



The stability and profitability of the informal WEEE collector in developing countries: A case study of China



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ABSTRACT

Different attitudes and practices toward WEEE recovery and recycling are found in developed and developing countries. As the largest developing country in the world, China's WEEE is widely regarded as a valuable product, and the resources contained in it offer potential profit for informal collectors. Unlike the formal collectors, who are supported by the government, informal collectors can only rely on themselves. However, formal and informal collectors often comfortably coexist in developing countries and there are even cases of informal collectors dominating the market. Obsolete television (OTV) in Beijing is employed as a case study. Questionnaire survey and multi-agent cost-benefit analysis are used to analyze the stability and profitability of the informal collector. The results show the following: (1) The factors of price, convenience and canonicity can affect consumers' motivations when selecting a collector, with price and convenience having the strongest impact. And informal collectors can better meet consumers' demands. (2) Stable cooperation within tier two collectors is formed by profit-driven individuals. The secondhand market can expand the profits of the first-tier collectors, while the remaining OTV, which cannot be reused, is delivered to the middleman, ensuring that the first-tier collectors are not menaced from the "rear". (3) The informal backyard recycler expands the profit of the middleman. Meanwhile, the WEEE processing fund is mostly shared by collectors and intensifies the confusion of the recovery market. We then create a new fund system to improve the regulation of OTV recovery. To make formal collections work, we suggest that the government charges an extra 40 Yuan fund when consumers buy new TVs and distribute it to formal collectors in order to exclude the informal collectors.

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1. Introduction

Increasingly diversified consumer demand has driven the rapid development of electrical and electronic equipment (EEE) products (Chan and Wong, 2013; Yu et al., 2010), followed by shortened life-cycles of and faster replacements for the old type of EEE (Umair et al., 2015; Xianlai et al., 2013). The amount of waste EEE (WEEE) will increase in the future. If WEEE is reasonably recycled, the value of the resources contained in it (i.e., metal, plastic and glass) should be huge (Widmer et al., 2005). However, if it is improperly recycled, toxic substances, such as polyvinyl chloride plastics, brominated flame retardants, and heavy metals, can be released and cause significant environmental pollution as well as negative impacts to

human health (Chan and Wong, 2013; Sepúlveda et al., 2010; Wang and Xu, 2014). Moreover, WEEE is among the most complex and persistent of all waste generated, which makes it difficult to dismantle solely via machine operations; therefore, intensive human labor is essential for the recycling of WEEE (Breivik et al., 2014). It is these coexisting characteristics of WEEE recycling (valuable, hazardous and labor-intensive) that compose the different attitudes and practices toward WEEE recovery and recycling in developed and developing countries.

In developed countries, strict and well-enforced environmental and occupational regulations (Coalition, 2002) and high labor cost (Breivik et al., 2014) have driven recycling operations to developing countries such as China, India, and Pakistan (Li et al., 2013; Yu et al., 2014). Despite being banned by the *Basel Action Network*, the proportion of illegally disposed waste can reach nearly 80% of all WEEE generated in developed countries (Hicks et al., 2005; Zhang et al., 2012). Therefore, compared to WEEE recycling, more attention is paid to the sound environmental management of the recovery process. Formal recovery networks have been built to

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prevent the illegal dumping and dismantling of WEEE, especially in the EU (European Union, 2011, 2012) and Japan (Aizawa et al., 2008; Ongondo et al., 2011).

In developing countries such as China, although the importance of environmental protection has been expounded on in recent years, the secondary resources extracted from WEEE remain of high interest for collectors and recyclers. And many conditions exist in developing countries that contribute to the income-generating opportunity of recycled materials, such as economic development restrictions and industrial structures dominated by low-end manufacturing, which is based on using nature resources as raw production materials (Hicks et al., 2005). Therefore, WEEE is still widely regarded as a valuable product, rather than a burden or responsibility (Yang et al., 2008), and the resources contained in it also offer a potential profit for informal collectors.

The basic characteristics of identification standards for informal collectors include being small and disadvantaged, having a low profit threshold, a high labor intensity, no registration, no tax, and no social welfare benefits (Chi et al., 2011; Ezeah et al., 2013; Wilson et al., 2006). Few specialized skills are needed in recyclables recovery, and recovery has become an important means for informal collectors to make a living (Asim et al., 2012; Matter et al., 2013; Wilson et al., 2009), making this “occupation” widespread in Brazil, Peru, India, China and some other developing countries (Babbitt et al., 2011; Chi et al., 2011; Gutberlet and Baeder, 2008; Kahhat and Williams, 2009). On the other hand, the informal collectors also have positive side effects related to their roles in the recovery system because they are extremely effective in the collection, reselling and dismantling of electronics (Williams, 2005; Williams et al., 2013). And the informal sector is also an important source of occupation and income. It is estimated that as much as 2% of the population in some developing countries survives by scavenging (Medina, 2000), and as many as 18 million people are engaged in waste recovery in China (National Development and Reform Commission, 2014; China Ministry of Commerce, 2014). Thus, the government could not explicitly prohibit it. Some researchers further suggest building an interface organization to connect the informal and formal sectors (Williams et al., 2013).

