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Closed-Loop Supply Chains in the Electrical and Electronics Industry of Japan

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ABSTRACT

We investigate the impact of the home appliance recycling law on closed-loop supply chain activities in the home appliance industry of Japan. We also examine the activities of PC (personal computer) recycling and mobile phone recycling in Japan to conduct comparative research on their reverse supply chains. This study is based on semi-structured interviews that were conducted with the managers of five major home appliance/PC manufacturers and public data. All the managers agreed that although the recycling business is not profitable for home appliance/PC manufacturers in Japan, government legislation and CSR (corporate social responsibility) compel them to be active in the recycling of their products.

Keywords:

Recycling, closed-loop supply chain, home appliance, personal computer, mobile phone, law, Japan

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Introduction

According to Guide, Harrison, and Van Wassenhove (Guide, Harrison, & Van Wassenhove, 2003), in the US (United States), companies have become increasingly interested in reverse supply chains for economic reasons (*e.g.*, (Giuntini & Gaudette, 2003)), while in the EU (European Union), companies have become interested because of legislation (*e.g.*, (Van Wassenhove & Ghaziri, 2004)). In Japan, companies have become more concerned with reverse supply chains for the latter reason.

The disposal of bulky products as waste is a serious problem in Japan due to the growing shortage of landfill sites. In January 2005, METI (Ministry of Economy Trade and Industry) and MOE (Ministry of the Environment) enacted the automobile recycling law in view of EPR (extended producer responsibility). Under the automobile recycling law, car owners must pre-pay the costs of the disposal of shredder residues, fluorocarbons, and air bags to recycle automobiles efficiently. The recycling fees vary among the automobile models produced by each manufacturer. According to Toyota, the recycling fee ranges from 10,000 yen[1] to 18,000 yen for a regular car and from 7,000 yen to 16,000 yen for a small car. The one-time payment of the recycling fee is made at the time of purchase for a new car or at the time of the first regular inspection for a car in use after January 2005. Once the recycling fee is paid, a recycling certificate is issued and passed to the next owner of the car.

Before the automobile recycling law took effect, METI and MOE brought the home appliance recycling law into force in April 2001. Under the home appliance recycling law, consumers must pay recycling costs when they dispose of air conditioners, TV (television)

[1] Approximate exchange rate: 90 yen = US$ 1. The fee does not include the 5% consumption tax.

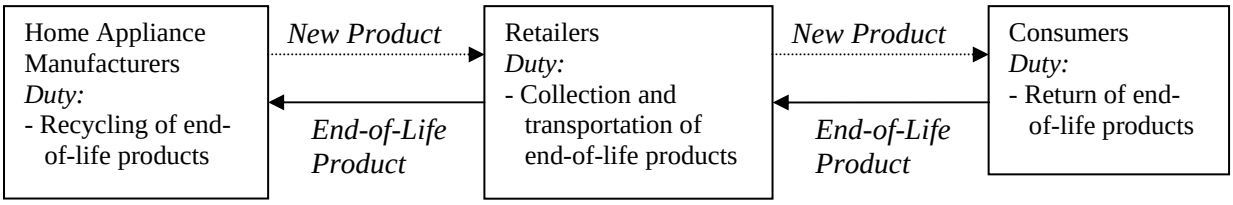
sets[2], refrigerators[3], or washing machines[4]. In general, the recycling fee that must be paid to the manufacturer is 3,000 yen[5], 2,700 yen, 4,600 yen, or 2,400 yen, respectively. In addition to the recycling fee, a consumer is required to pay approximately 2,000 yen to the retailer for the collection and transportation of an end-of-life product to the manufacturer's collection center. The recycling fee that a manufacturer charges is fixed; however, the collection and transportation fee for a product differs among retailers. For example, most large electric home appliance retailers charge only 500 yen for collection and transportation, whereas some small retailers quote more than 2,000 yen for this service.

Based on the concept of EPR, the manufacturers or importers of the four groups of home appliances are responsible for the recycling of their end-of-life products. The electric appliance retailers are accountable for their collection and transportation. The duties of the consumers, retailers, and manufacturers in the electric appliance industry of Japan are listed in Figure 1. In this reverse supply chain structure, a consumer bears all of the costs of recycling, a manufacturer obtains a recycling fee, and a retailer receives a collection and transportation fee. However, in contrast to the automobile recycling fee, the payment for the home appliance recycling fee is made only at the time of disposal (end-of-life). The total number of the four categories of home appliances that are currently used in Japan was estimated to be approximately 300 million. Since it is difficult to keep track of all of them, and the average duration of their usage is generally more than 10 years, it was decided that the recycling fee should be paid at the time of disposal.

[2] At this point, the home appliance recycling law targets only cathode ray tube CRT TV sets and not flat-panel TV sets (*e.g.*, LCD (liquid crystal display) TV sets or PDP (plasma display panel) TV sets). However, the law was revised in 2008 and it is confirmed that the new law will include flat-panel TV sets among the recycling items.
[3] Freezers are included in the category of refrigerators.
[4] It is confirmed that the new home appliance law will include electric clothes dryers in the category of washing machines.
[5] The original recycling fee for an air conditioner was 3,500 yen, but it was reduced to 3,000 yen due to the rise of the price of aluminum in 2007.

