An Empirical Analysis of the Impact of Multi-agent Recycling Behavior on Recycling Standards in Reverse Supply Chain

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Abstract

Recycling is the primary link in the reverse supply chain. Analysis of the multi-subject recovery behavior in the reverse supply chain can not only make up for the uncertainty in the recycling process, but also help to improve the economic and social benefits of the recycling industry. This article takes electronic products as an example,in the reverse supply chain system consisting of consumers, recyclers and manufacturers, the questionnaire analysis and statistical analysis methods were used to conduct an empirical analysis of the factors affecting the recovery of multi-subjects in the reverse supply chain. Research indicates: Consumer recycling behavior, recycler recycling behavior, and manufacturer recycling behavior have a significant positive impact on the construction of recycling standards.

Keywords

Reverse supply chain multi-agent, Recycling behavior, electronic products, recycling standards.

1. Introduction

The rapid development of industrial innovation and science and technology has increased people's dependence on the use of electronic products, and the speed of electronic product replacement and the shortened product life cycle have increased the number of discarded electronic products. At present, China has entered the peak period of scrapping of electronic and electrical products. According to the data of the Ministry of Industry and Information Technology, since 2015, the annual scrap of major electrical and electronic products in China has exceeded 200 million, become the world's largest producer of waste electrical and electronic products. For a huge number of discarded electronic products, although the innovative mode of electronic product recycling is constantly emerging, the recycling and processing of electronic waste in China still cannot build a standard recycling system, the recycling efficiency of e-waste has always been low, which has become an urgent challenge facing China and the world. The recycling of waste products is the primary link in the reverse supply chain. The standardization and standardization of the entire recycling process involved in the recycling have a great impact on the remanufacturing of remanufactured products. Therefore, in order to improve the recycling efficiency and recycling efficiency of waste electronic products,regulate the recycling market for waste electronic products, explore the construction of recycling standards for waste electronic products, in the reverse supply chain system consisting of consumers, recyclers and manufacturers, this article analyzes the influencing factors of the recycling behavior of these three subjects on the construction of recycling standards, in order to provide a corresponding basis for the future construction of electronic product recycling standards.

