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3R Initiatives and Circular Economy

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International aspects of recycling of electrical and electronic equipment: material circulation in the East Asian region

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Abstract This article examines the present circumstances of recycling of end-of-life electrical and electronic equipment discarded in Japan from the domestic and international viewpoints of material circulation. It is pointed out that some of the discarded items are absorbed into an invisible flow by informal economic activities, being exported in the form of secondhand equipment and secondary materials. Since the equipment has a pollution potential as well as a resource potential, it is anticipated that the pollution potential may possibly be realized if the equipment is mishandled at recycling plants in developing countries. To reduce the invisible flow as much as possible and to reduce the pollution potential from diffusion in developing countries, a policy tool such as extended producer responsibility should be applied to retailers of the equipment, as well as to producers.

Key words End-of-life electrical and electronic equipment · Material circulation · Extended Producer Responsibility

Introduction

The government of Japan has enacted several laws to promote the new 3Rs philosophy (reduce, reuse, and recycle) to overcome the difficulties brought about by the huge amount of discharged waste in the past 10 years. Following the implementation of the law for recycling of packaging and containers, the government introduced laws for recycling of end-of-life electrical appliances, end-of-life vehicles, and others. It also enacted and amended the Law for Promotion of Utilization of Recycled Resources, according to which the 3Rs of waste, as well as the introduction of resource-saving technology, are encouraged.

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Domestically, Japan has succeeded in reducing the amount of waste discharged and in accelerating recycling activities. Despite the modest growth of GDP in the past 10 years, the amount of municipal solid waste and that of industrial waste have not increased, and, roughly speaking, have been constant. Particularly, the amount of waste which is disposed of in landfills has decreased drastically. This means that recycling has proceeded well under the auspices of the laws for recycling and material circulation.

Similar circumstances can be found in other East Asian countries. Korea has, for example, introduced several laws for smooth material circulation and recycling, emphasizing the concept of extended producer responsibility (EPR). China is following Japan and Korea in its general environmental policy, as shown by Harashima and Morita,[1] and, in particular, in trying to introduce a powerful law for recycling end-of-life electrical and electronic equipment (ELEEE). Thus, it might be considered that the 3Rs are proceeding successfully in the East Asian region.

However, the international interface of recycling regimes is not well defined, so that resource allocation of end-of-life products (ELPs) and secondary materials is inefficient from the viewpoint of environmental economics. We adopt the definition of "secondary materials" following Yoshida et al.[2]: "secondary materials are defined as by-products from manufacturing processes, or scrap materials after the separation or dismantling of end-of-life products that are potentially recyclable." The term "secondary resources" is used interchangeably with "secondary materials" in this article, but the former term is used to make a contrast with the term "natural resources." For the definition of a regime, see Porter and Brown.[3]

Large amounts of ELPs and secondary materials are not collected in the well-equipped recycling plants in Japan, and vast amounts of them are considered to be exported to developing countries, where most are mishandled or recycled improperly in poorly equipped plants. Consequently, it is considered that resource extraction from ELPs or secondary materials is inadequate on the one hand, and pollution may possibly be diffused in the process of extraction on the other.

There have been some contributions which explore this problem, although the number is limited, to the best of the author's knowledge. Puckett and Smith[4] critically examined the flow of e-waste between developed and developing countries based upon their own fact finding. (E-waste is the same as ELEEE in this article, but it must be noted that ELEEE may not be waste, as it can be reused in other countries if exported and properly treated there.) From the viewpoint of an international NGO, Puckett and Smith pointed out defects in the international regime for trading e-waste and criticized the role of developed countries in the trade of e-waste.

Yoshida[5] surveyed the way information technology waste (IT waste) may possibly cause environmental problems not only in Japan but in developing countries when part of the waste is exported. He pointed out that hazardous substances such as lead and brominated flame retardants are contained in the IT waste, and suggested that if such waste is improperly treated in recycling plants, pollution may result. Hence, he concluded that those hazardous substances must be replaced by nonhazardous ones, and producers should be responsible for proper treatment or recycling of IT waste.

Yoshida et al.[2] revealed the actual circumstances of the trade of secondary materials between Japan and China. They analyzed the flow of large amounts of secondary materials such as plastics and scrap metals that are exported to China from developed countries, particularly Japan, and explored the destination of those materials. They also showed that China imports low-quality secondary materials from developed countries.

The purpose of this article is, based on the fact finding and analytical results of the preceding contributions, to explain, by taking ELEEE as an example, how the present material circulation of secondary resources has come to be distorted in the East Asian region and how this distortion of resource allocation can be rectified. It will be emphasized that a gap between the formal and informal economies for the trade of ELEEE has caused inefficient allocation of resources, possibly diffusing pollution in developing countries. To rectify this distortion, it is necessary to institutionalize formal economic activities of recycling and to create economic motivation that will cause the actors in the informal economy to move to the formal economy.

I develop the argument as follows. In the second section, I explain how the treatment and recycling of ELEEE is going on at present, taking some specific electrical appliances (personal computers and cellular phones) as examples. I also define resource potential and pollution potential for use in later arguments. In the third section, I analyze how the present treatment and recycling of ELEEE have come to be distorted from institutional as well as economic viewpoints. It is emphasized that a price differential of ELEEE between Japan and other parts of the East Asian region induces actors working on recycling activities to push ELEEE into an invisible flow, which sometimes results in improper treatment and may possibly cause pollution. In the fourth section, based upon the analysis of the previous section, I propose a new regime to promote the 3Rs in the East Asian region. The final section provides some concluding remarks.

