR producers, the South Korean government has qualified the export of used computer monitors for the purpose of reuse as legitimate recycling since 2004 (KMOE, 2003b, 2012b). In fact, EPR producers requested this international recycling program for used computer monitors (Chung and Yoshida, 2008). EPR producers achieve the recycling target of computer monitors by paying exporters for documentary evidence of an export declaration issued by customs [1]. South Korea does not delineate a particular strategy to combat the illegal export of used electronics. The export of used electronics for direct reuse is exempted from related duty imposed on waste trade (KMOE, 2012a). The criteria for exemption from duty refer to "used electronics which function fully, have a contract ensuring the export for the purpose of direct reuse and have a document of evaluation on products' functionality from the destination country" (KMOE, 2012a:308). However, exporters of used electronics are not required to prove that the exporting products are actually eligible for exemption [2].

In the EU a large proportion of WEEE is sent from retailers and municipalities to exporters after it is separately collected from consumers (EERA, 2007), and this amount is still counted in the collection rate target. It is unclear how many of these exporters engage in illegal practices. The EU set forth two main measures to deter illegal export of used electronics. One measure is to strengthen export inspections by requiring exporters to prove that the shipped items are reusable electronics intended for direct reuse, not WEEE, when requested by an inspection authority (WEEE Recast, 2012, art. 23, cl. 2). The cost of inspections and analyses for monitoring used EEE suspected to be WEEE can be charged to the producers or exporters (WEEE Recast,

1 Interview with the head of the International Cooperation Department of the Association of Electronics Environment (AEE), 7 February 2014.
2 Interview with the Export Control Officer of Incheon Customs, 23 September 2014.

2012, art. 23, cl. 3). The other measure is to set a high collection target to prevent the illegal export of used electronics by informal exporters (WEEE Recast, 2012, (15)).

In Japan, as a measure to curb illegal export of used electronics, Japan has regulated used home appliances and computer monitors since 2008 by using the Harmonized Commodity Description and Coding System (HS code) to categorize exports. Japan provides exporters with a prior consultation and presents a more detailed standard for the self-evaluation of legal exports of used electronics than is provided in South Korea and the EU. This standard is composed of five components: life span (below 15 years for air conditioners and televisions; below 10 years for freezers, refrigerators, washing machines, and clothes dryers) and appearance, function, packaging and loading, a contract proving sales for direct reuse, and empirical evidence of sales of direct reuse (JMOE, 2013).

5.3 Theoretical explanation of international recycling in South Korea

Fig. 5.1 presents a simplified economic model of an EPR domestic recycling management scenario. In the diagram, P_R is the marginal revenue for recyclers and MC_R is the marginal cost of recycling. Thus, $P_R - MC_R$ is the marginal profit from recycling. MC_L is the marginal cost of landfill disposal. The value of $P_R - MC_R$ is read from left to right and the value of MC_L is read from right to left; hence, the value of $P_R - MC_R$ decreases with volume and MC_L increases with volume.

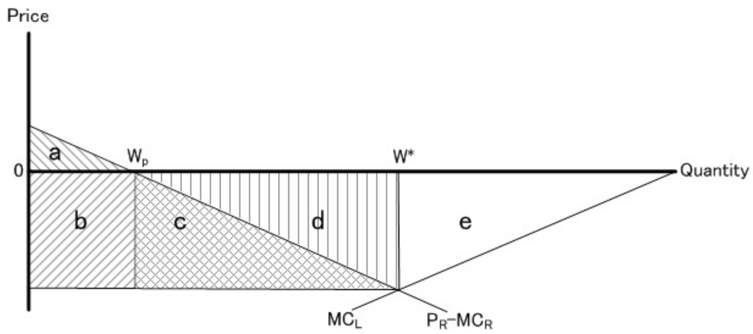

Fig. 5.1. Domestic recycling of computer monitors
Source: Adapted from Pearce (2001) by author

In this instance the recycling level in the market will normally be W_p, which is where recyclers' profits are maximized. We assume that the government imposes duties on producers to achieve the recycling level W^* that represents the optimal levels of recycling and landfill use. In this case, producers have to bear costs corresponding to b + c + d. In contrast, recyclers have gains of the area a + b + c, and society's cost of landfill is e.