2. Research status at home and abroad

In order to study the recycling of waste electronic products, scholars analyze the recycling behavior of the main bodies of the reverse supply chain from different angles. Murply and Technical (2004) pointed out that Germany has passed legislation to clarify that manufacturers have to reduce the obligation to recycle materials in the production process, so that the scope of responsibility of producers is further expanded. Murply and Technical (2004) pointed out that Germany has passed legislation to clarify that manufacturers have to reduce the obligation to recycle materials in the production process, which further expands the responsibility of producers[1]. Jofre and Morioka (2005) studied the waste electronic product management systems in the United States, Japan, and the European Union. They found that although they have different divisions of responsibility, they all achieved environmental and economic benefits, and also clarified the role of consumers as recycling subjects in the management of electronic product recycling[2]. Kahhat R, Kim J et al. (2008) explored the US e-waste management system and designed a solution for the United States to ensure proper retirement options while establishing a competitive market for e-waste for recycling and recycling services[3]. Aizawa H, Yoshida H and Sakai SI (2008) proposed that Japan should consider the difficulty of the government in managing waste electronic products, the collection place of waste electronic products, and the feasibility of re-commercialization and ecological design of electronic products when formulating the Law on Recommodification of Household Appliances[4]. T Shinkuma and S Managi (2010) believe that serious environmental pollution in China and India is caused by incorrect recycling methods, so economic models are used to verify the effectiveness of the government's licensing policy for e-waste recycling companies, the results show that the licensing system can only function effectively if the e-waste disposer is responsible for selling the e-waste to the license holder[5]. Espejo D (2011) stated that the German e-waste collection group is based on the classification of product categories according to the product category of electronic and electrical equipment[6]. Viscusi W, Huber J and Bell J (2012) investigated the recycling situation of plastic water bottles, and the results showed that the change of recycling laws would indeed change the recycling behavior [7]. A Atasu and R Subramanian (2012) build a competitive model of profit design, consumer surplus, and collective and individual producer responsibility based on the manufacturer's product recycling law, it is concluded that the product recycling regulations under individual producer responsibility should be improved and the operating cost efficiency under collective producer responsibility should be improved to reduce the cost of recycling[8]. Toktay and Wassenhove (2013) established a recovery cost function based on recovery and recovery to study the impact of the recycling cost structure on the manufacturer's optimal recycling channel selection, the conclusions show that the cost-structure-driven manufacturer's sales and recycling volume to retailers determine the optimal recycling channel choice[9]. Itoh H (2014) studied the rare metals in waste electronic products and verified that Japan's “urban mining” facility can minimize the energy and reagents required for the pulverization/crushing, separation and purification of rare metals [10]. Yoshida F and Yoshida H (2014) analyzed and evaluated the Japanese home appliance recycling system from an environmental and economic perspective. The results show that Japan's home appliance recycling system achieves economic and technological balance through cost sharing, but further considers the transparency of recycling costs in the future. At the same time, reduce recycling costs and more effectively coordinate the recycling of small electronic products[11]. Atasu, K Toshiki, M Zhou and S Kunikane (2014) conducted a comparative analysis of WEEE (waste electrical and electronic equipment) recycling systems in China, Japan and Korea from the perspective of producer responsibility, the results indicate that producer responsibility should be introduced into the WEEE recycling system and that manufacturers are required to pay for the recycling costs of waste electronic products[12]. Zhang S, Ding Y et al. (2015) explored the progress of WEEE recycling in China around the legal, recycling and technical systems, it is believed that the relevant laws and legislation of WEEE management need to be kept in sync with the recycling technology, and the construction of a comprehensive recycling system can improve the recovery of WEEE [13]. Nelles M, J Grünes and Morscheck G (2016) introduced the new German Closed Loop Management Act, which introduces new treatment technologies for the recycling of waste based on the disposal of the responsibility assigned to the manufacturer and distributor of the product. The goal is to transform waste management into resource management and improve recycling capacity [14].

Lu Junhua (2013) introduced the processing fund system for waste electrical and electronic products in Germany, which stipulates that the German mobile phone and recycling system adopts a collective competition mode, and that importers and producers pay for electronic waste recycling[15]. Liu Yijun and Peng Fen (2013) show that the recycling of electronic products such as Germany and the United States and Japan require manufacturers to take responsibility for product recycling, recycling and final disposal, Among the German manufacturer uses environmentally friendly materials in the production design of the products, and provides information for the recycling enterprises, as well as product recycling or disposal[16]. Liu Huihui, Huang Tao and Lei Ming (2013) obtained the value recognition of consumers for refurbished products through the dual-channel recycling competition model and the government subsidies not only help to regulate the recycling channels, but also promote the classification and recycling efficiency of recycled products[17]. Yan Mengling and Liu Lingqi (2016) believe that Japanese companies are responsible for research and development of recycling technologies, operation and management of recycling equipment, public awareness of environmental protection, and waste transportation and disposal, In order to focus on environmental protection and improve their image, manufacturers have integrated environmental protection concepts into product design, developed resin materials for manufacturing ultra-thin TVs to improve re-use, and are working to reduce the content of harmful substances [19].

In summary, the existing literature is based on developed countries such as Japan, Germany, and the United States, from the perspective of laws and social practice, this paper discusses the recycling treatment methods and existing problems of electronic products, so as to construct the recycling treatment system or the factors that affect the recycling behavior of the supply chain. However, from the perspective of multi-agents in the reverse supply chain, the research on the recycling behavior factors affecting the construction of recycling standards, and the related literature on the standardization of electronic product recycling standards are few and far between. Therefore, this paper will empirically analyze the factors that affect the recovery criteria of the multi-subject recovery behavior in the reverse supply chain.