Circumstances of ELEEE in Japan

Recycling of electrical appliances

Japan has implemented a variety of laws that promote the 3Rs. The Law for Recycling of Specified Kinds of Home Appliances, which is the law for the recycling of end-of-life electrical appliances (ELEAs), was enacted in 2000 and is in the process of being reviewed. Before the law was introduced, more than half of ELEAs were treated as municipal solid waste. Since municipalities were not considered to be well equipped for the recycling and proper treatment of ELEAs, the recycling rate at the time was estimated to be very low, and it was considered that the environmentally harmful substances contained in ELEAs, such as lead, chlorofluorocarbon (CFCs), and brominated noninflammable plastics, were not handled properly.

Hence, although the amount of ELEAs in the total amount of municipal solid waste was small, the government enacted the law for recycling of ELEAs in 2000. Four items are specified by the law: air conditioners, TV sets, refrigerators, and washing machines. These four items account for, in terms of weight, nearly 80% of the total amount of all electrical appliances. Producers of electrical appliances are responsible for recycling the specified items, and the legally targeted recycling rates in terms of weight are 50%, 50%, 55%, and 60% for refrigerators, washing machines, TV sets, and air conditioners, respectively.[6]

The specific feature of the law is that users of electrical appliances are supposed to pay the recycling charge at the stage of discard, as well as the charge for the transportation from the discard point to the designated stockyard. Thus, users who do not want to pay the charges may avoid the recycling route designated by the law, sometimes handing ELEAs over to illegal brokers or vendors, who resell some those ELEAs domestically, but most of them are considered to be exported to developing countries.

There is another aspect of the payment of the recycling charge. Since the markets of the specified items are almost saturated, purchase of any of the four items usually means the replacement of old ones by new ones. If the recycling and transportation charges are imposed on users at the stage of hand-over of old items to retailers, users may postpone the purchase of new ones, since the charge virtually implies an increase in the price of the new appliance. Being afraid that the volume of sales of new items will decrease due to the anticipated behavior of users, retailers or shops may take back old items without charge, and resell them to brokers or vendors who handle used electrical appliances. They may also hand over the old items to recyclers outside the legitimate route. Some of these transactions are suspected to be illegal.

The above flow of ELEAs that does not conform to the route designated by the law cannot be identified, and no one knows exactly how such ELEAS are handled. Some of

them may be reused domestically, but it is anticipated that most of them will be exported, possibly to developing countries, mainly for reuse, but some of them may be dismantled and recycled improperly in developing countries. This flow is called an *invisible flow*, since the trade flow is not transparent and, thus, cannot be identified.

The total volume of discarded ELEAs in Japan is unknown and can only be estimated. The following estimates on the specified ELEAs are quoted from The Central Environmental Council/The Industrial Structure Council.[7] It must be remembered that the estimates are obtained from quite rough calculations and are not considered to be precise. As for the specified ELEAs, the estimated number per year is roughly 23 million items, and nearly 11.6 million of these are collected and recycled in the route designated by the Law for Recycling of Specified Kinds of Home Appliances. In addition, municipalities handle roughly 0.7 million items; this is also a visible flow. Thus, 11 million appliances are not collected or recycled along the visible flow, going into an invisible flow. Some of these appliances are reused domestically, and the estimated number for domestic reuse is about 1 million. The volume of domestic recycling *not* under the Law for Recycling of Specified Kinds of Home Appliances is estimated to be 2.4 million items. Some of the extracted parts and materials from domestic recycling may be exported to developing countries as secondary materials. It is anticipated that the rest of the uncollected specified ELEAs under the law are, as just mentioned, exported mainly to developing countries. The estimated number of exported items for reuse purposes is about 6 million, and that for recycling purposes is about 1.8 million.

Recycling of electronic appliances

Personal computers

Sales of personal computers (PCs) have rapidly increased recently, both for business use and household use, and this implies that a huge number of PCs are discarded from the business sector as well as the household sector. In the past, end-of-life PCs (ELPCs) in business use were treated as industrial waste, while those in household use were treated as municipal solid waste. Clearly, it was almost impossible for municipalities to properly handle such a complicated item as a PC. Furthermore, it was inefficient to handle PCs in business use and household use separately.

Considering these circumstances, the government decided to promote recycling of ELPCs efficiently under the Law for Promotion of Utilization of Recycled Resources, whether from the business sector or the household sector. The target recycling rate, which is determined voluntarily by producers under the law, is 50%, 20%, and 55% for the main body of a desktop PC, a laptop PC, and the display apparatus, respectively.

Compared to ELPCs in household use, it is considered relatively easy for producers to collect ELPCs in business use, since the sales route of PCs for business use is easy to trace. There are four main collection routes, organized by (1) the producers themselves, (2) lease or rental companies, (3) retailers, and (4) expert collectors. Unlike ELPCs in business use, it is not so easy to collect those in household use. Hence, under the law, PCs for household use which were sold after October 2003 must be collected for free by producers. Yet, there is considered to be a large number of PCs that were sold before that date and are stored in households. Producers are not obliged to collect those for free.

There is another problem. A PC that is at the end-of-life stage for certain users may possibly be still usable by different users. This is particularly applicable to ELPCs in business use, since the business sector replaces old PCs with new ones rather early in the life stage of a PC, even though they are still usable. Most of these old PCs seem to be sold in the market for secondhand PCs, and it is anticipated that some of them are exported.