The above literatures have described the role of the informal sector in developing countries. But it is worth recounting that there is a major problem that has not been solved: why does the informal sector thrive well in developing countries. Unlike the formal collectors, who are supported by the government, informal collectors can only rely on themselves. However, formal and informal collectors often comfortably coexist in developing countries such as China, and there are even cases of informal collectors dominating the market. What type of market structure and what profitability, for both types of collectors, reinforce this stability?

2. Case study

Beijing, the capital and one of the most affluent cities in China, is used as a case study to address this issue. The resident population in Beijing exceeded 21 million in 2013, which generated a huge amount of WEEE (Beijing Statistical Bureau, 2014). According to Liu's research, the number of major household appliances in Beijing will reach 2.31 million units in 2015 (Liu et al., 2006). Meanwhile, as political center, China's central government, Beijing municipal government and enterprises of the Beijing office are gathered; therefore, there are a large number of appliances being used in offices that will also eventually increase the amount of WEEE. In addition, according to statistics, obsolete televisions (OTV) recycled by the dismantling companies was approximately 38.2 million units in 2013, which accounted for 92.0% of total WEEE formal dismantling amount, and this proportion was 83.2% in 2014

(China National Resources Recycling Association, 2014–2015). That means OTV is the main catalog of WEEE in China. Therefore OTV is employed as the case study in the paper.

Beijing has the most comprehensive reverse logistics system in China, characterized by an intertwined system of formal and informal collectors, which represents the dominant direction of the WEEE collection process. The collectors can be divided into four categories: peddler, collection station, distributor, and middleman. The first three are directly connected to the consumer and belong to the first-tier of collectors. The middleman, or the second-tier collector, is who gathers the WEEE recovered by the first-tier collector and transports it to the recyclers (including the dismantling company and the backyard recycler). The characteristics of the four types of collector are described as follows.

The peddler exhibits strong cohesion as a family unit. The man often goes door-to-door and transports the WEEE by tricycle, while the woman maintains a fixed stall in the residential community for consumers consulting recovery prices. There are no fixed costs for the peddler, and peddling activities are flexible enough to escape the supervisory and regulatory framework, which makes peddlers the primary type of informal collector in China.

The collection station is jointly set up by the government and the main collection companies and is leased to the collector at a low price. The collection station is supervised by several departments, including the commercial bureau, the traffic management bureau, and the municipal commission, and is required to pay taxes and administrative fees (Beijing Municipal Commission of Commerce, 2006). Moreover, the van is their main means of transportation because the tricycle is banned by the government. Therefore, the collection station should be included as a formal collector.

The distributor uses an existing sales network to recover EEE by means of the “old for new” trade model organized by the government or a volunteer company. China's government implemented this model from 2009 to 2011, and trading in one of the major household appliances listed in the program reduces the new EEE price by 10% (Chung and Zhang, 2011). The program was deemed such a success that distributors became the major collectors of WEEE during this period. However, government stopped funding the program in 2012, because it would cause a huge financial deficit. The “old for new” trade model now exists only through volunteer companies. Distributor recovery is interrelated with EEE sales and is thus closely monitored by the government; therefore, distributor belongs to the formal collector.

The middleman can be divided into the main collection companies and the self-employed. The former were state-run material recovery companies before the early 1980s (Wilson et al., 2009). After the Reform and Opening-up Policy, all of these companies shifted to privately owned ones under market principals (Zhang and Wen, 2014). There are currently 22 main collection companies dispersed in each district of Beijing, each of which is closely monitored by the commercial bureau and therefore belongs to the formal collector category. However, according to our survey, WEEE recovery is not typically included in the main collection companies' business in Beijing, which is probably because self-employed middlemen squeeze them out of the market. Although some of the self-employed middlemen could obtain a business license, violations are still prevalent such as the unauthorized replacing or dismantling of valuable components (Zhang et al., 2012) or secretly sending WEEE to a backyard recycler which is the main source of pollution in recycling (Chi et al., 2011; Williams et al., 2008). Therefore, the middleman should be included as an informal collector.

Recovery is an intermediate link in the obsolete-disposal chain; its raw material is derived from consumers. Whether consumers submit WEEE and which collector they choose are directly related to the structure of the recovery market, while the recyclers and the