FIGURE 1

Home Appliance Recycling (End-of-Life) Product Flow in a Supply Chain



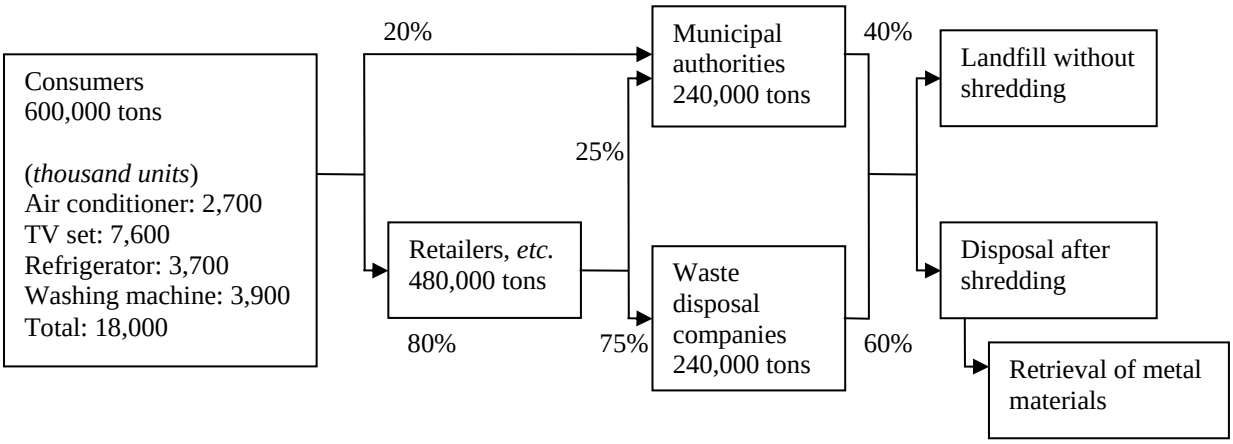
In this study, we investigate the impact of the home appliance recycling law on environmental supply chain activities in the electric home appliance industry of Japan. We also examine the activities of PC (personal computer) and mobile phone recycling in Japan to conduct comparative research on their reverse supply chains. This study is based on semi-structured interviews with the managers of four major home appliance manufacturers and a leading PC producer as well as on public data.

Background of Home Appliance Recycling

The waste disposal flow of home appliances before the enforcement of the recycling law is illustrated in Figure 2 (Ministry of Economy Trade and Industry & Ministry of the Environment, 1998). At that time, it was estimated that consumers disposed of 600 thousand tons of home appliances every year. This was equivalent to 18 million units: 2.7 million units of air conditioners, 7.6 million units of TV sets, 3.7 million units of refrigerators, and 3.9 million units of washing machines. Then, 80% of these units were returned to retailers, and 20% went to municipal authorities. Before the recycling law was enforced, most metal materials were dumped as shredder residue and not recycled. At that time, a scarcity of landfill capacity for shredder residue had become an urgent problem in Japan. Thus, the Japanese Diet enacted the home appliance law in June 1998, and it went into effect in April 2001.

FIGURE 2

Annual Disposal Flow of Home Appliances before the Enactment of the Recycling Law



The four product categories of home appliances (*i.e.*, air conditioners, TV sets, refrigerators, and washing machines) were selected for the home appliance recycling law for the following reasons: (1) It is difficult for municipal offices to recycle or dispose of these products; (2) it is necessary to recycle these products (due to valuable material compositions); (3) it is important for manufacturers to consider the design of these products and selection of materials used in these products for recycling; and (4) it is reasonable for retailers to collect these products from consumers (because they also deliver the products to the consumers). Thus, retailers and manufacturers play crucial roles in achieving a "closed-loop economy and society", which is the primary purpose of the home appliance recycling law.

Performance Data Concerning Home Appliance Recycling

The recycling rates have experienced a constant growth since the home appliance recycling law went into effect in April 2001, as shown in Table 1 (Ministry of the Environment, 2008). This implies that the manufacturers' efforts toward the efficient recycling of their end-of-life products have yielded fruitful rewards. The only exception is

TV sets after 2004. The decrease in the recycling rates of TV sets is mainly due to limited demand of CRT (cathode ray tube) glasses for recycling in the new era of flat-panel TV sets.

TABLE 1

Recycling Units and Rates for the Four Home Appliance Categories in 2001–2007

	Air conditioner	TV set	Refrigerator	Washing machine
Recycling units in 2001 (tons)	45,019	58,814	76,359	30,783
Recycling rates in 2001 (%)	78%	73%	59%	56%
Recycling units in 2002 (tons)	56,739	72,110	91,006	42,967
Recycling rates in 2002 (%)	78%	75%	61%	60%
Recycling units in 2003 (tons)	57,058	76,025	97,119	52,288
Recycling rates in 2003 (%)	81%	78%	63%	65%
Recycling units in 2004 (tons)	64,939	83,868	103,546	58,710
Recycling rates in 2004 (%)	82%	81%	64%	68%
Recycling units in 2005 (tons)	72,585	83,530	108,284	69,664
Recycling rates in 2005 (%)	84%	77%	66%	75%
Recycling units in 2006 (tons)	66,791	91,092	112,106	74,854
Recycling rates in 2006 (%)	86%	77%	71%	79%
Recycling units in 2007 (tons)	68,861	115,563	116,683	77,231
Recycling rates in 2007 (%)	87%	86%	73%	82%

Note: Year 2001 (from April 2001 to March 2002); Year 2002 (from April 2002 to March 2003); Year 2003 (from April 2003 to March 2004); Year 2004 (from April 2004 to March 2005); Year 2005 (from April 2005 to March 2006); Year 2006 (from April 2006 to March 2007); Year 2007 (from April 2007 to March 2008). All the decimal points are cut off.