3. Research hypothesis

Consumers involved in the recycling process as the main actors, had many factors affecting recycling behavior. Lan Ying and Zhu Qinghua (2009) believe that in the recycling management of used household appliances, the main influencing factors affecting consumers' participation in electronic waste recycling are behavioral attitudes, subjective norms, service motives, economic motives and behavioral disorders[19]. Fang Qiaohong (2010) takes manufacturers as the research object and uses game theory to analyze the impact of consumers' environmental awareness on enterprise remanufacturing. It is believed that the improvement of consumers' environmental awareness can not only reflect the improvement of manufacturers' recycling rate. It will also directly reflect the increase in consumer demand for environmentally friendly products, which will enable manufacturers to obtain greater market space and actively invest in remanufacturing activities of recycled products [20]. Li Chunfa, Yang Qiqi and Han Fangxu (2014) analyzed the responsibilities of various stakeholders in the WEEE recycling network system based on stakeholder theory, the factors that drive consumers to recycle e-waste are recycling benefits, environmental and social responsibilities, and interest coordination strategies should be accomplished by raising awareness of conservation and environmental protection, choosing formal recycling channels, and purchasing green-designed electronics[21]. Liu Yongqing, Gong Qingming and Hu Yirun (2015) used AHP and MATLAB to verify the main influencing factors of consumers' participation in electronic waste recycling, the results show that economic motivation is the most important factor affecting the recycling of electronic waste, and plays a key role in recycling prices [22]. Wang Jianming and Zhao Qingfang (2017) constructed the value-emotion-behavior model hypothesis by using structural equation modeling. The results show that Taoist values can provide judgments and standards for individual behaviors, and help to stimulate the generation of environmental emotions in consumers[23].

Consumers are affected by different behavioral factors in the recycling process, and these behavioral factors have an important impact on the construction of electronic product recycling standards. Based on this, the author believes that in order to build a reasonable recycling standard system, it is necessary to consider the potential important factors in the consumer recycling behavior, so consumer recycling behavior is one of the main factors affecting the construction of recycling standards. Therefore, this article proposes the hypothesis Ha:

Ha: Consumer recycling behavior has a significant positive impact on recycling standards

Tang Shaoyi (2012) proposed that the large-scale development of e-waste recycling should establish formal recycling channels, improve laws and regulations and market mechanisms to achieve economic policy and value-driven drive the development of stimulus recycling market[24]. Zhang Yuchun and Guo Ning (2014) constructed a system dynamic model of a closed-loop supply chain consisting of manufacturers, retailers and recyclers to explore the impact of environmental policy indices on closed-loop supply chains, the study found that the environmental policy index affecting the behavior of recyclers has a more significant impact on the bullwhip effect of the ordering rate of members at all levels[25]. Zhu Dan (2014) proposed that the construction of a professional recycling logistics system should take into account the value of each participating entity in the supply chain system[26]. Zhou Xu, Zhang Bin and Wang Zhaohua (2015) based on the empirical analysis of grounded theory and questionnaires,the main factors that affect the company's responsibility to fulfill e-waste recycling include the company's recycling costs and environmental awareness, government policies and regulations, consumer environmental awareness and participation in recycling[27]. Lingjiang, Zheng Yang, etc. (2016) believe that the recycling of electronic products in China has problems such as unclear powers and responsibilities between producers and recyclers, unclear fund subsidy conditions, and irregular recycling channels, which affect the construction of waste electrical and electronic products management systems[28].