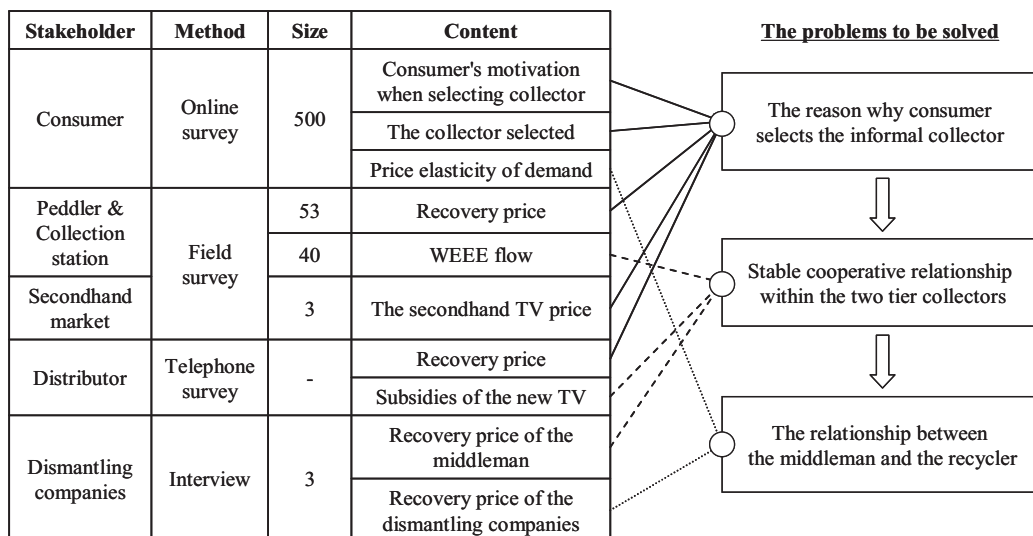


Fig. 1. The corresponding relationship between the survey content and the problems to be solved.

secondhand market, connecting with collectors downstream, are the main profit sources.

The four types of collectors, the consumer, and the secondhand market have to be evaluated as follows to address the issue raised in section 1: (1) whether the services provided by the first-tier collector suit the motivations of the consumer determines the consumer's choice of collector when submitting WEEE. The matching degree should be analyzed to explain the reason why waste recovery can operate under market principals and why the informal collector can thrive in China. (2) The stable cooperation among tier two collectors should be analyzed to discover the main source of profits for the first-tier collectors. (3) The game between the middleman and the recycler should be analyzed to explain why the formal and informal collectors can comfortably coexist in developing countries. (4) A new policy option should be proposed to remove informal collectors relying on the profitability of all the collectors.

3. Methodology

3.1. Questionnaire survey

Due to the significant differences between the objects in the survey, the corresponding survey methods and contents are designed according to their characteristics. The detailed questionnaire survey is shown in the Supporting information. However, the middlemen and backyard recyclers were reluctant to participate in the survey. That is because per unit profit of them is low but the quantity of recovered waste is high. In another words, there is a keen competition between them. Therefore, they are afraid to reveal the true recovery price even if they will get a certain fee for the survey. Therefore, we can only use the secondary data collected from the dismantling companies to approximately replace firsthand data on middlemen and backyard recyclers. Six objects, which are shown in Fig. 1, are employed to collect the price of the WEEE and the status quo of its reverse logistics system.

3.1.1. Survey on the consumers

Online survey (<http://www.sojump.com>) is used to obtain the motivations behind consumers selecting collectors, and 30 random households were selected as a sample in Aug. 2014. The test results show that the price, convenience and canonicity (canonicity means whether the collector is formal, because the informal collector may have bad credit history and may even rob the consumer) that a

collector could provide are the main influencing factors, which is similar to Chung's results from the study of Hong Kong (Chung et al., 2011). Therefore, the author designed the questionnaire, and 619 households were selected randomly with OTV to be submitted for collection was selected to participate in an online survey from December 2014 to January 2015. And 500 valid questionnaires were received. Beyond the basic questions such as income and age, four questions were designed, which is shown in the Supporting information. The first question is the same as the test above, and the three main factors are given as answer options. The second question asks about the size of the OTV and the corresponding minimum acceptable price the consumer is willing to accept. The third question asks which type of collector will be selected to submit your WEEE to, and six alternatives (distributor, peddler, collection station, hibernation, donation and discard) are given as answer options on the basis of the status quo in China. The private repairer and the moving company are included in the peddler option because the choice of a downstream collector is not under government supervision and is very similar to the peddler. The final question is a simulation hypothesis: if the price of the OTV increased by 10 percent (such as 13 RMB Yuan, 1 US dollar ≈ 6.365 RMB Yuan) would you retire the TV earlier?

3.1.2. Survey on peddlers and collection stations

Due to the similar scope of business, the same questionnaire was designed to obtain the material flow of the obsolete EEE, which is shown in Supporting information. One is the average price of each OTV size and the other is the downstream stakeholders and the corresponding proportion. Students from Beijing University of Technology were employed to implement the field survey in different residential areas from July to August in 2014. The survey received a total of 93 valid respondents, including 53 peddlers and 40 collection stations.

3.1.3. Survey on secondhand markets

Three big markets, namely Zhongshang Hezhong Flea Market, West Fifth Ring Flea Market and the Meidu Likang flea market were surveyed to get the retail price of each size of OTV.

3.1.4. Survey on dismantling companies

Three business executives from GEM High-Tech Co., Ltd., Xiangyu Renewable resources Technology Co., Ltd., and Huaxin Green Spring Co., Ltd. were interviewed respectively in July and

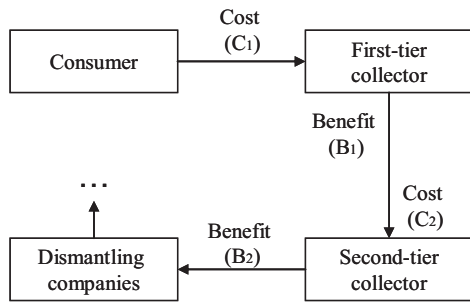


Fig. 2. Multi-agent cost-benefit analysis.