Furthermore, even completely obsolete PCs are valuable in the market of secondary materials, since they contain precious metals such as gold, as well as nonferrous metals. In particular, the printed circuit boards obtained from ELPCs contain gold, silver, and palladium, for example, so that they are traded as a valuable material. Hence, quite a large number of obsolete PCs, whether they are in business use or in household use, are also sold domestically or exported to developing countries.

To sum up, although the collection of ELPCs is supposed to be the producers' responsibility under the Law for Promotion of Utilization of Recycled Resources, most ELPCs are not handled by the route designated by the law and are absorbed into the invisible flow. What is worse, a great volume of unusable ELPCs is exported to developing countries where small business recyclers dismantle and recycle them in an improper way. Old parts from ELPCs, such as the printed circuit board, are also exported to developing countries along the invisible flow. According to the estimate by the Japan Electronics and Information Technology Industries Association,[8] of the ELPCs from business use in fiscal year 2004, 48 000 tons went to recyclers via producers, while 20 000 tons went via lease/rental companies and retailers. It is estimated that 32 000 tons of ELPCs from business use went to the secondhand market, whether domestic or international. As for ELPCs from household use in the same year, 19 000 tons went to the secondhand market via retailers, expert vendors, and net auctions, while 7000 tons were recycled by recyclers or municipalities. It is considered that 14 000 tons are stored in households. However, it must be remembered that these numbers are calculated from rough estimates and are not precise.

Cellular phones

The proper treatment or recycling of end-of-life cellular phones (ELCPs) is neither a target of any specific recycling law, nor that of the Law for Promotion of Utilization of Recycled Resources in Japan. This is amazing when we consider that huge numbers of ELCPs are produced, sold, and disposed of every year. More than 25 million ELCPs

are discarded every year (Yoshida[5] and the Clean Japan Center[9]).

The Clean Japan Center[9] estimates that only 40% of ELCPs are collected by retailers. Furthermore, it is not specified how many of them are returned to carriers. (A carrier of cellular phones is a telecommunications company which contracts with cellular phone users.) If the discarded ELCPs are returned to carriers, they are properly treated and efficiently recycled. The final destination of this route is nonferrous refineries where precious metals such as platinum, gold, silver, and palladium, as well as nonferrous metals such as copper, are extracted without causing pollution. In this article, the final destination is defined as the place where secondary metals are extracted from ELEEE or its parts so that those materials can be sold as *resources* in markets.

There seems, however, to be a huge number of ELCPs that are collected by retailers but not returned to carriers. Most of these phones are thought to be bought by expert vendors or brokers, most of whom possibly export them to developing countries, although the details of these transactions are not clear at all. This implies that a very large number of ELCPs are swallowed up in the invisible flow.

Resource potential and pollution potential

ELEEE and secondary materials which are extracted from ELEEE have two contradictory characteristics: resource potential and pollution potential. Let us define the two characteristics as follows (see Hosoda[10] for a detailed explanation of the definition):

Definition 1 (Resource potential) *Resource potential is defined as an attribute that substances, after they are properly treated, contribute to production by positive marginal productivity. Resource potential may not be realized if substances with the potential are not treated in a proper way*.

Remark 1 *Resource potential is defined independently of pollution potential, which is defined below. For example, the resource potential of gold contained in a printed circuit board is considered to be realized if it is recycled at a plant such as a nonferrous metals refinery; however, there is the possibility of pollution due to mishandling of hazardous substances such as lead, for example. Thus, the resource potential may be realized with the pollution potential*.

Definition 2 (Pollution potential) *Pollution potential is an attribute of substances that degrade environmental quality if they are treated in an improper way. Pollution potential may not be realized if substances with the potential are treated in a proper way*.

Remark 2 *Pollution potential is defined independently of resource potential, which is defined above. For example, the pollution potential of lead contained in a printed circuit board is considered to be realized if it is recycled at a poorly equipped plant, even though precious metals such as gold may possibly be extracted. Thus, the pollution potential may be realized with the resource potential*.

It must be noted that the same substance has resource potential as well as pollution potential to a certain degree. For instance, lead in a battery may be recycled as a resource, whereas it may be a source of pollution if it is left in the natural environment. Which character of the potential is realized depends upon the market conditions of the resources, the business cycle, the social system, and other factors. The resource potential of the specified ELEAs is summarized in the Table 1.

As for the pollution potential, refrigerators and air conditioners contain CFCs, which can catalytically destroy the ozone layer in the stratosphere if released into the atmosphere. Some of these appliances contain hydrofluorocarbon (HFCs) and hydrochlorofluorocarbon (HCFCs), which promote the greenhouse effect, although these substances are not given in the following table. TV sets contain brominated flame retardants, and, furthermore, all the specified electrical appliances contain lead in the solder.

The resource and pollution potential of a desktop PC is summarized in Table 2.