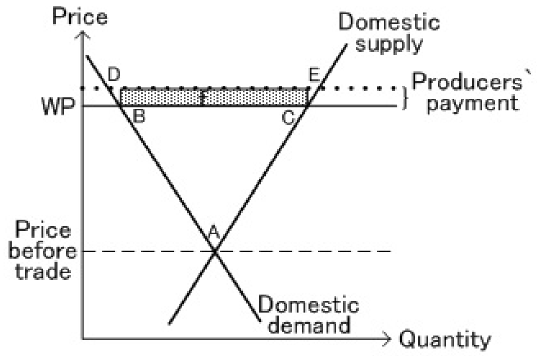

Fig. 5.2 International trade of used computer monitors and producer’s cost

Fig. 5.2 shows the international trade of used computer monitors and producer’s cost. The domestic equilibrium price before trade (A) is below the world price (WP), which means that South Korea will be a net exporter. We assume that the line segment W_pW^* of Fig. 5.1 and BC of Fig. 5.2 are the same. Owing to the international recycling program, EPR Producers can fulfill the volume of recycling duty corresponding to the line segment BC by providing exporters with a payment in exchange for export declarations for used computer monitors. In this case, the cost to the producers corresponds to the shaded area f. Theoretically, this can result in the increase of the supply to the length of the line segment DE because it has the same effect as increasing the product price by the amount of payment from producers to exporters (Chung and Yoshida, 2008).

Table 5.2. Additional costs (–) and benefits (+) in domestic and international recycling.

	Producer	Exporter	Recycler	Society	Sum
International recycling	–f	f	a	–e	a – e
Domestic recycling	–b – c – d	0	a + b + c	–e	a – d – e
Difference	–f + b + c + d	f	–b – c	0	d

Through international recycling, the producer’s additional savings is the area –f + b + c + d. Recyclers suffer a loss of –b – c. For society, there is no change so long as the same residue for landfill disposal remains after recycling, and exporters can make additional profits corresponding to f. The additional net benefit of the international recycling is d as a whole. Our theoretical analysis implies that the South Korean government adopted the international recycling program for used computer monitors to increase recycling and accrued gains at the same time.

5.4 Exports of used computer monitors in action

5.4.1 Data

International trade of used electronics and new electronics are not differentiated by HS codes, which are used globally for the classification of trade commodities, up to the level of 6 digits. Some countries, such as Japan, specify additional digits for the HS codes to classify used electronics. However, it is difficult for most countries to quantify the trade of used electronics from only trade statistics.

Because South Korea does not specify extended HS codes for used electronics, we examine the details of export declarations to estimate the total export volume of used electronics. In this paper, we examine five types of electronic appliances: air conditioners, computer monitors, refrigerators, televisions, and washing machines. The HS codes for the selected electronics and details of the method for selecting data are provided in the Appendix.

Because the export volume of used electronics in this paper is based on self-declarations by exporters, undeclared export shipments are not included in the export volume. In particular, comprehensive data on export freight of monetary value less than two million KRW are not available. The reason for this is that it is not necessary to declare such exports in South Korea; this exemption is based on South Korea Customs Service Notification (2014).

In order to observe the time-series data of exported used electronics not including fluctuations in the amount of discarded electronics generated in South Korea, we quantified the export rate on the basis of the volume of discarded electronics. The export rate is calculated by dividing the exported volume of the used electronics by the volume of discarded electronics generated in South Korea. For annual volumes of discarded electronics, we referred to Kim et al. (2013). Those data were estimated from sales data by using a delay model that considers the product lifespan distribution. The volume of computer monitors was updated to agree with the data according to the same method [3].

The volume of discarded computer monitors is estimated from sales data (IDC Korea, 2010; KOSIS) and a product lifespan distribution. The shape parameter of the lifespan distribution of computer monitors is fixed at 2.4 in this paper. This value is chosen because it represents the average shape of the 22 types of electronics (Oguchi et al., 2006). The average lifespan of computer monitors was assumed to be 5–6 years according to the Public Procurement Service (2011) and Baek (2006).

5.4.2 Export rate

The export rates of used electronics are shown in Fig. 8.3. The export rates of used air conditioners and washing machines were estimated at below 1%, and refrigerators were below 3% during 2002–2009.

[3] See Kim et al. (2013) for a complete description of the estimation procedure.