Under the home appliance recycling law, manufacturers must recycle 60% of the materials used in air conditioners, 55% in TV sets, 50% in refrigerators, and 50% in washing machines. The recycling rates for each product category in 2007 were 87%, 86%, 73%, and 82%, respectively. Their breakdowns are provided in Table 2 (Ministry of the Environment, 2008). The recycling rates of the four home appliance categories in 2007 sufficiently exceeded the minimum recycling rates stipulated by the law.

TABLE 2

Recycling Units for the Four Home Appliance Categories in 2007

	Air conditioner	TV set	Refrigerator	Washing machine
Collected units at designated collection centers (thousand units)	1,890	4,613	2,725	2,884
Processed units for recycling (thousand units)	1,872	4,542	2,724	2,879
Processed units for recycling (tons)	78,715	134,283	159,763	94,101
Recycling units (tons)	68,861	115,563	116,683	77,231
Recycling rates (%)	87%	86%	73%	82%

Note: Total units from April 2007 to March 2008. All the decimal points are cut off.
Recycling rate = Recycling units (tons) / Processed units for recycling (tons).

Table 3 summarizes the recycled resources in the four product categories in 2007 (Ministry of the Environment, 2008). In addition to these materials, 1,084,342 kilograms of refrigerants[6] were retrieved from air conditioners and 298,145 kilograms from refrigerators in order to be destroyed in 2007. The same elements were only 467,316 kilograms and 135,779 kilograms, respectively, in 2001. Between 2004 and 2007, 562,020 kilograms of the liquefied fluorocarbons contained in the insulation materials of refrigerators were also retrieved for destruction. The enforcement of the home appliance recycling law had a significant impact on recycling activities in Japan. In fact, many home appliance manufacturers improved their recycling performance.[7]

[6] CFC (Chlorofluorocarbon) refrigerants deplete the ozone layer.

[7] Many home appliance manufacturers show their recycling performance data based on the classification in the recycling law. For instance, Matsushita's (Panasonic's) recycling units in 2007 (from April 2007 to March 2008) were 10,035 tons for air conditioners, 22,940 tons for TV sets, 23,161 tons for refrigerators, and 15,465 tons for washing machines (http://panasonic.co.jp/eco/recycle/data.html; in Japanese). Matsushita's recycling rates were 83%, 84%, 69%, and 78%, respectively. Similarly, Mitsubishi's recycling units in 2007 (from April 2007 to March 2008) were 9,462 tons for air conditioners, 8,323 tons for TV sets, 13,642 tons for refrigerators, and 5,073 tons for washing machines (http://www.mitsubishielectric.co.jp/recycle/home/zisseki/index_b.html; in Japanese). Mitsubishi's recycling rates were 89%, 87%, 75%, and 84%, respectively.

TABLE 3

Materials Recycled from the Four Home Appliance Categories in 2007

	Air conditioner	TV set	Refrigerator	Washing machine
Iron (tons)	23,729	13,881	68,435	40,755
Copper (tons)	5,076	4,951	1,994	1,240
Aluminum (tons)	8,634	73	325	612
Ferrous and non-ferrous compounds (tons)	24,453	1,199	20,188	12,915
CRT (cathode ray tube) glass (tons)	---	68,269	---	---
Other valuable materials (tons)	6,969	27,190	25,741	21,709
Total weight (tons)	68,861	115,563	116,683	77,231

Note: Total units from April 2007 to March 2008. All the decimal points are cut off.
Other valuable materials include printed circuit boards, plastics, etc.

Profitability of Home Appliance Recycling

We visited five major home appliance/PC manufacturers—Matsushita (Panasonic), Toshiba, Mitsubishi, and Sanyo for electric appliances, and NEC for PCs—and conducted semi-structured interviews with their managers to obtain information to complement the public data. In particular, information regarding recycling profitability is not available to the public. Among the various home appliance manufacturers, we selected these four companies because of (1) their large market shares in all four product categories[8] and (2) the different recycling groups to which they belong[9]. Similarly, among all the PC manufacturers, we chose

[8] The top market shares of air conditioners in Japan in 2006 were (1) *Matsushita* (20.8%), (2) Daikin (18.6%), (3) *Mitsubishi* (14.1%), (4) *Toshiba* (12.8%), and (5) *Sanyo* (10.0%) (Nikkei, 2007). The top market shares of CRT TV sets in Japan in 2006 were (1) *Matsushita* (23.7%), (2) Sharp (20.0%), (3) Sony (15.8%), (4) *Toshiba* (12.1%), (5) *Sanyo* (5.8%), and (6) *Mitsubishi* (4.2%) (Yano Research Institute, 2007). The top market shares of refrigerators in Japan in 2006 were (1) *Matsushita* (21.4%), (2) *Toshiba* (16.9%), (3) Sharp (16.5%), (4) *Mitsubishi* (14.8%), (5) Hitachi (13.6%), and (6) *Sanyo* (Yano Research Institute, 2007). The top market shares of washing machines in Japan in 2006 were (1) Hitachi (22.9%), (2) *Matsushita* (21.0%), (3) *Toshiba* (18.6%), (4) Sharp (14.7%), (5) *Sanyo* (13.1%), and (6) *Mitsubishi* (9.7%) (Yano Research Institute, 2007). Thus, only Matsushita, Toshiba, Mitsubishi, and Sanyo appear among the top 5 or 6 companies in all four product categories.