Table 1. Composition (weight %) of the specified electrical appliances

Appliance	Iron	Copper, etc.	Aluminum	Plastics	Glass	Others
Refrigerator	49	4	1	43	0	3
TV Set	12	3	1	26	53	5
Air conditioner	54	18	9	16	0	3
Washing machine	52	2	4	33	0	9

Reproduced from Hosoda.[11] The original data are based upon a 1993–1994 report by the New Energy and Industrial Technology Development Organization
The capacity of the refrigerator in the table is above 300l. The washing machine is a fully automatic appliance with a capacity of more than 5 kg

Table 2. Composition of a desktop PC (%)

Plastics	Lead	Aluminum	Iron	Tin	Copper	Zinc	Cadmium	Mercury	Gold
23.0	6.3	14.2	20.5	1.0	6.9	2.2	0.009	0.002	0.002

Source: Microelectronics and Computer Technology Corporation[12]

Table 3. Composition (g) of a of cellular phone weighing 100 g

Iron	Aluminum	Copper	Other nonferrous metals	Plastics	Fiber	Glass	Others
6.5	3.2	5.9	7.5	51.3	0.1	2.7	22.8

Reproduced from Hosoda.[11] The original data are based on a report by the Communication and Information Network Association of Japan

Table 4. Nonferrous metals (g) contained in a cellular phone weighing 100 g

Gold	Silver	Copper	Palladium
0.028	0.189	13.71	0.014

Source: Clean Japan Center[9]

The resource potential of cellular phones is shown in Tables 3 and 4.

Amazingly enough, the amount of gold in a ton of cellular phones is greater than that in the highest grade of natural ore. Furthermore, a cellular phone contains other precious metals such as silver and palladium. On the other hand, it also contains hazardous substances such as lead, arsenic, cadmium, a chromium compound, and brominated flame retardants, although the amounts of these substances are quite small.

Dual aspect of the economy of ELEEE in the East Asian region

The present circumstances of the trade of ELEEE in the East Asian region

Japan has many recycling plants which are well equipped for extraction of resources and pollution prevention, and have sufficient capacity for recycling. Quite a large amount of ELEEE does not, however, arrive at these plants; some may be transported to poorly equipped domestic recycling plants, but most is exported to developing countries. Since well-equipped domestic plants can enjoy the merits of scale and can treat ELEEE more cheaply if they process more, the present circumstances of collection of ELEEE does not seem efficient. It must also be noted that nonferrous metals refineries in Japan can extract precious metals as well as nonferrous metals from dismantled parts of ELEEE at a very high rate of recovery.

Most of the recyclers of ELEEE in Japan are highly efficient at resource extraction and compliance to the legal system. Particularly in the case of the specified electrical appliances and PCs, recyclers who have a close relationship with producers of the equipment are regarded as the producers' partners. Thus, it can be safely said that their business makes up a formal part of the economy. They collect items of ELEEE only from a visible flow which is defined legally, and can be easily traced and identified.

As I mentioned in the previous section, however, there is also an invisible flow that is neither legally defined nor protected. First of all, the invisible flow is often made possible by illegal activities such as illegal collection by collectors who ignore the business license requirement for collection and illegal hand-over from retailers. Although the activities along the invisible flow do not always mean illegality, the flow of ELEEE sometimes results in illegal domestic recycling or illegal export to developing countries, infringing the Basel Convention and the domestic laws concerning waste transportation in both exporting and importing countries.

The export of ELEEE from developed countries to developing countries would not cause any problem if all the items of ELEEE were exported in a legitimate way and were treated and recycled in a proper manner in developing countries. The reality is quite far from such ideal circumstances. Most recyclers in developing countries are not well equipped for the proper treatment of waste, clean recycling, or pollution prevention. Therefore, generally speaking, the recovery rate of resources of such recyclers is considered to be low compared to that of recycling plants in Japan. Furthermore, hazardous or toxic substances do not seem to be handled and treated in a proper way, and this means that pollution is possibly being diffused around recycling plants in developing countries, as Puckett and Smith have reported.[4]

The small-scale recycling businesses in developing countries are a typical example of an informal sector, which is not under legal protection on the one hand, and has no intention of legal compliance on the other. The elasticity of labor supply with respect to wage rate in this sector is virtually infinite. Thus, insofar as there is increasing demand for secondary materials, the business can absorb a huge labor force at a low wage rate. In addition to the poor equipment for resource extraction and pollution prevention, workers in the business are not well trained to handle potentially hazardous used parts, such as printed circuit boards and secondary batteries, for example. This is why workers in the business are considered to be badly affected by hazardous substances.

Despite the environmental laws enacted and the apparent attitude of the central governments against pollution in developing countries, the consciousness of legal compliance in terms of environmental protection is relatively low there. Small-scale recyclers are more interested in the extraction of resource potential from ELEEE, rather than lowering pollution potential in the process of recycling. They have no incentive to invest in pollution prevention.

The problem of a dual economy

Let us consider the present circumstances of trade of ELEEE in the East Asian region in terms of a dual economy, which is defined as follows:

Definition 3 (A dual economy) *A dual economy is defined as an economy that consists of two different characteristics.*

One is that actors do business complying with the legal system, and the transaction flow is visible to almost all the actors. Such an economy may be called a formal economy. The other characteristic is that actors usually belong to an informal sector, sometimes ignoring the legal system, and the transaction flow is invisible. Such an economy may be called an informal economy. A dual economy is defined as an economy that has both these two characteristics.

It must be noted that there is gradation between the two economies, and it is sometimes difficult to distinguish a formal economy from an informal one. It is quite possible that the same actor is active both in formal and informal economies. Some actors may switch their field from an informal economy to a formal one, and vice versa. If all the economic actors belong to a formal economy, the dual aspect of the economy disappears.

In the case of the transaction of ELEEE or secondary materials related to ELEEE, whether they are domestic or international, the economy clearly has a dual nature. Let us explain the dual nature of an economy, taking up the example of ELEAs. Nearly 12 million items of the specified ELEAs are collected and recycled in a formal economy in Japan. Appliances discarded by users are mostly carried via retailers to the designated stockyards, from where producers are responsible for collecting and transporting them to their recycling plants. All the actors are formal and the flow is mostly visible.