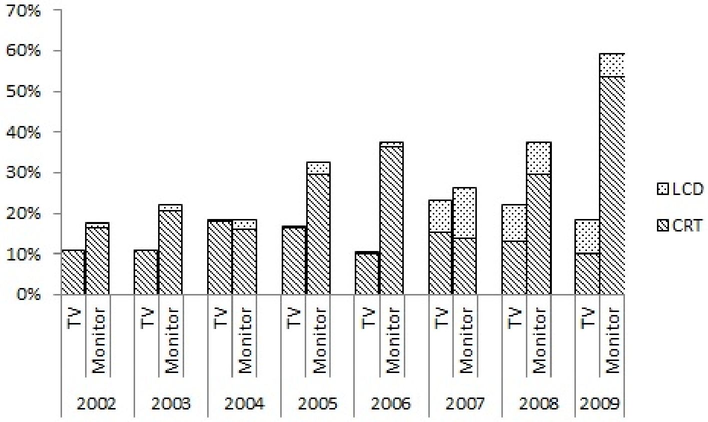

Fig. 5.3. Export rates of used computer monitors and televisions from South Korea during 2002–2009 (weight basis).
Note: Air conditioners, refrigerators, and washing machines are not shown because their export sizes are negligible.
Source: Compiled by author from data in the Korea Customs Trade Development Institute (KCTDI) database.

Since 2002, the export rates of used computer monitors have increased, reaching 59% in 2009. During the entire period, most exported used monitors were CRT monitors. The export rates of used televisions were relatively low in comparison with the rates for used computer monitors, ranging between 11% and 24%. Since 2007, used flat screen televisions have accounted for around 40% of total exports of used televisions. It is noteworthy that the export rate of computer monitors declined in the years 2004 and 2007 despite EPR producers' payments to exporters of used computer monitors.

5.4.3 Export destination

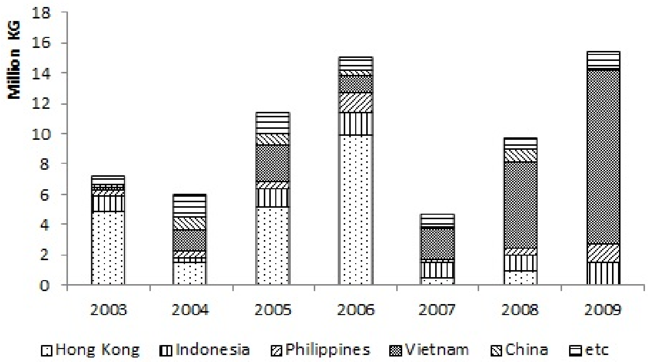

Fig. 5.4. Export destinations of used CRT monitors during 2003–2009.
Source: Compiled by author from data in the KCTDI database.

CRT computer monitors were directed mostly to Asian countries during the entire period.

The main destinations for used CRT monitors were Hong Kong (2003–2006) and Vietnam (2007–2009). Drastic decreases of export volume to Hong Kong can be observed in 2004 and 2007. The export rates of used computer monitors mirror those changes for those years (see Fig. 5.3).

Hong Kong is famous as an entrepôt of China for recyclable resources and secondhand products (Kojima and Yoshida, 2007). As contamination by electronic waste in China intensified, the Environmental Protection Department (EPD) of Hong Kong conducted investigations and uncovered illegal electronic waste disguised as reusable electronics in 2003 (Kojima and Yoshida, 2007). In July of 2004, the EPD required the South Korean government to enact countermeasures against illegal export of used electronics (Byun, 2004). In April 2006, Hong Kong adopted a stringent policy, issuing the Advice on Import and Export of Used Electrical and Electronic Appliances having Hazardous Components or Constituents (EPD, 2006). Although exports to Hong Kong were decreased in response to these stringent regulations in 2004 and 2007, South Korea’s total export volume of used CRT monitors has not declined since then. Instead, the main destination changed from Hong Kong to Vietnam. In 2009, 74% of export volume of used CRT monitors was headed for Vietnam.

5.5 Market conditions of Vietnam

5.5.1 Entrepôt for used electronics

Vietnam has economic and geographical conditions that make it likely to replace Hong Kong as an entrepôt for the trade of used electronics. It shares borders with China and some ASEAN countries. Vietnam has belonged to the ASEAN Free Trade Area (AFTA) since July 1995, and, as of 2008, Vietnam’s import tariff is below 5% for 98% of the products in the Inclusion List when imported from an AFTA country (ASEAN, 2008). It has been below 5% for 45% of the products when imported from South Korea since the South Korea-ASEAN FTA took effect in 2007 (KMOFAT, 2011). In July 2005, Vietnam started abolishing tariffs with China (KMOFAT, 2011). Vietnam further exempts goods imported temporarily for re-export from tariffs and value-added taxes (JETRO, 2014; HSK Vietnam Audit company).