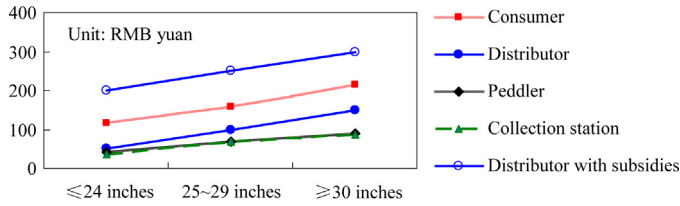


Fig. 3. The gap between the recovery prices with the consumer's minimum acceptable price.

October 2014, and January 2015 and their recovery prices and the main problems which may exist in the OTV recovered from middlemen were obtained. In addition, the secondary data of the recovery price of the middlemen and the backyard recyclers were also provided by the dismantling companies.

3.2. Multi-agent cost-benefit analysis

A cost-benefit analysis is an important technique for calculating and comparing the costs and benefits of a project, decision or government policy. As shown in Fig. 2, the consumer, first-tier collector, second-tier collector, and dismantling company are sequentially located in one industrial chain, which means the benefit to the upstream stakeholder is an important part of the cost to the downstream one. A multi-agent cost-benefit analysis method consisting of three steps is designed to calculate the profit of each collector. (1) The first step is determining the possible trading process in the reverse logistics system. (2) The second step is determining the scope of the cost and benefit to each collector. The cost should at least include the price of the OTV and other expenses necessary to guarantee a smooth progress of recovery, such as a transit fee, storage charge, tax, and staff costs. The benefit should include the resale revenue and any additional revenue. (3)

The third step is calculating the profit margin using the formula $P = \Sigma B - \Sigma C$, where P is the profit, B is the benefit, and C is the cost.

4. Results and discussion

4.1. The reason why the consumer selects the informal collector

4.1.1. The reasons for the formation of the recovery market

The necessary condition for the formation of a traditional market is that the price set by the distributor must be higher than the consumer's minimum acceptable price. As shown in Fig. 3, the recovery prices of collection stations and peddlers are very similar. Also, they are both lower than that of the distributors. In addition, only the price of the "distributor recovery with subsidies" (including the price that the distributor gives to consumer for recovering WEEE and the subsidies given by the government reducing the new EEE price by 10%) is higher than the consumer's minimum acceptable price. Otherwise, consumers prefer storing and waiting for a higher recovery price to submit their OTV. A total of 12% of the respondents in the survey choose hibernation, although the proportion was previously much higher according to Yang's survey (Yang et al., 2008).

However, as is shown in Fig. 4, over half of the OTV in Beijing are recovered by collection stations and peddlers. This means a great difference exists between the recovery market and the traditional market. Service is also an important factor in a consumer's decision-making. Additionally, the consumer becomes the seller in the recovery market. According to the loss aversion theory, the endowment effect will lead the consumer to raise the expected price (Kahneman and Amos, 1984). However, when compared with income and the sales price of the new TV, the recovery price is much lower. Residents are not sensitive to OTV recovery price changes and will thus typically easily accept it.

4.1.2. The collector's ability to match the demand of the consumer

(1) The motivation when the consumer selects a collector

As mentioned in Section 3.1, price, convenience and canonicity are the main factors influencing consumers' motivations when consumer selects a collector. In particular, among all of the respondents, 43.2% of them chose the price as decisive factor, 39.0% chose the convenience, and only 17.8% chose the canonicity. It can clearly be seen that collectors who provide higher prices and more convenient service are favored by consumers.

In order to verify whether the consumer's motivation will change along with economic development, the survey results are divided into three parts on the basis of consumer income. The low-income group is defined as those people whose monthly family income is lower than 8000 RMB Yuan (about \$1290 USD), which accounts for 34% of the results. If the monthly family income was

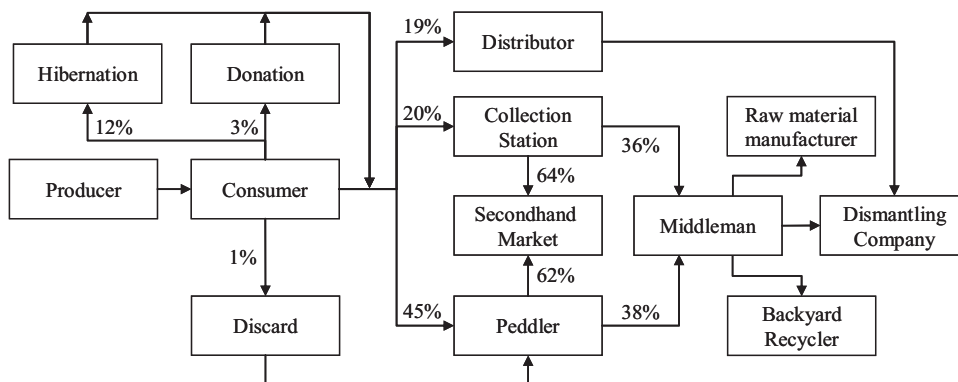


Fig. 4. Material flow of WEEE reverse logistics in Beijing.