Recyclers are an indispensable part of the reverse supply chain system and a practitioner of recycling standards. Therefore, the construction of recycling standards must consider the main influencing factors that affect recyclers' recycling of electronic products. Therefore, this article proposes the hypothesis Hb:

Hb: Recycler recycling behavior has a significant positive impact on recycling standards construction

Wang Fang (2008) formulated the evaluation indicators for recycling of used household appliances in consideration of the technology, cost, environmental protection and operability of electronic waste recycling, and assigned responsibility for the recycling system[29]. Mu Yanfen, Nie Jiajia and Ma Zujun (2015) believe that in the case of manufacturers actively recycling electronic waste, manufacturers are fully recycling electronic products that are subject to recycling revenue, recycling costs and consumer sensitivity to remanufactured products[30]. Tian Qinghua, Li Yu et al. (2015) introduced the technological advancement of manufacturers in extracting precious metals from recycled electronic products[31]. Liu Guangfu, Liu Wenxia and Zhang Shibin (2016) consider the maximization of ecological benefits, it is believed that manufacturers who are the first to implement e-waste can get more benefits, and when manufacturers get the advantage of remanufacturing cost, both consumers and manufacturers can benefit[33]. Zhu Yongming, Zhang Hao, et al. (2017) argue that a supply chain system that consists of retailers and manufacturers, manufacturers have a competitive advantage over retailer recycling under certain conditions[34].

With the implementation of the extension of production responsibility, manufacturers are also responsible for recycling. As a producer, manufacturers should consider the range of issues they face when recycling products. Therefore, the author believes that the manufacturer's recycling behavior is a major factor in the study of the impact of the construction of recycling standards. Therefore, this article proposes the hypothesis Hc:

Hc: Manufacturer recycling behavior has a significant positive impact on recycling standards construction

4. Questionnaire and inspection

4.1 Questionnaire design

At present, by reading a large number of domestic and foreign literatures on the recycling of electronic products, it is found that most scholars the developed countries such as Japan, Germany, and the United States have studied the recycling of electronic products from the perspective of laws, regulations, and social practices. Therefore, this article extracts the factors affecting the multi-subject recovery behavior of the reverse supply chain from these documents, and the potential variables as the structural model are summarized, so as to design the items of the questionnaire based on the multi-agent behavior of the reverse supply chain. In table 1

Table 1 The theoretical variable system constructed by the multi-agent behavior of reverse supply chain to the recycling standard

Potential variable	Observation variable	Item design
Recycling standard build	Product recycling standard(A1)	In the process of building recycling standards, product recycling standards can improve the recovery rate and utilization efficiency of recycled products.
	Recycling classification standard(A2)	In the process of building recycling standards, recycling taxonomy can maximize resource utilization efficiency throughout the life cycle of electronic products.
	Recycling inspection standard(A3)	In the process of constructing recycling standards, recycling inspection standards can enable the detection of hazardous substances and improve environmental protection.
	Recycling pricing standard(A4)	In the process of constructing recycling standards, recycling pricing standards meet the interests of all participants.
	Recycling technology standard(A5)	In the process of building recycling standards, recycling technology standards can reduce the amount of e-waste and develop environmentally friendly products.
Consumer recycling behavior	Economic incentive (B1)	Consumers can get some financial compensation for participating in electronic product recycling
	Responsibility concept(B2)	Consumers participate in electronic product recycling to enhance social responsibility and self-fulfillment
	Self-realization(B3)	Consumers participate in the recycling of electronic products to enhance environmental awareness and ability
	Ecological care(B4)	Consumer participation in the recycling of electronic products is affected by environmental protection policies or organizational propaganda？
	information feedback(B5)	The extent to which consumers provide information on recycled products to the recycling of electronic products
	Recycling method (B6)	The enthusiasm of consumers to participate in the recycling of electronic products is affected by the way of recycling services.
Recycler recycling behavior	Recovery price mechanism(C1)	Recyclers consider the market price and recycling cost of electronic products when recycling electronic products.
	Product catalog(C2)	Recycling companies' reasonable and effective classification of recycled electronic products can improve recycling efficiency
	Recycling value(C3)	Recyclers understand the value of recycled products and the degree of product damage when recycling electronic