In contrast, the appliances which are not collected and recycled under the legal framework are supposed to be collected by brokers or vendors, and most of those appliances are thought to be exported to developing countries. Some retailers, who sometimes act legally, may, in some cases, hand over the specified appliances to illegal brokers or vendors, knowing the illegality of their actions. It is also believed that some retailers occasionally hand over the specified ELEAs to recyclers who have a license for industrial-waste treatment. This is also considered illegal. These informal economic activities support the invisible flow of ELEAs. Almost the same thing is applicable to ELPCs.

Things are quite different for cellular phones, since there is no formal system legally supported to collect and recycle ELCPs. They are targeted neither by any recycling law nor the Law for Promotion of Utilization of Recycled Resources. Thus, an informal economy dominates the transaction flow of ELCPs and only 40% of ELCPs are collected by retailers. Quite a large number of ELCPs are traded in an informal economy by informal actors.

From the description above, it is clear that ELEEE moves along *either* a visible flow, being treated and recycled in a formal economy *or* an invisible flow, being treated and recycled in an informal economy. If an informal economy is closed in one developed country, say, Japan, the problem caused by informal activities may be relatively small, since illegal activities are supposed to be identified relatively easily in Japan, compared to those internationally, and pollution may possibly be prevented in advance. We cannot, however, be too optimistic on domestic illegal activities in an informal economy. There are some cases of illegal treatment in Japan, such as illegal discharge of CFCs, mishandling of hazardous substances, and so on, which may bring about environmental degradation.

Yet, compared to the effects described above, those due to improper treatment of ELEEE in a wider area, namely the East Asian region, are likely to be more serious. Actually, an informal economy is not isolated in one country, being connected to those in other countries, mostly in developing countries. The invisible flow of ELEEE crosses over both developed and developing countries, making an informal economy internationally open. Since the economies of the East Asian region, such as China, Korea, Taiwan, Vietnam, and Thailand, are developing and growing rapidly, absorbing secondary resources as well as natural resources, they are importing ELEEE through both visible and invisible flows.

Actors working in the visible flow handle ELEEE or used parts extracted from ELEEE in a proper way, so that the resource potential of ELEEE is efficiently realized by reuse or recycling, while pollution potential is well controlled. On the other hand, actors working in the invisible flow do not always handle ELEEE and its used parts in a proper way, so there is the strong possibility that the resource potential is not efficiently realized and, what is worse, the pollution potential is realized. Particularly when developing countries in the East Asian region experience an economic boom, it is hard to choke the invisible flow of ELEEE, and thus, pollution may possibly be diffusing along the flow.

Free entry to an informal economy

Let me explain why there is a strong incentive for actors to try to enter the informal part of the dual economy in Japan. First of all, it is more costly for them to enter the formal part of the dual economy than the informal part, since they have to adhere to many qualifications or requirements imposed by legal systems. In order to transport, treat, or recycle ELEEE in the formal economy, actors have to obtain a qualification or a license for the respective activity, unless the ELEEE has a nonnegative price. (In Japan, materials which are negatively priced are regarded as waste in a legal sense, and actors who handle these materials are required to obtain a license to handle them.) It requires not only pecuniary, but nonpecuniary costs, including adjustment costs and administrative costs, to do so.

Compared to this, there are no such costs in handling ELEEE in the informal economy. Actors who have no precise knowledge of handling hazardous or environmentally harmful substances can have easy access to this economy. They may try to cheat the authorities, behaving as if they were handling positively priced ELEEE, even if this is not the case. One obstacle for them in acting in such a way is that illegal activities are punished if they are discovered by the authorities.

Secondly, actors can save costs by treating or recycling ELEEE in an improper way in an informal economy. They may extract resources from ELEEE and its secondary materials, paying no attention to their pollution potential,

and so they do not usually pay costs for pollution prevention. While improper treatment or recycling, if any, is rather easily identified by the authorities in a formal economy, it is not so in an informal one. This cost saving is additional to the above-mentioned one, so that cost saving may be double in an informal economy.

Clearly, the effect of cost saving on the incentive to enter an informal economy would not be so strong if it were not for sufficiently robust demand for ELEEE and its secondary materials. A demand-pull factor is crucial for actors to enter into an economy to supply goods or service, whether their activities are formal or informal. Here, it is worth remarking that there is actually a robust demand and it comes from developing countries in the East Asian region at present. Since informal economies are connected to one another via an invisible flow in the East Asian region as already mentioned, the power of the demand strengthens the actors' incentive to work in the informal economy.

Price differential between the two flows

I have suggested that the reason for the existence of the invisible flow which connects informal economies in the East Asian region is that there is strong demand for ELPs and their used parts in developing countries in the region. There is, however, another reason. Generally speaking, there is a big price differential with respect to ELPs and secondary materials between Japan and other East Asian countries, both for institutional reasons as well as economic reasons. This is particularly true for ELEEE. Let us explain this in more detail.

As already mentioned, Japan has constructed institutional frameworks for the promotion of recycling of specified ELEAs and ELPCs. This is because the market mechanism did not work for clean and efficient recycling of those end-of-life products, and some of them were treated and recycled inefficiently as either municipal solid waste or industrial waste. Some of them were absorbed into an invisible flow. The market mechanism did not work well for proper recycling, since high-quality recyclers could not earn positive profits by recycling, whereas low-quality recyclers could sometimes make a profit by using illegal methods, and thus reuse or recycling in an improper way was supposed to spread via the invisible flow. If such a situation had remained, so-called adverse selection would have occurred, and quality recyclers might have disappeared.