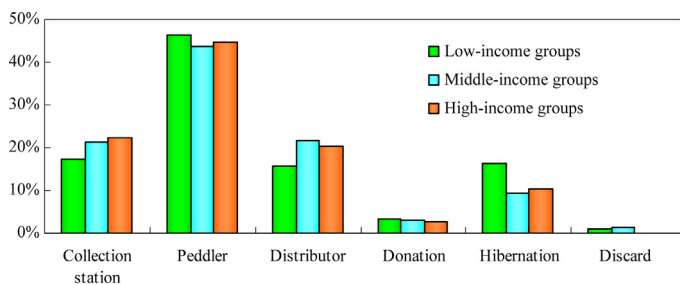


Fig. 5. The selected collector of each income group.

over 12,000 RMB Yuan (about \$1934 USD), they were classified into the high-income group, which accounts for 32% of the study. If the monthly family income falls between these limits, then they are considered to be in the middle-income group. As shown in Fig. 5, changes in consumers selecting a collector to submit their OTV do not really differ among the different income groups, and the extreme deviations in the fluctuation are less than 10%. In particular, the peddler is consumer's highest frequency choice for each income group, and the extreme deviation is only 2.7%. Thus, if the existing regulation policy does not shift, the preferences of the consumer will not change along with movement on the income ladder, which means that price and convenience will continue to dominate the consumer's motivations in the future.

(2) Comparative analysis of the services provided by the collector

The price factor. As shown in Supporting information, the recovery price of the distributor is the highest (when compared with other first-tier collectors), and the subsidy on the new TV is equivalent to a raise in the recovery price. However, this model is based on the premise that the consumer has to purchase a specific TV. Moreover, as the government has stopped the program, this model is not suitable for each brand and type of TV, which limits its scope of application. If the consumer does not fit the requirements for the "old for new" program, the peddler or the collection station is their only choice. Although both the peddler and the collection station have similar scopes of business, the peddler is more flexible in terms of bargaining and the recovery price is relatively higher, which may be attributed to two reasons: first, peddlers do not have to pay staff salaries, store rents, taxes, or transportation costs. Second, there is no principal-agent relationship or complex profits distribution for the peddler.

The convenience factor. The distributor often recovers the OTV when delivering new TVs. Distributors require that the consumer book their delivery/recovery time in advance, and having a long waiting time is typical; for example, the distributor can only promise to recover the OTV within 24 h downtown or within a week in rural areas. However, the OTV can be recovered by a peddler or a collecting station at almost any time. Compared with the collecting station, peddlers can provide more convenient services. The combination of moving and fixed recovery options dramatically reduces the search cost for consumers. Furthermore, peddlers can cover all of the communities in Beijing, which cannot be achieved by a collection station because the infrastructure cost of building a collection station is approximately 40,000 RMB Yuan (Wei, 2014; Adama, 2012).

The canonicity factor. The distributor is closely monitored by the government and can directly connect the consumer to a formal dismantling business; therefore, the canonicity factor of the distributor is optimal. Although the collection station is also a formal collector, it operates under a contract system that empowers it to choose the downstream collector. The informal middleman is likely to be their downstream choice, thus compromising their canonicity advantage. The peddler, however, is not controlled by the

government and may cooperate with backyard recyclers, which results in the worst canonicity score of all of the collector choices. Moreover, there is a potential risk of burglary owing to the liquidity of a peddler, which also may affect a consumer's choice.

(3) Analysis of the recovery market structure

The consumer's motivation compared with the collector's services is summarized in Table 1. The distributor is the consumer's first choice, owing to its very high recovery price. However, the scope of its application is narrow. The remaining market share is dominated by peddlers, with 45% of the OTV being submitted to them for a higher price and more convenience. Finally, 20% of the market share goes to the collection station, as it can provide for those consumers who prioritize canonicity.

4.2. The stable cooperation within the two tier collectors

Unlike the diversity demand of the consumer, profitability is the only goal of the collector. If there is no policy intervention, the recovery price of the downstream stakeholder will determine the material flow of the OTV. Excepting the distributor who delivers the OTV to a dismantling company, there are diverse downstream collectors from which first-tier collectors can choose. As shown in Fig. 4, 62% of the OTV are delivered to the secondhand market by peddlers, while the remaining 38%, which is of poor quality and cannot be reused, are delivered to the middleman. A similar situation also applies to the collection station.

4.2.1. Secondhand market: expanding the profits of the first-tier collectors

A TV has both resource-value and use-value. The use-value is much higher than the resource-value, for example the sales price of a new TV is much higher than that of an OTV which has basically lost its use-value. The secondhand market can restore the use-value and effectively raise OTV prices by replacing damaged parts or refurbishing their appearances. Meanwhile, the prices of second-hand products are much lower than that of new ones, and the low income groups are also willing to buy them (Williams et al., 2013). Although the sellers surveyed in the three secondhand markets were reluctant to tell researchers the exact recovery price of an OTV, the OTV resale price is marked up by more than triple the recovery price of a peddler or a collection station, which provides adequate profit margins for the first-tier collectors. On the other hand, the first-tier collectors provide an adequate OTV supply to the secondhand market, which reduces search costs and expands seller's choices. Thus, a mutually beneficial partnership is formed between first-tier collectors and secondhand market sellers.