To protect the domestic market and the environment, Vietnam takes measures to avoid the illegal inflow of used electronics. In principle, Vietnam bans the import of used electronics (GOV, 2006), especially used information technology appliances such as CRT computer monitors, desktop computers, mobile phones, and televisions (MOPTV, 2006). However, Vietnam allows the temporary import of used electronics intended for re-export (GOV, 2006). In 2012, Vietnam prohibited the import of refrigerators containing chlorofluorocarbon refrigerants, desktop computers, and televisions, even for the purpose of re-export (MOITV, 2012). Items not specified in MOITV (2012) can be legally imported for the purpose of re-export; hence, used computer monitors are still allowed to be imported into Vietnam so long as they are intended for re-export.

Hai Phong Harbor and Mong Cai City in northern Vietnam share a border with the city of Dongxing in China and act as hubs for the trade in used electronics (Shinkuma and Huong, 2009). Hai Phong harbor works as an export route to China, and is a known port for smuggling (Terazono and Yoshida, 2012). From Mong Cai city, a large amount of imported used electronics goes into

Dongxing before being transported to Guangzhou (Shinkuma and Huong, 2009). Electronic waste from Guangzhou is supplied to Guiyu, which is in the same province (Lee, 2002). Plastic recovered in Guiyu is supplied to many global electronics companies (Watson, 2013).

Guiyu is widely known to experience severe environmental pollution as a consequence of substandard recycling of electronic waste (Leung et al., 2006). High levels of lead are present in the blood of children; high concentrations of persistent organic pollutants (POPs), such as flame-retardants, are present in various environmental media; and dioxin pollution is known to be severe (Huo et al., 2007; Wong et al., 2007; Li et al., 2007). These problems accrue from the hazardous constituent materials in the electronics in combination with improper recycling processes.

Another hub of trade in used electronics in the south central part of Vietnam is the Nhat Tao Market in Ho Chi Minh City. Used electronics are typically brought to Nhat Tao Market through Da Nang Port, Saigon Port, and the Sihanoukville Port in Cambodia (Hai et al., 2005; Shinkuma and Huong, 2009; Kojima, 2005).

5.5.2 Case study of Ho Chi Minh City

In Vietnam 17.3% of households have a computer and 90.3% have a television (General Statistics Office of Vietnam, 2012). This implies that demand for computer monitors is low, while that for new and replacement television purchases is high and stable.

New CRT televisions have not been sold in the market since 2014 because the Vietnamese government is pushing the transition from analog to digital broadcasting, with completion slated for 2020, and has banned production and import of televisions that cannot receive digital television signals (MOICV, 2013). However, CRT televisions are sold in the Nhat Tao market. CRTs removed from computer monitors are mostly used for rebuilding CRT televisions[4]. This is due in part to low demand for used CRT computer monitors and in part to high demand for CRT televisions. Rebuilding refers to not only refurbishment (which usually includes tests for functionality and defects before selling) but also changes and capability upgrades[5]. The price of a rebuilt 17-inch CRT television is around 35 USD, compared with around 300 USD for a brand new 32-inch flat screen television[6].

Occupational health risks for recyclers and exposure of their children to high levels of toxins via breast milk are reported at Vietnamese electronic waste recycling sites (Tue et al., 2010). Occupational health risks are also high at the plastic recycling factories in the outskirts of Ho Chi Minh City. Such factories operate in a closed environment to conceal the smell of combustion of plastics and to avoid public attention[7]. A huge volume of plastic waste is gathered in Ho Chi Minh city in response to active Chinese brokers who export many types of recovered materials from Cambodia and south central Vietnam to China (Yoshida, 2013).

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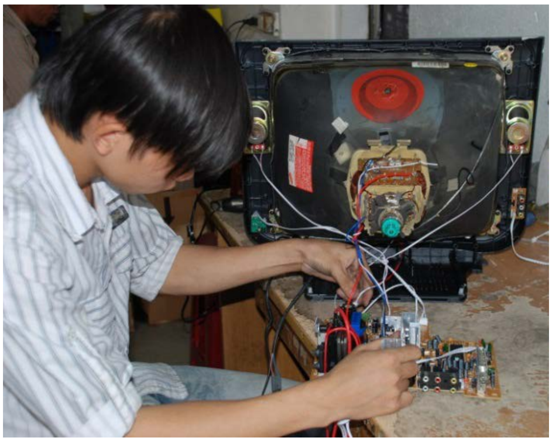
[4] Interview at Nhat Tao Market, 28 March 2014.
[5] Interview at Nhat Tao Market, 28 March 2014.
[6] Interview at Nguyen Thi Minh Khai, 27 March 2014.
[7] Interview at plastic recycling factory on Ao Doi street, 28 March 2014