[9] There are two groups related to the efficient recycling of the four home appliances: Groups A and B. Group A includes *Matsushita*, *Toshiba*, Daikin, JVC, Samsung, LG, Electrolux, *etc.* Group B includes *Mitsubishi*, *Sanyo*, Hitachi, Sharp, Sony, Pioneer, Fujitsu General, Daewoo, *etc.* Group A has 30 recycling plants in Japan, while Group B has 16 recycling plants as of March 2007 (Association for Electric Home Appliances, 2007). Each plant is responsible for several prefectures in Japan, and a plant belonging to Group A or B exclusively recycles products manufactured by companies belonging to Group A or B except the recycling factory of NKRC (Nishinihon Kaden Recycle Corporation). Each company in Groups A and B has 190 designated collection centers (*i.e.*, 380 centers in total) across Japan. AEHA (Association for Electric Home Appliances) is in charge of (1) products manufactured by small manufacturers/importers that do not belong to either Group A or B; (2)

NEC because (1) the company has been occupying the largest market share in Japan's PC industry for more than 10 years[10] and (2) the company used to be an electric appliance manufacturer. In addition to NEC, we also visited Toshiba's PC recycling facilities and Mitsubishi's PC monitor recycling facilities.

In theory, manufacturers and retailers can profit from recycling because the consumers bear all the costs. Redesigning the products and reselecting the materials used in the products will reduce the manufacturer's recycling costs. Since the recycling fee that is charged to the consumers is almost fixed, the reduction in recycling costs will lead to an increase in the manufacturer's profit. Thus, home appliance manufacturers have an incentive to develop products that are suitable for recycling. In fact, this is the fundamental goal of EPR. On the other hand, retailers can use the collection and transportation fee in price negotiations. Since retailers normally deliver new products to consumers, it is not costly for them to collect the old products from the consumers when they deliver the new products. Thus, retailers can offer the potential buyers of new products some discounts for the collection and transportation fee of their end-of-life products.

In practice, however, the managers of all the five home appliance/PC manufacturers agreed that they are not profiting from the recycling business due to their initial investment in their facilities as well as the labor-intensive recycling processes. They do not receive any subsidy from the government. Their primary revenue sources are part of the recycling fees paid by the consumers and the sales of the recycled materials to raw material suppliers[11]. The

products manufactured by NEC that discontinued the production of electric appliances; and (3) orphans, that is, products whose manufacturers are unknown.

[10] The top market shares of PCs in Japan in 2006 were (1) NEC (20.1%), (2) Fujitsu (17.5%), (3) Dell (14.2%), (4) Toshiba (9.9%), and (5) Hewlett-Packard (6.5%) (Nikkei, 2007).

[11] The recycled materials can be used for home appliances or some other products. The recycled materials cannot be 100% genuine; they are normally mixed with fresh materials when they are used for new products.

manager of Matsushita admitted that these revenues may be insufficient to cover the recycling costs even in the future. However, it is difficult for manufacturers to increase the recycling fees charged to consumers because the fees are often equivalent to more than 10% of the new product prices. The potential buyers of new products may hesitate to purchase them if the recycling fees for the old products are relatively high. According to the manager of Toshiba, the current recycling fees are close to the threshold of potential buyers' willingness to pay, and any fee increase will negatively influence new product sales, which is the ultimate goal of home appliance manufacturers. In fact, one of the objectives of the home appliance recycling law is to encourage consumers to continue to use their old appliances in an effort to reduce waste. However, our interviews show that the manufacturers are not completely in favor of this.

Unlike the production process of a new product, the recycling process of an end-of-life product is not standardized because of its different design, size, materials used, *etc.* Therefore, the recycling process basically requires manual disassembly and the segregation of a product's components. The manager of Mitsubishi affirmed that although many machines are installed in the recycling plants, the recycling process cannot be as automated as the production process, In Japan, labor costs are high; thus, labor-intensive recycling processes hinder cost reduction. The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal prohibits manufacturers from moving end-of-life products to low-labor-cost countries for the purpose of their disposal. Thus, the manager of Matsushita claimed that the recycling business is not profitable for home appliance manufacturers in Japan. The manager of Mitsubishi insisted that the survival of the recycling facilities depends on the parent company's commitment to continuing to offer them financial assistance. However, all of the five home appliance/PC manufacturers agreed that the

endurance of non-profit-making recycling plants is assured because they are essential for the corporate group's CSR (corporate social responsibility) activities.

Matsushita engages some full-time staff in its recycling facilities for R&D (research and development) concerning recycling technology and processes. The company also transfered several staff who are involved in the new product development of eco-friendly home appliances to its recycling facilities. The company regularly communicates with new product development teams in its parent company to develop eco-efficient products. For example, they determine the kind of material that is easiest to recycle and the product design that can improve recycling processes. On the other hand, Toshiba does not designate any staff to recycling technology R&D in its recycling facilities; rather, it relies on its employees' commitment to the philosophy of *kaizen* (continuous improvement) to achieve efficient recycling processes. The staff's ideas on eco-efficient products are conveyed to new product development teams in the parent company whenever necessary. Approximately 100 personnel from Mitsubishi were transferred to its recycling facilities. This arrangement promotes effective communication between the recycling facilities and the parent company not only with respect to the R&D of recycling technology and processes but also concerning new product development.