4.2.2. Middleman: stable downstream demand of the first-tier collectors

Considering the high standard unit transportation costs and the restrictions in terms of conveyance, the transportation radius is small for peddlers and collection stations, and only a handful of first-tier collectors can directly deliver the OTV to a recycler. However, a middleman can establish a link between the first-tier collectors and recyclers, solving the problem of transport costs and radius and ensuring that first-tier collectors are not menaced from the "rear".

4.3. The relationship between the middleman and the recycler

4.3.1. Backyard recycler: expanding the profit of the middleman

In terms of the national layout, it is easy for formal dismantling companies to create regional monopolies. However, they are not the only choice of middleman. The competition from informal backyard recyclers limits the monopoly power of the dismantling companies, thereby increasing the middleman's bargaining power.

Table 1

The collector's ability to meet the demand of the consumer.

Stakeholder	Consumer	Peddler	Collection station	Distributor
Price	High	Middle	Low	Very high
Convenience	High	High	Middle	Low
Canonicity	Low	Low	Middle	High
Scope of application (requirement)	–	High	Middle (locate in the corresponding resident community)	Low (match the requirement of "old for new")
Market share	–	Dominate	A few	First choice

Additionally, the survey results show that a few valuable components inside the delivered OTV are often missing or substituted for cheaper ones. This may be because China's government only regulates the minimum standards of the total weight and basic components of the dismantled OTV, which are needed to obtain the fund subsidies; it does not, however, require the content and proportion of high value components such as the deflection coil, degaussing coil, or power supply wire (Ministry of Environmental Protection of China, 2014). This loophole in the law is heavily used by the middlemen. Some of the OTV were first transported to a raw material manufacturer for substitution of high value components and then delivered, defective, to a formal dismantling company to improve the profit margins of the middleman.

4.3.2. WEEE processing fund: intensifying the confusion of the recovery market

China implemented the "waste electrical and electronic products processing fund" in 2012: 13 Yuan per TV is collected from the producer and is used to subsidize the formal dismantling companies 85 Yuan per TV, which is approximately 4.5 times higher than the fund collected (Yu et al., 2014). However, this fund is not completely used by the dismantling company, and is mostly shared with the WEEE collector.

It can be seen from the recovery price of the dismantling enterprises, for example, that the price of a 21-inch OTV was less than 20 Yuan in 2011 and was nearly 80 Yuan in 2014, an increase of as much as triple the originally measured price. This increase is attributed to the serious overcapacity of the dismantling companies. China's WEEE dismantling capacity is more than 100 million units, but actual dismantling occurred at less than 50 million units in 2013 (China Household Electric Appliance Research Institute, 2014). Formal dismantling companies urgently need a stable supply of WEEE, and the only way to solve this problem is to increase the recovery price of WEEE. Thus, the fund is shared with middlemen who are also willing to buy the OTV from first-tier collectors at a higher price.

Furthermore, the recovery price of the first-tier collector has not significantly risen in recent years, which means that the fund did not trickle down to consumers but was primarily distributed through the recovery process. This is because raising the collection price does not significantly increase the total amount of OTV. It can be seen from the research results that if the price of the

OTV increases by 10%, only 0.8% of the respondents will choose to retire the TV earlier than they would have otherwise. Although the collection price is a major factor influencing the consumer in selecting a collector when replacing an OTV, it cannot accelerate the retirement of an in-use TV. This may be due to the major gap between the collection price of the OTV and the sales price of a new TV. Regardless, although consumers may choose temporary hibernation or donation, the OTV will eventually enter the recovery market. This means that consumers have rigid requirements for submitting an OTV and that there is no reason for the collectors to raise the recovery price in the long run. The fund is mostly shared with WEEE collectors, which enhances their profitability. As a result, more informal collectors are willing to enter the recovery and recycling industry, intensifying the chaos in the recovery market.

4.4. Cost-benefit analysis of collectors

4.4.1. Cost and benefit of collectors

The cost of the collector includes the recovery cost, staff salary, transit fee, store rents and taxes, which is shown in Table 2 (details in Supporting information).

The benefits from the secondhand market and the downstream collector are both discussed in Section 4.1.2 and are shown in Fig. 6. The middleman also has other benefits, and the survey results show that 5% of the OTV have their copper substituted for a cheaper metal. For example, the polarization coil and the wire inside the OTV are made of copper; some middlemen replace them with aluminum wires which are much cheaper. Then they sell the substituted OTV to recyclers at the regular price (because these wires are inside OTV and difficult to identify), and sell the copper to raw material manufacturers for other benefits. A 21-inch OTV is taken as an example: the weight of the OTV is 22 kg/unit (Ministry of Environmental Protection of China, 2015), and 8 wt% is copper (Dodbibia et al., 2008). As is shown in Fig. 6, if the copper is replaced with a cheaper metal, the profit could reach up to 30 Yuan/unit.