		products.
	Recycling channel construction(C4)	Recyclers improve recycling efficiency by building diversified recycling channels
	Legal policy(C5)	Recyclers understand the recycling laws and regulations and policies when recycling electronic products
	Dismantling difficulty (C6)	Time-consuming and laborious process for recyclers to recycle electronic products for disassembly and inspection
Manufacturer recycling behavior	Production cost savings(D1)	Manufacturers can recycle electronic products to reduce production costs
	Technical research and development capabilities(D2)	The level of recycling technology can influence the enthusiasm of manufacturers to participate in the recycling of electronic products
	Product eco design(D3)	Manufacturer's R&D personnel consider green raw materials in the process of product design
	Collective competition model(D4)	The collective competition mode can realize the construction of WEEE recycling system and the full competition of recycling industry
	Producer responsibility(D5)	Manufacturers'electronic product recycling responds to producer responsibility extension
	Corporate environmental image(D6)	Manufacturers'electronic product recycling can enhance the company's own image

4.2 Exploratory factor analysis

In general, the questionnaire needs to measure the use of content validity and structural validity. Among them, content validity refers to the suitability and logical consistency of the items and the measured variables. The questionnaire used in this study is based on the literature review to show the relationship between variables or the association construction, and according to the results of the pre-survey, the wording and expression of the item are further revised and improved. Therefore, the scale can be considered to have the content validity of the requirement. The focus of this artile is to study structural validity, which is the ability of a project to measure a measured variable, this study used the exploratory factor analysis (EFA) test to verify the structural validity of the scale.The exploratory factors need to be analyzed by KMO test and the factor load of each item. The general criterion is KMO>0.7, and the factor load is greater than 0.5. However, due to the initial analysis of the 23 influencing factors, the factor load of B6 and D6 is less than 0.5, so the two items are deleted, and the remaining items continue to be exploratory factor analysis,the results are as follows.

The KMO test is to reflect whether a set of observation data is suitable for factor analysis. When KMO>0.9, it indicates that it is very suitable; when KMO>0.8, it indicates that it is suitable; when KMO>0.7, it indicates that the factor analysis is general; when KMO>0.6 , it indicates that it is not suitable for factor analysis; when KMO < 0.5, it is very unsuitable for factor analysis. The exploratory factor analysis using SPSS 23.0 was performed on the scales for KMO and Bartlett's spherical tests. The results are shown in Table 2 below.

From Table 2.3 above, KMO=0.931 is obtained, which is greater than 0.9, and Bartlett's spherical test

Sampling enough Kaiser-Meyer-Olkin metrics		.931
Bartlett's spherical test	Approximate chi square	5179.279
	df	276
	Sig.	.000

value is significant (Sig.<0.001), indicating that the questionnaire data is in good agreement with the premise requirements of factor analysis. Therefore, the principal component analysis method is used to continue the factor extraction analysis, and the common factor is extracted with the feature root greater than 1 as the factor, and the factor is analyzed by the maximum orthogonal rotation of the factor rotation. The analysis results are shown in the following table 3

Table 3 Composition matrix after rotation

Item	Ingredient			
	Recycler recycling behavior	Recycling standard build	Manufacturer recycling behavior	Consumer recycling behavior
C1	0.840			
C3	0.826			
C2	0.805			
C6	0.804			
C5	0.802			
C4	0.721			
A4		0.875		
A1		0.847		
A2		0.824		
A3		0.821		
A5		0.813		
D1			0.870	
D2			0.842	
D3			0.801	
D5			0.800	
D4			0.749	
B1				0.854
B2				0.816
B5				0.816
B3				0.802
B4				0.797
Total	4.158	3.824	3.603	3.574
Percentage of variance	19.801	18.210	17.157	17.020
accumulation %	19.801	38.011	55.168	72.189

It can be seen from Table 3 that the factor analysis results have a total of four factors, and the total explanatory power has reached 72.189% and more than 50%, indicates that the four factors selected are well represented. Moreover, the factor load of each measurement item is greater than 0.5, and the cross load is less than 0.4. Each item falls into the corresponding factor, indicating that the scale has good structural validity.

4.3 Reliability and validity test

Reliability Analysis uses Cronbach's Alpha reliability coefficients to check the consistency of the questionnaire study variables across the measurement items. Devellis (1991) believes that the Cronbach's Alpha coefficient must be greater than 0.7 for good reliability[34].