Challenges in Home Appliance Recycling

One of the major challenges in the home appliance recycling law is illegal dumping. Since consumers need to pay a recycling fee at the time of disposal, those who are unwilling to pay the fee can avoid doing so by leaving a bulky home appliance at a garbage dump, in an empty space, in a forest, or near a river. As a basic rule, the illegally dumped products are collected by the municipal authorities. Table 4 shows the numbers of illegally dumped home

appliances (Ministry of the Environment, 2007a). Most municipal authorities have reinforced the monitoring activities of illegal dumping as a countermeasure. As a result, the number of illegally dumped products has been reducing in all the four categories of home appliances since 2006.

TABLE 4

Illegal Dumping of the Four Home Appliances in 2001–2006

	Air conditioner	TV set	Refrigerator	Washing machine
Illegal dumping in 2001 (units)	16,786	65,441	27,445	22,481
Illegal dumping in 2002 (units)	17,899	82,935	35,739	29,154
Illegal dumping in 2003 (units)	17,138	88,331	38,006	31,505
Illegal dumping in 2004 (units)	15,786	86,640	38,638	31,263
Illegal dumping in 2005 (units)	10,501	82,702	34,755	27,421
Illegal dumping in 2006 (units)	5,831	72,647	30,941	22,197

Note: Year 2001 (from April 2001 to March 2002); Year 2002 (from April 2002 to March 2003); Year 2003 (from April 2003 to March 2004); Year 2004 (from April 2004 to March 2005); Year 2005 (from April 2005 to March 2006); Year 2006 (from April 2006 to March 2007). The numbers in each year are the total sum of the data from municipal authorities, which covers the following percentage of the population in Japan: 95.4% in 2001; 99.6% in 2002; 99.2% in 2003; 99.9% in 2004; 99.7% in 2005; 94.7% in 2006.

Prior to this, some experts in recycling policy in Japan claimed that the payment scheme for home appliance recycling should be changed to an advance payment system like that of PC recycling to reduce consumers' illegal dumping activities. However, it was decided that the payment scheme would not change in the revised home appliance recycling law due to the appliance manufacturers' objection against the advance payment of recycling fees. In fact, in our interview with the managers of Sanyo, they insisted that the increase in the legal dumping of home appliances is related to the increase in the number of new product units sold approximately 10 years ago.

The other major challenging issue in home appliance recycling is the illegal sale of end-of-life products that should have been deposited at recycling facilities. For example, the

logistics companies, to which leading retailers outsource the delivery of end-of-life appliances to their producers, were caught not returning the products to their manufacturing companies, though consumers paid the recycling fees. They were illegally exporting these products to developing countries in Asia so that they could receive money from both the retailers and the trading companies.

PC Recycling

In addition to the recycling of the four groups of household appliances, consumers are also aware of PC recycling. The Law for Promotion of Effective Utilization of Resources was enacted in May 2000 and was enforced in April 2001. The original law required the recycling of PCs for office use only, but the revised law that came into effect in October 2003 requires the recycling of PCs for home use as well. This law necessitates 3R, that is, *reduce*, *reuse*, and *recycle*. In the case of PC manufacturers, they need to *reduce* PC waste, *reuse* PC components, and *recycle* PC materials. PC recycling is also restricted by the Waste Disposal and Public Cleaning Law in Japan, and this law prohibits the retailers from collecting and transporting end-of-life PCs without permission.

Under the PC recycling law, the targets for the recycling/reuse of materials/components are 50% for desktop PCs, 20% for notebook PCs, 55% for CRT monitors, and 55% for LCD monitors. The PC recycling/reuse rates for home use in 2007 were 71.2%, 47.6%, 76.8%, and 64.3%, respectively. Their breakdowns are provided in Table 5 (Ministry of the Environment, 2007c). Table 6 shows the PC recycling/reuse rates for home use from 2003 to 2007 (Ministry of the Environment, 2007c). Similar to household appliance manufacturers, PC manufacturers announce their recycling performance based on

the classification of desktop PCs, notebook PCs, CRT monitors, and LCD monitors for office use and home use[12].

TABLE 5

PC Recycling/Reuse Units for Home Use in 2007

	Desktop PC	Notebook PC	CRT Monitor	LCD Monitor
Processed units for recycling/reuse (units)	112,866	51,459	108,707	36,079
Processed units for recycling/reuse (tons)	1,271	174	2,604	250
Recycling/reuse units (tons)	905	83	1,999	161
Recycling/reuse rates (%)	71.2%	47.6%	76.8%	64.3%

Note: Total units from April 2007 to March 2008.
Recycling rate = Recycling/reuse units (tons) / Processed units for recycling/reuse (tons).

TABLE 6

PC Recycling/Reuse Units and Rates for Home Use in 2003–2007

	Desktop PC	Notebook PC	CRT Monitor	LCD Monitor
Recycling/reuse units in 2003 (tons)	216	9	406	7
Recycling/reuse rates in 2003 (%)	78.0%	50.3%	72.8%	64.8%
Recycling/reuse units in 2004 (tons)	709	30	1,452	33
Recycling/reuse rates in 2004 (%)	75.6%	51.9%	77.4%	65.7%
Recycling/reuse units in 2005 (tons)	873	44	1,693	65
Recycling/reuse rates in 2005 (%)	69.5%	46.6%	77.1%	63.1%
Recycling/reuse units in 2006 (tons)	933	66	1,629	113
Recycling/reuse rates in 2006 (%)	69.9%	47.1%	73.8%	62.6%
Recycling/reuse units in 2007 (tons)	905	83	1,999	161
Recycling/reuse rates in 2007 (%)	71.2%	47.6%	76.8%	64.3%

Note: Year 2003 (from October 2003 to March 2004); Year 2004 (from April 2004 to March 2005); Year 2005 (from April 2005 to March 2006); Year 2006 (from April 2006 to March 2007); Year 2007 (from April 2007 to March 2008).