4.4.2. The profitability of the collector

The average profitability of the collector is shown in Table 2. The peddler's profitability is significantly higher than the other three collectors, which further intensifies the price advantage and allows more room for price negotiations with consumers. There is

Table 2

The average profitability of collectors (a. the figure before the "+" is the transit fee to bring the OTV from the upstream stakeholder, while the figure after the "+" is the transit fee for transporting the OTV to the downstream stakeholder).

Stakeholders		Scope of the cost (Yuan)					Scope of the benefit (Yuan)			Profitability per unit (Yuan)
		Recovery cost	Staff salary	Transit fee ^a	Store rent	Tax	Benefit from the secondhand market	Benefit from the downstream collector	Other benefit	
Formal collector	Collection station	36.8	14.9	0+4	2	0.5	75	65	–	13.2
	Distributor	50	14.9	10+3	–	0.8	–	80	–	1.3
Informal collector	Peddler	42.8	–	–	–	–	75	65	–	28.4
	Middleman	65	3.7	0+3	2	0.2	–	80	1.5	7.6

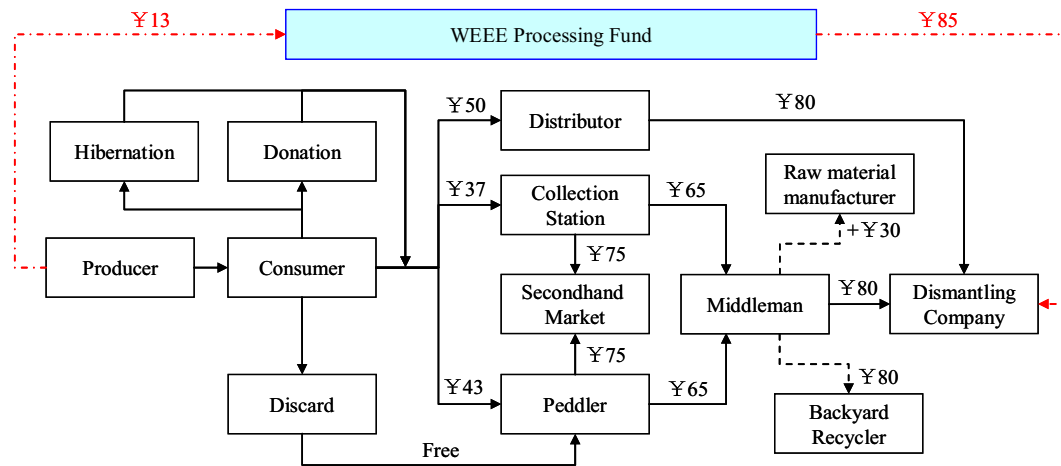


Fig. 6. Cost flow analysis of the OTV recovery process in Beijing.

also some profit for the collection station, although its competition ability is obviously lower than that of the peddler. The profit of the middleman is lower than that of the peddler and the collection station, however, the quantity of the recovered OTV is higher, which improves the total margins. For the distributor, the profit is only 1.3 Yuan/unit, which dramatically reduces one's enthusiasm for recovery.

4.5. Public policy to improve the regulation of OTV recovery

It is difficult to develop the regulated recovery market while relying on China's current WEEE processing fund. In order to squeeze informal collectors out of the recovery market, it is suggested that the government make full use of the existing collection stations and main collection companies to replace informal peddlers and middlemen because of the correspondence effects of the two groups. Price, convenience and canonicity are the three main influential factors behind a consumer's choice of collector, while profit is the only goal of the collector. And the formal recovery market can be stabilized only when the demands of the two stakeholders (consumers and collectors) have been simultaneously met.

A new subsidy rule of the WEEE processing fund is employed to promote the profitability of formal collectors. As shown in Fig. 7, in addition to the current fund system, an extra 40 Yuan fund could be charged by the government when consumers buy a new TV. If we assume that the lifespan of the TV is six years and that the fund has an average yearly appreciation rate of 2%, then the fund will increase to more than 45 Yuan over the lifetime of the TV. A recycling coupon is needed, which refers to that in Japan (Panasonic Eco Technology Center, 2001). When the OTV is transferred from a collection station to a main collection company and further to a dismantling company, each collector should stamp the coupon with his/her official seal to prove that the OTV was recovered by him/her. Only when the coupon, stamped by the formal collectors, is aggregated to the dismantling company and handed over to the WEEE processing fund center will the subsidies of 40 Yuan, 5 Yuan, and 85 Yuan be distributed to the collection station, the main collection company, and the dismantling company, respectively.

Converse derivation is used to explain the reason why the fund system could achieve a formal recovery system. The main collection companies are willing to recover the OTV if the same profit (7.8 Yuan) as that of the informal middleman could be achieved. As shown in Fig. 7, less than 68 Yuan can be paid as the upstream

recovery price from the first-tier collector. Calculated by the same method, the collection station could pay less than 72 Yuan to the consumer for the OTV. Compared with the maximum acceptable price (71 Yuan) of the peddler, there is a greater price advantage for the collection station. Furthermore, although the informal middleman could pay a higher price than the main collection company to the collection station, if the collection station selects the middleman, they will lose the 40 Yuan subsidy, which will make the collection station unprofitable. The same reason is also appropriate for the backyard recycler. Therefore, the new subsidy can promote the profit of formal collectors and squeeze informal collectors out of the market.