It should be remarked that, for high-quality recycling, the cost of transportation, storage, dismantling, recovery of resources, treatment of residues, and so on (i.e., the recycling cost in a broad sense) usually exceeds the sales of resource materials which are obtained by recycling. This is partly because quality recyclers pay their workers relatively well compared to poor recyclers, and partly because the former have the cost burden of heavy investment for efficient recycling and pollution prevention, while the latter does not. Consequently, quality recyclers would be in deficit if their business were carried out in an ordinary market.

In order to solve this problem, the Law for Recycling of Specified Kinds of Home Appliances was introduced for recycling of specified ELEAs. In this scheme, users have to pay the recycling charge at the stage of discard, and this charge is applied to the recycling deficit. Therefore, collected items of ELEAs under the law are supposed to be treated and recycled efficiently as the law requires, but there are a huge number of uncollected pieces under the law, since some users try to avoid paying the charge and some retailers try to avoid charging the recycling fee. This is a natural reason why the uncollected items of ELEAs are absorbed into the invisible flow.

As for ELPCs, for computers for household use which were sold after October 2003, the recycling charge is paid at the stage of purchase, and free collection of these ELPCs has begun under the Law for Promotion of Utilization of Recycled Resources. But, apparently, computers sold before then are not the target of free collection. If users paid the proper recycling charge for the old ELPCs at the stage of discard, there would be no deficit for recyclers of ELPCs, and proper recycling should proceed. Yet, expert brokers and vendors collect ELPCs at a nonnegative price, paying very small amounts of money to users. Clearly, this is more attractive to users. The result is clear; most of the ELPCs in household use are not collected in the legitimate system of recycling, and go into the invisible flow. The same thing is true for cellular phones, since there is no legitimately organized system for collecting and recycling them.

The economic situation is quite different in developing countries, which have a strong demand for ELEEE and its secondary resources. The same ELEEE that has a negative or zero value in Japan is positively priced. First of all, end-of-life products in Japan do not always mean "end-of-life" in other countries, and such appliances are usable. Hence, they are purchased like new products in developing countries. Secondly, secondary materials obtained from ELEEE are also positively priced, since the recycling cost is exceeded by the sales of secondary materials obtained from ELEEE, partly due to cheap labor and the low cost of poor equipment for recycling. Thus, there is no deficit in the recycling processes of ELEEE.

Getting together the facts mentioned above, we can understand clearly why there is a big invisible flow of ELEEE from Japan to developing countries in the East Asian region. If the present situation remains, sooner or later the pollution potential of ELEEE will certainly be realized as real pollution in the form of soil pollution, water pollution, and air pollution, among others. It is quite important to note that the existence of the flow is due not only to economic reasons, but also to institutional reasons in Japan, although the two reasons are intertwined.

A new regime to promote the 3Rs in the East Asian region

Restriction of the invisible flow

So far, in the market of ELEEE, the informal sector still has strong control over the flow of ELEEE, which

strengthens the invisible flow of ELEEE and makes the informal economy prosperous. Insofar as there is a strong demand for ELEEE and secondary resources obtained from ELEEE in developing countries in the East Asian region, and insofar as there is a price differential of ELEEE between Japan and other East Asian countries, as well as the institutional factor which pushes ELEEE and its secondary materials from the former to the latter, it is very hard to reduce the invisible flow and stop pollution diffusion caused by the improper treatment of ELEEE. In the present regime of international resource circulation, illegal or improper trade in ELEEE in the informal economy is anticipated to diffuse pollution.

Certainly, the present regime has the apparatus to control the flow of hazardous waste from developed countries to developing countries: the Basel Convention and some domestic laws corresponding to it are expected to prevent illegal transportation of hazardous waste from developed countries to developing countries. Yet, it is very hard for governments or local authorities to restrict the international flow of waste effectively by means of this apparatus alone.

The mere restriction of the international trade of ELEEE by means of a legal apparatus is not effective in controlling the invisible flow, since the restrictions surely cannot affect demand for ELEEE and its secondary resources from developing countries, and, further to this, the price differential as well as the institutional factors mentioned above will still exist despite the restrictions.

What is worse, such restrictions may drive economic actors to the informal economy of ELEEE, which has the nature of high risks with high returns. Recyclers who try to comply with the legal system find larger marginal costs in the transaction of ELEEE and its secondary resources, due to the severe restrictions, than those who do not comply. It is very costly and burdensome for recyclers and traders to make international transactions of ELEEE and its secondary resources following the restrictions. A competitive force encourages economic actors to do business more in the informal economy than in the formal economy, driving them to pursue high return with high risk. As a consequence, the invisible flow will continue to grow if the restrictions become severer without introducing any proper driving force which encourages the actors to follow the visible flow.

Some principles which promote the 3Rs

In order to make the flow of ELEEE and its secondary materials as visible as possible and to promote the 3Rs in the East Asian region without diffusing and realizing pollution potential, it seems to me that the following simple principles must be observed in light of the spirit of the Basel Convention. (Clearly, the following principles are not the same as the contents of the Basel Convention, but I consider that the principles reflect the spirit of the Basel convention.)

The first is the domestic treatment principle: to prevent pollution diffusion in the region, ELEEE and its secondary materials which have pollution potential should, in principle, be treated domestically. If they are exported over long distances, information about the contents of the ELEEE or its secondary materials will easily become dissipated, even along the visible flow, and mishandling of these substances may occur. *A fortiori*, if they were absorbed in the invisible flow, mishandling and improper recycling of the substances with pollution potential can hardly be avoided. In that sense, the fact that there is a large number of items of ELEEE uncollected by formal economic activities in Japan is problematic.