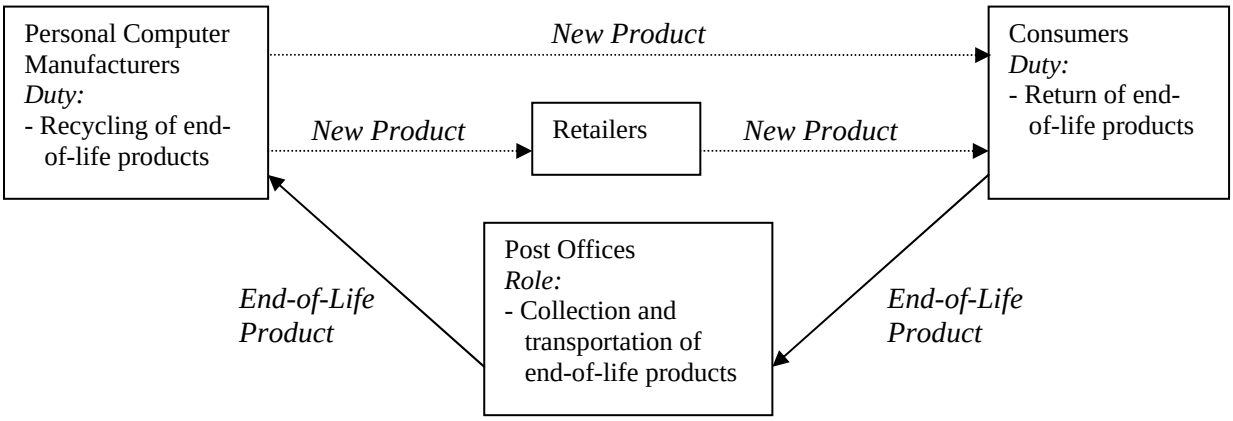
There are some differences between PC recycling and home appliance recycling. First of all, PC recycling includes component reuse as well as material recycling. Normally, none

[12] For instance, in 2006, the total PC recycling/reuse units of NEC for both home use and office use were 681.1 tons for desktop PCs, 110.3 tons for notebook PCs, 723.9 tons for CRT monitors, and 116.9 tons for LCD monitors (http://www.nec.co.jp/eco/ja/04/4-9-04.html; in Japanese). NEC's total PC recycling/reuse rates were 76.7%, 45.9%, 72.8%, and 55.8%, respectively. Similarly, in 2003, the PC recycling/reuse units and rates of Toshiba were 29.6 tons and 69.6% for desktop PCs, 26.4 tons and 54.9% for notebook PCs, 89.7 tons and 76.3% for CRT monitors, and 4.6 tons and 58.4% for LCD monitors (http://dynabook.com/pc/eco/haiki06.htm; in Japanese).

of the components of household appliances are reused except for ICs (integrated circuits) in air conditioners; however, some components of PCs are reused as repair parts. Secondly, unlike home appliance retailers, PC retailers are generally not involved in the reverse supply chain, as illustrated in Figure 3[13]. Most PC retailers[14] are not responsible for the collection and transportation of end-of-life PCs to manufacturers. Instead, PC home users are required to bring their PCs to one of 20,000 post offices in Japan after they pay the recycling fees and receive their payment receipts from PC manufacturers. Then, the post offices deliver them to the PC manufacturers' recycling plants. Alternatively, they can ask the post offices to collect their PCs from their residences without paying additional charges.

FIGURE 3

Home-Use PC Recycling (End-of-Life) Product Flow in a Supply Chain



Thirdly, unlike electric appliance manufacturers, in general, PC manufacturers do not have a common group to recycle their end-of-life products. According to NEC, the company refurbishes some PCs if they are in good condition and sells them as "NEC Refreshed PCs". In addition, some components have been discontinued, and such components are sometimes

[13] In the flow of new products, some consumers buy their PCs directly from PC manufacturers (*e.g.*, Dell) without going through retailers, unlike home appliances.
[14] PC retailers (*e.g.*, Tsukumo Denki) that sell their private-label PCs or distribute imported PCs are responsible for the collection and transportation of these PCs. They also sell other major brand PCs in the same outlets, but are not responsible for the collection of those PCs.

kept as repair parts after they are retrieved from old PCs. Thus, it is convenient for NEC to handle its PC recycling without collaborating with other PC manufacturers.

Fourthly, the financing options vary between PC recycling and home appliance recycling [15]: cost-internalization/invisible fees for PCs and end-of-life fees for home appliances. PCs that are sold after October 1, 2003 do not oblige home users[16] to pay recycling fees because the fees are included in their prices. However, PCs that were sold prior to October 1, 2003 or were manufactured by companies that do not recycle their products require the recycling fees. The recycling fees are 3,000 yen[1] for desktop PCs, 3,000 yen for notebook PCs, 4,000 yen for CRT monitors, and 3,000 yen for LCD monitors. These fees include postal charges for the collection and transportation of the products.