However, although the price and canonicity factors can be achieved by the fund, convenience is also a key factor in the consumer selection of collectors. China is promoting the establishment of community service facilities, and the goal of their coverage is set at 90% of all communities in 2015. As a key development task of the service facility, the collection station will dramatically improve its convenience. Furthermore, with the development of the internet and the mobile internet, online booking services are becoming a new but fast-growing way to recover WEEE. For example, the YiFeiBao that has been tried relies on the application platforms of mobile phones; the web-based Gome shopping mall and Baidu online recovery station are also providing convenient services. Kahhat et al. also proposed the building of an e-Market for returned deposit, which is enabled by a radio-frequency identification device placed in the EEE to track information, monetary and product flows. If this vision can be implemented, WEEE will be recovered conveniently (Kahhat et al., 2008). The collection station is bound to be eventually integrated into the network platform. Consumers could then get their community services in the shortest amount of time without leaving their homes. Therefore, the consumer is likely to be willing to select the formal collection station in the near future.

Overall, the key reason why the fund could contribute to the development of formal collectors is that the consumer unity of money in different markets is unequal. The 40 Yuan collected from the consumer is only 1% of the TV price. However, when the fund is transferred to the recovery process, it almost doubles the recovery price of the collection station. Therefore, the new subsidy rules could deliver the fund from a less-sensitive market to a more-sensitive one, which improves consumer utility. Additionally, as seen from the cost flow of the OTV, the recovery price of the collection station increases by approximately 35 Yuan, which means that the actual cost that the consumers paid to the fund center is only 5 Yuan.

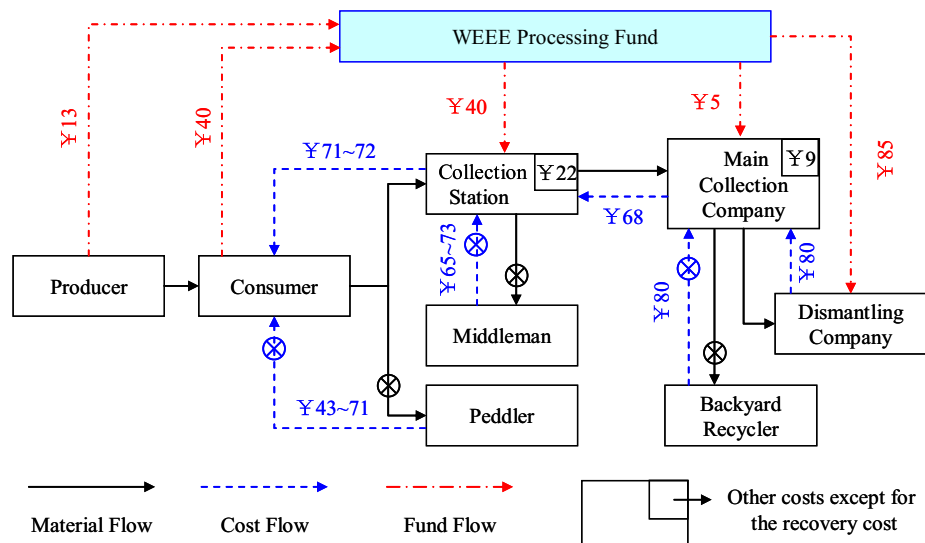


Fig. 7. The new subsidy rules of the WEEE processing fund.

5. Conclusion

Price, convenience and canonicity will affect the motivation of consumers when selecting a collector and the first two play leading roles. Distributors can provide the highest recovery price, but the scope of application is too narrow to fit all consumers. The remaining market share is dominated by peddlers, who provide a higher recovery price and more convenience.

Unlike the diversity demand of the consumers, profitability is the only goal for the collectors. The stable cooperation among tier-two collectors is formed by their profit-driven motivation. The secondhand market can expand the profits of the first-tier collectors, while the remaining OTV, which cannot be reused, is delivered to the middleman, ensuring that the first-tier collectors are not menaced from the “rear”.

The informal backyard recycler limits the monopoly power of dismantling companies, thereby increasing the middleman’s bargaining power. Meanwhile, the fund is mostly shared with the WEEE collectors, owing to the serious overcapacity of the dismantling companies and consumers’ rigid requirements to submit OTV. Therefore, the existing fund system improved informal collectors’ profitability, intensifying the chaos in the recovery market.

A multi-agent cost-benefit analysis is built to calculate collectors’ profitability. The peddler’s is significantly higher than the other three, which further intensifies their price advantage. The quantity of the OTV recovered by middlemen is higher, therefore improving the total margin. The distributor’s profit is only 1.3 Yuan/unit, which reduces the enthusiasm for recovery. Then, a new fund system is built to improve the regulation of OTV recovery. In order to make the formal collection station and the main collection company work, we suggest that the government charges an extra 40 Yuan fund when consumers buy new TVs and distribute it to formal collectors in order to exclude the informal collectors.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.resconrec.2015.12.004>.

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