The second principle is the effective trade principle: if proper domestic treatment of ELEEE and its secondary materials in developing countries is difficult for technical or economic reasons, they may be exported for the purpose of proper treatment and recycling to a developed country such as Japan, which has high-quality recycling plants. To guarantee this principle, developing countries would be required to remove as many informal brokers and recyclers as possible, although it is actually hard for the government or local authorities to do this.

The third is the quality trade principle: ELEEE and its secondary materials that have no pollution potential, such as usable secondhand products, scrap iron, nonferrous metal scraps, well-sorted waste paper, and well-sorted plastics, may be traded internationally, particularly in the East Asian region. (This does not mean that *all* secondhand electrical and electronic appliances are allowed to be traded internationally. Only those which are comparable with new appliances in terms of quality may be traded.) To guarantee this principle, there should be a system of quality control for these substances, whether it is compulsory or voluntary, so that information about the contents is always clear, and the flow of international transactions becomes more visible.

To create a new regime

Let us propose a policy option for Japan to create a new regime for promoting the 3Rs in the East Asian region following the fact finding and analysis which are found in the preceding sections. Here, we have to note that there are controllable boundary conditions of a regime and uncontrollable boundary conditions.

The potential power of the strong demand from developing countries in the East Asian region for ELEEE and its secondary materials is not directly controlled by any policy, and must be regarded as a given factor. To be sure, it might be indirectly controlled by fiscal and financial policies through a macroeconomic effect, but it cannot specifically be targeted by these policies. Thus, the demand conditions of ELEEE and its secondary materials in the East Asian region should be considered the uncontrollable boundary in this article.

The fundamental part of the price differential of ELEEE and its secondary materials between Japan and other East Asian countries is also considered as a given factor, since the relative prices are determined in the international

general equilibrium system. The differential, however, can be manipulated to some degree by means of public policy. For example, the information cost to perform transparent transactions may be controllable, since it can be lowered artificially by scale merits of an information network under the auspices of the public policy.

It is most clear that the institutional factor already mentioned is controllable in both Japan and in other East Asian countries. Particularly, the timing of the payment of the charge for recycling of the specified ELEAs in Japan can be changed from the discard stage to the stage of purchase of a new product, so that users or retailers are effectively discouraged from avoiding payment or charge for the additional cost of proper recycling and from handing over the specified ELEAs to expert brokers or vendors who are active in the informal economy.

There is another good point to the change of timing of the payment. Since retailers can collect the specified ELEAs more easily, their controllability of the flow of ELEAs becomes stronger. Also, there is less incentive for them to hand over items to expert brokers or vendors insofar as the latter actors do not pay a reasonable amount of money for them. This implies that natural and reasonable selection occurs as to which items are really reusable and resalable.

In addition to this, if electrical certification which identifies the transaction of the specified ELEAs for recycling is issued, really reusable and resalable items among ELEAs are identified and screened from those which are not reusable, and are transported to recycling plants, unlike those which may legitimately be reused domestically or internationally. Thus, the amount of visible flow would be expected to become much bigger than the invisible flow, and the domestic treatment principle will possibly be realized for the specified ELEAs. It is natural that informal recyclers or brokers must be excluded from this system.

Whether exported materials have pollution potential or not must be checked. Clearly, secondary materials with high pollution potential, such as used batteries and printed circuit boards, among others, should not be allowed to be exported according to the domestic treatment principle. It is also necessary to construct a tracing system for secondary materials obtained from the specified ELEAs if they have some pollution potential. This can be done without difficulty in cases where pieces of the specified ELEAs are transported via the visible flow, since almost all the domestic recycling plants and their activities can be identified. By so doing, producers' responsibility for the specified ELEAs would become heavier, and design for the environment will be promoted. Let me give an example of the traceability of materials.

Example 1 *Well-sorted culets obtained from the cathode ray tubes (CRTs) of TV sets are exported from Japan to Thailand for recycling. Producers are responsible for this activity, and the pollution potential of the culets is considered to be low, even though the funnel glass contains lead, since the separation of panel and funnel glass parts is complete. This flow is completely visible under the Law for Recycling of Specified Home Appliances, and it guarantees the final destination of the CRT culets, which is a recycling plant of high quality.*

Basically, the same system mentioned above is applicable to ELPCs and ELCPs. If a tracing system is constructed for the flow of these ELPs, potentially hazardous substances could remain in Japan and be recycled in high-quality plants. Although proper recycling of ELPCs is a target of the Law for Promotion of Utilization of Recycled Resources, ELCPs are not targeted for recycling. Being outside of any law for recycling or material circulation, it is impossible to control the flow of ELCPs. It is absolutely necessary to institutionalize the recycling of ELCPs under the concept of extended producer responsibility, as in the case of the specified ELEAs and ELPCs.

Yet, ELPCs and ELCPs have some specific features that differ from those specified ELEAs. Quite a large number of ELPCs for business use are considered to be resold for reuse purposes in the market, and some of them are exported. Insofar as they are really workable, the transaction should not be hindered, since they are basically almost the same as new ones. The point is whether all those ELPCs transacted for reuse purposes are *really* workable. To ascertain the validity of the transaction, implementation of a certification system is required. It is also necessary to apply extended producer responsibility (EPR) to retailers of reused computers. Retailers, as well as producers, should be obliged to promote collection of ELPCs which are not usable. This collaboration is unavoidable.