According to retailers at the two markets, the CRT computer monitors exported from South Korea to Vietnam are mainly re-exported to Guangzhou, China or circulated domestically. In Guangzhou and Ho Chi Minh City, the rebuilding of used electronics is a thriving industry. Although the rebuilding process itself does not seem to cause severe environmental problems, parts that remain after rebuilding and used electronics unsuitable for rebuilding are supplied to substandard recyclers, who cause environmental pollution. Coupled with the above occupational health risks, it is highly likely that the negative externalities of CRT computer monitors are being transferred to Vietnam.

CRT monitors piled up in Nhat Tao market



Rebuilding a television with a CRT taken from a computer monitor

Rebuilt televisions displayed in Nhat Tao market for sale

Melting process in a plastic recovery factory on Ao Doi street

Fig. 5.5. Recycling of CRT computer monitors in Ho Chi Minh City (Photos by Kim).

5.6 Cost–benefit analysis for used CRT computer monitor exports

South Korea admits the export of used computer monitors for the purpose of reuse as legitimate recycling. Additional benefits of export of used CRT computer monitors are estimated against domestic recycling in South Korea (Table 5.3). Our estimate shows that international recycling programs accrue a net benefit to South Korea.

Table 5.3. Additional cost/benefit per unit for international recycling against domestic recycling (KRW).

		Producer	Exporter	Recycler	Government	(Vietnam)	Sum
Benefit	Producer	3,102 [a)]	596 [a)]				
	Recycling			3,907 [b)]		(+)	
	Landfill				490 [b) c)]		
Cost	Producer	596 [a)]		3,102 [a)]			
	Recycling			3,426 [b)]		(+)	
	Landfill				186 [b) c)]		
	Health risk					(+)	
Net benefit		2,506	596	-2,621	304	(-)	<785

Sources: a) AEE, 2012; b) AEE, 2013; c) Mok, 2005.

In domestic recycling carried out under the EPR recycling program, producers provide reprocessing companies with a payment of 3,102 KRW per unit to cover collection and recycling costs (AEE, 2012). International recycling enables producers to save 2,506 KRW per unit because the producers pay only 596 KRW per unit to the exporters (AEE, 2012). Exporters obtain an additional profit of 596 KRW per unit from EPR producers in return for reporting the export (AEE, 2012). On the other hand, international recycling deprives reprocessing companies of sales revenue of 3,426 KRW per unit and producers' payments of 3,102 KRW per unit, while saving 3,907 KRW per unit that is supposed to spend for recycling costs (AEE, 2012, 2013). The government additionally saves landfill disposal costs of 304 KRW per unit, where a unit corresponds to 9.5 kg of incombustible waste because the recycling rate of a CRT monitor is 38% (5.8 kg of 15.3 kg is recycled) (AEE, 2013). From interviews and observation at Nhat Tao market, we can guess that Vietnamese recyclers and consumers gain a bit at the cost of health and environmental risks.

In total, the net benefits from international recycling are estimated as at most 785 KRW per unit. In 2009, EPR producers exported 406,886 units of used CRT computer monitors as international recycling (KECO, 2013). In total, 320 million KRW can be estimated as net additional benefits to South Korea from international recycling in 2009. The larger concern is the health and environmental cost in Vietnam, which overshadows the smaller net benefit generated from the international recycling program.

5.7 Discussion

In South Korea, used electronics that satisfy certain criteria are exempted from related duties imposed on waste export at the time of export. In addition, exporters of used electronics are not required to prove that the exporting products are eligible for exemption. Our estimate shows that 74% of the export volume of used CRT computer monitors headed for Vietnam was marked as being for reuse in 2009. This implies that South Korea does not strictly implement a monitoring system for export of used electronics because Vietnam permits only temporary import for re-export, not for reuse. EPR producers must ensure that exporters submit an export declaration, issued by customs, for the used computer monitors. However, they do not have to ensure proper reuse and/or re-export at the export destination[8]. Exporters of used electronics do not face any sanctions for noncompliance unless they are uncovered at the time of export inspection.