In the case of PCs whose manufacturers are not located in Japan (*e.g.*, self-assembled PCs, personally imported PCs, or PCs whose manufacturers or importers are no longer in business in Japan), the PC 3R Promotion Center[17] takes care of the recycling of such PCs. The return processes of the PCs are the same as those of PCs whose manufactures are located in Japan. However, the recycling fees for these PCs are 1,000 yen higher. Thus, the recycling fees including postal charges are 4,000 yen[1] for desktop PCs, 4,000 yen for notebook PCs, 5,000 yen for CRT monitors, and 4,000 yen for LCD monitors. The illegal dumping of PCs is not as serious as that of the four home appliances. Table 7 shows the numbers of illegally dumped PCs from 2003 to 2006 (Ministry of the Environment, 2007b).

[15] In the case of automobiles, as explained earlier, advanced recovery fees are charged to new car owners in Japan. The fees are visible and collected separately from the car prices when consumers purchase cars.
[16] The PCs that are sold after October 1, 2003 are labeled "PC Recycle". However, the recycling schemes are strictly applicable to PCs for home use. Regardless of the presence of the "PC Recycle" label, firms need to contact PC manufacturers for the recycling of PCs for office use. The collection points, transportation companies, and recycling fees for office use are different from those for home use.
[17] The center was established by JEITA (Japan Electronics and Information Technology Industries Association) in May 2004 to promote "PC 3R activities".

TABLE 7

Illegal Dumping of PCs in 2003–2006

	Desktop PC	Notebook PC	CRT Monitor	LCD Monitor
Illegal dumping in 2003 (units)	1,315	368	1,324	88
Illegal dumping in 2004 (units)	2,800	779	2,627	228
Illegal dumping in 2005 (units)	2,912	599	2,418	204
Illegal dumping in 2006 (units)	2,138	507	2,295	216

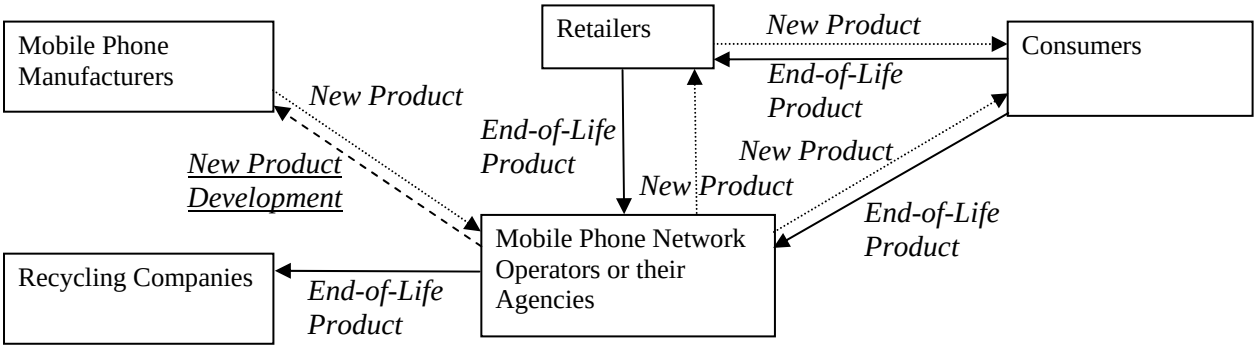
Note: Year 2003 (from October 2003 to March 2004); Year 2004 (from April 2004 to March 2005); Year 2005 (from April 2005 to March 2006); Year 2006 (from April 2006 to March 2007). The numbers in each year are the total sum of the data from municipal authorities, which covers the following percentage of the population in Japan: 73.6% in 2003; 82% in 2004; 82.8% in 2005; and 61% in 2006.

Mobile Phone Recycling

In Japan, there are more than 100 million mobile phone subscribers. However, currently, there are no laws for mobile phone recycling in Japan. However, TCA (Telecommunications Carriers Association) and CIAJ (Communications and Information Network Association of Japan) jointly promote consumers' returns of end-of-life mobile phone handsets. In April 2001, TCA and mobile phone network operators started the MRN (Mobile Recycle Network) to promote recycling by encouraging consumers to return their end-of-life mobile phones to one of approximately 9,500 retail shops or agencies of the mobile phone network operators. Figure 4 illustrates the reverse supply chain structure in Japan's mobile phone industry. Rather than the mobile phone manufacturers, mobile phone network operators voluntarily collect end-of-life handsets. This is because mobile phone handsets are all sold under the mobile phone network operator names in Japan. Thus, a mobile phone manufacturer receives its product development costs from its mobile phone network operator.

FIGURE 4

Mobile Phone Recycling (End-of-Life) Product Flow in a Supply Chain



Thus, the reverse supply chain structure is different from that in the home appliance or PC industries. Unlike in the cases of the four home appliances or PCs, there is no return fee for mobile phones, though NTT DoCoMo[18], the largest mobile phone network operator in Japan, estimated the collection costs to be at least 170 yen[1] per unit in 2001 (NTT DoCoMo Report, 2003). In the current mobile phone recycling system, each mobile phone network operator bears the costs for the collection of their end-of-life products. The operators will continue to collect their end-of-life mobile phones voluntarily not only because of the public opinion toward 3R activities but also because the mobile phones contain some precious metals. Although the latest data are not available, NTT DoCoMo calculated the weight of the materials recycled from their mobile phones, batteries, and battery chargers in 2001 as shown in Table 8 (NTT DoCoMo Report, 2003). NTT DoCoMo dominated approximately 81%, 79%, and 69%[19] of the market for mobile phones, batteries, and battery chargers, respectively, which were collected for recycling in 2001.