Usually, a producer which is designated by EPR is understood in a very limited sense, particularly in Japan. Thus, the producer targeted by EPR is often regarded as the manufacturer. However, the term "producer" should not be grasped in such a narrow sense, since the responsibility for ELPs must be taken by an economic actor who has the strongest controllability of the ELPs, and this actor does not always mean the manufacturer. A retailer or a distributor may take the responsibility in some cases.

As for ELCPs, I should mention one important characteristic intrinsic to them: their resource potential value is very high compared to other ELPs. Following Table 4, I have calculated the potential value at the time of writing. Assuming that a cellular phone weighs 100 g, the potential value of a unit is 164 yen, which surely exceeds the transportation and recycling costs. (The market prices of gold, silver, palladium, and copper were taken from the Nikkei newspaper on January 17, 2007.) Although the exact data on these costs have not been obtained, it does not seem that they amount to more than 100 yen per unit of ELCP, considering the general circumstances of treatment of industrial waste, particularly ELEEE. Thus, the recycling of ELCPs should be profitable.

There are, however, many ELCP units which are not collected by carriers, as already mentioned. This is partly because there is no collection system arranged by retailers, so that users have no route for returning their ELCPs. Once users can return ELCPs to retailers without any charge, it is quite easy for those retailers to get them back to a

recycling plant via carriers, since retailers have a close connection to carriers. Hence, if EPR is applied to retailers and carriers for collecting and recycling ELCPs, a visible flow will soon be created, and proper recycling will be promoted by the economic incentive.

There is another reason why ELCPs are not properly collected. Japanese CPs have many other functions beside mobile communication, such as inbuilt cameras and digital storage, among others. Since new CPs are often incompatible with old ones insofar as such functions are concerned, users tend to keep old CPs at hand even after replacing them with new ones. Further to this, new CPs are priced at a much lower level than the production cost, and this gives the wrong signals to consumers for early replacement. This explains why the number of ELCPs that are not collected by carriers is so huge. Carriers are responsible for revising these policies in order to collect as many as ELPCs as possible.

Finally, as a reference for establishing a visible flow of secondary materials obtained from ELEEE, let me mention an example which has been recently observed. It is the experimental export of used plastics from photocopy machines which the city of Kitakyushu has tried.

Example 2 *The city of Kitakyushu has carried out a pilot plan to export well-sorted clean used plastics obtained from photocopy machines and similar devices to the city of Tianjin in China for recycling. The two cities cooperated to construct a visible flow along which both the departure of the material from Kitakyushu and the final destination for recycling in Tianjin are completely identified. Traceability is guaranteed by IT apparatus as well as the guidelines customized for this procedure.*

The above examples demonstrate that the flow of secondary materials extracted from ELEEE is controlled so that all the procedures along the flow are transparent to everyone. Such flow control is often called *product chain control.*[10] For product chain control to be completed along the flow of ELEEE or its secondary materials, all the actors who handle them must take responsibility for efficient collection and proper recycling. Users must hand over ELEEE to legitimate actors on a production chain, say retailers, who collect and transport them to recycling plants cooperating with producers. Naturally, recyclers are obliged to promote proper recycling, while producers are responsible for recycling physically or financially (EPR). All the procedures must be accountable.

Concluding remarks

I have explained the present circumstances of recycling of end-of-life electrical and electronic equipment (ELEEE) discarded in Japan. A remarkable feature is that many items are absorbed into an invisible flow, off the route of proper recycling, despite the fact that items of ELEEE collected by legitimate means in Japan are transported to recycling plants which are of good quality, with a high recovery rate of resources, and without pollution.

Although some items in the invisible flow are resold and reused domestically, most of them are assumed to be exported. It is considered that some of the exported ELEEE will not be working, and so will be dismantled for recycling. However, improper recycling at poorly equipped recycling plants in developing countries may realize the pollution potential of ELEEE, since recyclers at those plants are sometimes interested only in the resource potential of ELEEE, ignoring the pollution potential. The same situation is applicable to the recycling of secondary materials of ELEEE exported from developed countries to developing countries.

The invisible flow exists due to informal activities of actors such as vendors, brokers, and recyclers, among others, who sometimes ignore the legal system of recycling and material circulation of both Japan and other countries in the East Asian region. Since items of ELEEE go along *either* the visible flow *or* the invisible flow to arrive at their final destinations, it is required for the authorities to increase the former flow and reduce the latter with the purpose of increasing the efficiency of resource extraction from ELEEE and also of controlling the pollution potential. Yet, mere reinforcement of restrictions such as the Basel Convention or domestic laws concerning waste transportation and treatment cannot fulfill the purpose, since they certainly increase the cost of the proper procedure of transportation and recycling, thus possibly driving the actors related to recycling more to informal economic activities than to formal ones. As a consequence, the invisible flow will be increase.

To prevent the pollution potential from diffusing to developing countries via these informal activities, it is necessary to control the flow of ELEEE and its secondary materials by means of the revision of institutional aspects and the utilization of potential economic incentives. Although it is very hard to get rid of the price differential for ELEEE between developed and developing countries, institutional aspects can be changed so that most items of ELEEE become absorbed into the visible flow instead of the invisible flow. To complete the procedure, all the actors along the product chain must be responsible for collecting and recycling ELEEE. Combining the responsibility of each actor, the gap in the price differential can be narrowed due to the saving in costs of transportation and information, for example.

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