The EU and Japan require exporters of used electronics to act more responsibly than is required in South Korea. The EU requires member states to strictly monitor for illegal exports of used electronics and clarifies that the relevant costs for inspection of used electronics suspected to be WEEE will be imposed on producers. The Japanese government presents a detailed standard for the used electronics and specifies the HS code for selected used electronics as a way of making the flow transparent. Compliance of exporters still depends on the strictness of government inspections.

This implies that comparably less stringent countermeasures against illegal and fraudulent export of used electronics have been established in South Korea than in the EU and Japan. These less stringent measures incentivize exporters of South Korea to export WEEE under the guise of reuse and encourages importers having a contract with exporters of South Korea to shirk their responsibility to prove a sale for direct reuse.

In the future, RoHS-type legislation in South Korea, the EU, and Japan may reduce the transfer of negative externalities via international trade of used electronics. However, the impact of such legislation can be quite limited because South Korea sets a target of only 26 types of electronics for an RoHS framework.

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[8] Interview with the head of the International Cooperation Department of AEE, 7 February 2014.

5.8 Conclusion

One purpose of green growth is to achieve economic growth that maximizes social welfare while minimizing ecological impact (UNESCAP, 2008). South Korea aims to achieve this purpose through international recycling. This chapter demonstrates theoretically and empirically that EPR producers, exporters, and the government of South Korea obtain economic gains from international recycling and that this will increase South Korea’s resource productivity. However, these gains come at the expense of health and environmental risks to importing countries, such as Vietnam.

The identified gains, however, accrue in part from South Korea’s insufficient system for monitoring against illegal or fraudulent export of used electronics. Materials to prove that the exporting object is functionally reusable and directly reused in destinations are not monitored, and this causes severe asymmetry of information regarding the condition of exported objects. To maximize the economic and environmental benefits both domestically and globally, and to minimize negative externalities in the importing countries, South Korea should establish a more stringent monitoring system and enforce it more strictly.

Appendix

Export declarations for South Korea consists of a 56-item list which must be filled out when exporting. The shipped products must be identified as either brand new or used. The “condition of goods” item must be specified as either “N” (new) or “O” (used). As the second component, “name of goods”, used goods are specified as “USED” along with the commercial name of the exported product, and new goods lack the “USED” prefix. In this paper, we used the sum of the total amount of shipped goods specified as “O” in the condition of goods and, from among the shipped goods specified as “N”, those having the word “USED” in the name of the goods. The reason for adding the latter criterion is to capture shipments that were mistakenly declared as used electronics for only one component.

The HS Code list of the 5 selected electronics from 2002–2009

Year	Air conditioner	Computer monitor	Refrigerator	TV	Washing machine
2002–2006	841510	8471602021	84181010	85281290	84501
	84158	8471602023	84182	85281390	845020
2007–2009	841510	8528410000	84181010	852872	84501
	84158	85285110	84182	852873	845020

Chapter 6 Discussion

The objective of this study is to clarify the economic reasons of EPR and the appropriate goal of EPR itself. Based on the EPR principle clarified by this study, it aims to examine whether this principle functions effectively in EPR policy of Korea. In order to achieve this purposes, the study raised three research questions. At first it asks (1) how different is the EPR policy of Korea with the EPR of economic theories and the OECD' EPR. Secondly it examines based on empirical studies (2) how much has the current EPR policy reduced waste and (3) how is the costs and benefits accrued from waste management changed after EPR policy.

With respect to the economic reasons of EPR, theoretical researches and OECD discussions on EPR are reviewed in Chapter 2. In economic arguments, EPR's purpose is not distinct from other optimal solutions which internalize all the externalities and arrive at the optimal level of production and pollution level. However EPR is mostly supported due to practical aspects that EPR provides households no incentive for illegal dumping and it does not require a complete recycling market. Meanwhile, OECD's EPR aims at providing producers incentives to take account of the external effects of their products in the disposal phase and promoting changes in production phase. OECD believes that this incentive is mostly created by imposing responsibility for waste management costs on producers.

However, Chapter 2 suggests that OECD's EPR may not promote a change in production phase if it only imposes economic responsibility of wastes on producers. It is because it depends on the producer's decision how to minimize waste management costs by either reducing it in production phase or in the disposal phase.

In order to examine whether this EPR principle functions effectively in EPR policy, this study raised three research questions and carried out three case studies on EPR policy in Korea. With respect to the research question (1) how different is the EPR policy of Korea with the EPR of economic theories and the OECD' EPR, two different features were clarified.