[18] The market share of mobile phone network operators in Japan in 2006 was (1) NTT DoCoMo (54.4%), (2) KDDI (29.1%), and (3) Softbank (16.4%) (Nikkei, 2007).

[19] In 2001, NTT DoCoMo collected 10.57 million units of mobile phones, 9.33 million units of mobile phone batteries, and 2.92 million units of mobile phone battery chargers (NTT DoCoMo Report, 2003). The total collected units for recycling in 2001 were 13.107 million, 11.788 million, and 4.231 million, respectively (Telecommunications Carriers Association, 2007).

TABLE 8

Materials Recycled in NTT DoCoMo in 2001

Recycled Materials	Weight
Copper (kilograms)	61,908
Iron (kilograms)	14,218
Cobalt (kilograms)	5,430
Nickel (kilograms)	2,880
Silver (kilograms)	769
Aluminum (kilograms)	450
Gold (kilograms)	133
Palladium (kilograms)	49
Slug (kilograms)	230,677

Note: Total units from April 2001 to March 2002.

Table 9 shows the metal recycling units of mobile phones, mobile phone batteries, and mobile phone battery chargers[20] in 2004 (Telecommunications Carriers Association, 2004). At this point, the metal recycling rates for mobile phones, batteries, and battery chargers were 19%, 53%, and 23%, respectively. The latest data are not available for metal recycling, but the material recycling rates for mobile phones and batteries are more than 60% and 30%, respectively (Telecommunications Carriers Association, 2007). Table 10 summarizes the collected units of mobile phones for recycling from 2000 to 2007 (Telecommunications Carriers Association, 2007). The collected units have been decreasing over the last three years because many young people tend to keep their old mobile phones at home. A multi-functional mobile phone can be used as a phone directory, a HDD (hard disk drive) for data backup, a digital camera, a game player, an alarm clock, a wallet for electronic money, *etc.*, and it also contains private data such as digital photos and e-mails. In addition, mobile phones do not occupy much space, unlike PCs or bulky home appliances. Thus, the decrease in the collected units of mobile phones does not imply the increase of their disposal as waste.

[20] A mobile phone battery charger basically consists of an AC (alternating current) adapter and a desktop holder.

TABLE 9

Metal Recycling Units of Mobile Phones in 2004

	Mobile Phone	Battery	Battery Charger
Collected units (thousand units)	8,528	7,312	3,181
Collected units (tons)	677	159	288
Metal recycling units (tons)	129	84	52
Metal recycling rates (%)	19%	53%	23%

Note: Total units from April 2004 to March 2005.
*Metal recycling units (tons) = Metal recycling rates (%) * Collected units (tons)*
Metal recycling rates = metal contents in a mobile phone.

TABLE 10

Collected Units of Mobile Phones for Recycling in 2000–2007

	Mobile Phone	Battery	Battery Charger
Collected units in 2000 (thousand units)	13,615	11,847	3,128
Collected units in 2001 (thousand units)	13,107	11,788	4,231
Collected units in 2002 (thousand units)	11,369	9,727	3,355
Collected units in 2003 (thousand units)	11,717	10,247	4,387
Collected units in 2004 (thousand units)	8,528	7,312	3,181
Collected units in 2005 (thousand units)	7,444	6,575	3,587
Collected units in 2006 (thousand units)	6,622	6,133	3,475
Collected units in 2007 (thousand units)	6,443	7,198	3,706

Note: Year 2000 (from April 2000 to March 2001); Year 2001 (from April 2001 to March 2002); Year 2002 (from April 2002 to March 2003); Year 2003 (from April 2003 to March 2004); Year 2004 (from April 2004 to March 2005); Year 2005 (from April 2005 to March 2006); Year 2006 (from April 2006 to March 2007); Year 2007 (from April 2007 to March 2008).

Conclusion

In this study, we introduced closed-loop supply chain activities in the electrical and electronics industry of Japan. We focused on the home appliance industry and compared it with the PC and mobile phone industries. We used public data to analyze the recycling performance in the three industries. To investigate recycling profitability in our study, we conducted semi-structured interviews with the managers of four major home appliance manufacturers and a leading PC producer.

During the next decade of recycling activities in the electrical and electronics industry, we may need to consider ways to achieve efficient recycling across borders. For example, a photocopy manufacturer successfully created an international resource recycling network covering nine Asia-Pacific countries and regions outside Japan, overcoming the political challenges brought by international laws such as the Basel Convention (Shimada, Kemarangsi, & Methawattanakul, 2006). The company achieved a higher material recycling rate in its recycling factory in Thailand than that in Japan. This achievement was the result of relatively low labor costs that enabled highly manual disassembly. In Japan, the company's standard photocopy machine is disassembled into 44 categories, while the same photocopy machine is separated into 65 categories in Thailand. Among them, the plastic materials themselves are classified into 6 categories in Japan and 14 categories in Thailand. In fact, the manager of Mitsubishi acknowledged that the material recycling rate of the electric appliances can further increase by more disassembly and segregation of their components; however, they also increase labor costs.

Now, China is a production base of new products in Asia due to its low labor costs. Similarly, in the future, China, or some other developing countries, may become a recycling base of end-of-life products in Asia to achieve efficient recycling by gaining economies of scale. In fact, the Japanese Government has been working toward establishing a transboundary material recycling system in Asia or between Japan and China. This attempt will lead to the establishment of an environmentally sustainable society.

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