At first, EPR policy of Korea focuses on waste stream by promoting recycling rather than on production phase, while the most critical feature of OECD's EPR is to promote producers to take waste management costs into consideration in manufacturing.

However, even though EPR policy of Korea focuses on recycling of wastes and obliges EPR producers to recycle the assigned waste volume, case studies for selected products imply that the recycling level is not so high. In this regard the key responses to the second research question, (2) how much has the current EPR policy reduced waste can be addressed. Chapter 3 estimated, the collection rates of the five targeted WEEE are below 30% in 2009; 7% of air-conditioner, 15% of mobile phone, 26% of refrigerator, 23% of television and 28% of washing machine based on the waste volume generated in Korea. In chapter 4, the recycling rate of metal packaging dropped from 59% in 2000 to 40% in 2011 and recycling volume dropped accordingly.

Second feature of EPR policy of Korea is that it requires relatively small economic responsibility for waste management to producers. It resulted in low level of recycling level as discussed above. In Korea, the social consensus on producer's responsibility for waste management was not able to arrive at a high level in collection- and recycling financing in EPR policy. It is because criticisms such as excess burden on producers and undermining the industrial competitiveness were strong and they were escalated around end of the 1990s because of the 1997 Korea financial crisis.

Since Producer's compliance costs are only increasing proportional to the increase of recycling duty assigned by the government in Korea, EPR producers are likely to oppose the government against setting the high recycling goal. It lacks economic incentive for producers to accept high recycling duty because they have only little chance to offset the EPR compliance costs in the current EPR scheme.

With respect to the research question, (3) how is the costs and benefits accrued from waste management changed after EPR policy, Chapter 4 found based on the cost-benefit incidence analysis of metal packaging recycling program that net social benefits decreased by 2.8 billion won (2.5 million US dollars), while the net benefits to producers increased by 1.9 billion won under the EPR program compared with the WDR program. These changes in costs and benefits mainly resulted from a decrease in the amount of recycling, which ultimately increased costs for landfill disposal.

Furthermore, with respect to this research question (3), Chapter 5 made cost-benefit incidence analysis of international recycling of used CRT computer monitor against domestic recycling. In total, the net benefits from international recycling are estimated as at most 785 KRW per unit. Concretely, since EPR policy introduced international recycling of used CRT computer monitor, it enables producers to save 2,506 KRW per unit, exporters to obtain an additional profit of 596 KRW per unit. On the other hand, international recycling deprives reprocessing companies of revenue of 2,621 KRW per unit. The government additionally saves landfill disposal costs of 304 KRW per unit.

Exporting of used computer monitors brings about environmental benefits to Korean society. However, as discussed in chapter 5, it has high possibility to spread out negative externalities because waste is likely to be exported to substandard recyclers in developing countries. Exporting of wastes can cause not only environmental loss globally, but also undermines the original concept of EPR, because producers do not have incentive for design change if they can satisfy their recycling duty with exporting cheaply.

It suggests that it is necessary to add an environmental strategy to the existing EPR policy of Korea so as to incentivize producers to take waste management costs into consideration in the production phase.

Chapter 7 Conclusion

7.1. Summary of this study

EPR principle of OECD is still in a developing stage and has different interpretations. Due to this ambiguity, EPR tends to be used as a generic name of environmental policy in waste management field. This research clarifies what are critical features of OECD' EPR and its limitation. To summarize, critical feature of OECD's EPR is to promote producers to take waste management costs into consideration in manufacturing by imposing them the responsibility for waste management. Meanwhile, OECD's EPR may have a limitation because it depends on producers' decision how to minimize the waste management cost whether they reduce it in production phase or in disposal phase. This study examined the function and limitation of EPR policy in practice based on three case studies of Korea. EPR policy in Korea focuses on waste stream by promoting recycling of producers. At the same time it allows exports of collected waste as a legitimate recycling manner to curb the economic burden on producers. This study suggests that EPR policy in Korea may lead to different outcomes, i.e. reduction of producer's economic responsibility and transfer of negative externalities abroad against intention of OECD's EPR.

Research questions and key findings

Research question 1. how different is the EPR policy of Korea with the EPR of economic theory and the OECD's EPR?

Chapter 2 clarifies critical features of EPR. In the economic discussions, EPR aims at the optimal production and pollution level and expects source reduction as a result. In the OECD discussion, EPR is focusing not only on source reduction and but also redesign of products for cost minimization of waste management. Meanwhile, contrary to the original purpose, OECD's EPR may have a limitation to promote a change in production phase if it only imposes economic responsibility of wastes on producers. It is because it depends on the producer's decision how to minimize waste management costs by either reducing it in production phase or in the disposal phase.

In the EPR policy of Korea, it focuses on waste stream rather than production phase. EPR producers have the financing responsibility only for the recycling of the assigned waste volume and thus relatively small economic responsibility. Furthermore, recycling duty can be satisfied not only by domestic recycling, but also by exporting of collected waste for the purpose of recycling. In this regard, EPR can be undermined in Korea because if producer's responsibility can be cheaply satisfied through export, producers do not feel that investment for producing the more recyclable products is necessary.

Research question 2. how much has the current EPR policy reduced waste

Chapter 3 estimated the collection rate of WEEE based on waste generation. Waste generation was estimated by the population balance model. Population balance model is. As a result, the collection rates of the five targeted WEEE are below 30% in 2009; 7% of air-conditioner, 15% of mobile phone, 26% of refrigerator, 23% of television and 28% of washing machine. Except refrigerator, the other estimated items have been showing a slight increase in collection since 2006. However, regarding computer monitor, chapter 5 found that producers satisfied most of the recycling duty through export. 59% of used computer monitors discarded in Korea was exported in the year 2009 to Vietnam. It brings economic benefits to Korean EPR producers and exporters, and ecological benefit to the Korean society, but at the cost of increased occupational health risk in Vietnam. Also, the collection rate of metal packaging is 40% in 2011.

Chapter 4 estimated the collection rate of metal packaging. It found that the recycling rate dropped from 59% in 2000 to 40% in 2011 and recycling volume dropped accordingly.

Research question3: how is the cost and benefits accrued from waste management changed after the EPR policy.

Chapter 4 made cost-benefit incidence analysis of metal packaging recycling program in Korea. It found that net social benefits decreased by 2.8 billion won (2.5 million US dollars), while the net benefits to producers increased by 1.9 billion won under the EPR program compared with the WDR program. These changes in costs and benefits mainly resulted from a decrease in the amount of recycling, which ultimately increased costs for landfill disposal.

Chapter 5 made cost-benefit incidence analysis of international recycling of used CRT computer monitor against domestic recycling. In total, the net benefits from international recycling are estimated as at most 785 KRW per unit. Concretely, it enables producers to save 2,506 KRW per unit, exporters to obtain an additional profit of 596 KRW per unit. On the other hand, international recycling deprives reprocessing companies of revenue of 2,621 KRW per unit. The government additionally saves landfill disposal costs of 304 KRW per unit.

However, it showed that the larger concern is the health and environmental cost in Vietnam, which overshadows the smaller net benefit generated from the international recycling program.

7.2 Remaining challenges

Critical features of EPR policy is that it promotes producers to take waste management costs into account in production phase. In order to design a EPR policy to play that role effectively, it is necessary to clarify in the future in which condition EPR policy can lead to source reduction and design change for environment, and promotes dynamic movement of producers.

This study made a comparative analysis of EPR schemes. In the future it is necessary to scale up and elaborate the comparative analysis of EPR practices, outcomes and limitation in various socio-economic level of countries. It will lead to the improvement of EPR policy.

As this study examined, EPR policy has an aspect that stimulates export of collected waste to developing countries. In the future it is necessary to discuss how to promote international resource circulation in a sustainable way and how EPR policy contributes.

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Abbreviation

AEE: Association of Electronics Environment of South Korea
ASEAN: Association of Southeast Asian Nations
CRT: Cathode ray tube
EEE: Electrical and electronic equipment
EPR: Extended producer responsibility
DfE: Design for environment
GMOE: The German Ministry of Environment
GOV: Government of Vietnam
JMOE: The Japanese Ministry of Environment
KCTDI: Korea Customs and Trade Development Institute
KECO: Korea Environment Corporation
KEI: Korea Environment Institute
KMCRA: Korea Metal Cans Resources Association
KMOE: The Korean Ministry of Environment
KOSIS: Korea Office of Statistics
KPE: Korea Power Exchange
KRW: Korean Won
LCD: Liquid crystal display
OECD: Organization for Economic Co-operation and Development
PBM: Population balance model
PRO: Producer responsibility organization
RoHS: Restriction of the use of certain hazardous substances
WDR: Waste deposit recycling program
WEEE: Waste of electrical and electronic equipment