The collected data were tested for reliability using SPSS21.0 and AMOS 17.0 statistical software. The Cronbach’s Alpha coefficient was obtained in Table 4.

Table 4 Reliability Analysis

Variable	Number of items	Cronbach's Alpha
Consumer recycling behavior	5	0.897
Recycler recycling behavior	6	0.908
Manufacturer recycling behavior	5	0.899
Recycling standard build	5	0.925

As can be seen from Table 2.5, the Cronbach's Alpha coefficients constructed by consumers' recycling behavior, recycler recycling behavior, manufacturer recycling behavior, and recycling standards are 0.897, 0.908, 0.899, and 0.925, respectively, all of which are greater than 0.7, indicates that the variable has good internal consistency reliability.

5. Empirical analysis of the construction of recycling standards for multi-agent recycling behavior in reverse supply chain

5.1 Model hypothesis test

The AMOS 17.0 statistical software was operated, and the model path coefficients were obtained as shown in Table 5. Observed, the manufacturer's recycling behavior had a significant positive impact on the recovery standard construction ($\beta=0.261$, $p<0.001$), and the Ha hypothesis was established. Recycler recycling behavior has a significant positive impact on the recovery standard construction ($\beta = 0.243$, $p < 0.001$), and the Hb hypothesis is established. Consumer recycling behavior has a significant positive impact on the recovery standard construction ($\beta = 0.221$, $p < 0.001$), and the Hc hypothesis is established.

Table 5 Path Coefficients of Multi-agent recycling behavior of reverse supply chain

Path			Standardization coefficient	Non-standardized coefficient	S.E.	C.R.	P	Hypothesis
Recycling standard build	<---	Consumer recycling behavior	0.261	0.254	0.061	4.144	***	establishment
Recycling standard build	<---	Recycler recycling behavior	0.194	0.193	0.068	2.841	0.004	establishment
Recycling standard build	<---	Manufacturer recycling behavior	0.278	0.261	0.060	4.313	***	establishment

5.2 Analysis of model results

The indicators that affect manufacturers' recycling behavior are production cost savings, technology research and development capabilities, producer responsibility, product eco-design, and collective competition models.

Therefore, the recycling standards for building electronic products should take into account the impact of consumer recycling behavior, recycler recycling behavior, and potential variables in the manufacturer's recycling behavior. Consumer recycling behavior mainly affects the construction of recycling standards through economic incentives and responsibility concepts. Recyclers in the recycling process mainly consider the factors of the recycling price mechanism and product catalog classification, which further affect the construction of recycling standards, Manufacturers mainly recycle their own products, so they consider the remanufacturing of recycled products when recycling, which is limited by production cost savings and technology research and development capabilities. Since the recycling standards are also built for the recycling of recycled products, the manufacturer's skill level and cost savings also potentially affect the construction of recycling standards.

6. Conclusion

Through the establishment and verification of the structural equation model constructed by the multi-agent recycling behavior of the reverse supply chain, the consumer recycling behavior, the recycling behavior of the recycler, and the recycling behavior of the manufacturer all have a significant positive impact on the construction of the recycling standard. The following two important factors in the selection of factors affecting the recovery behavior of the three subjects are proposed:

(1) Consumer recycling behavior perspective: Emphasis on economic incentives for consumer recycling behavior, such incentives are not only material incentives, spiritual incentives are equally important. Economic incentives can first enhance consumer recycling initiative, reduce the environmental pollution of electronic products, and at the same time, with certain spiritual incentives, consumers can feel the value of recycling.

(2) Recycling dealers' recycling behavior: First of all, the recycling cost should be considered. If the recycling cost is too high, it will bring economic burden to the recycler, which will directly lead to the backlog of recycled materials, which will reduce the enthusiasm of recyclers. Requires the development of electronic product recycling standards to set reasonable recycling prices for recyclers and reduce the burden on recyclers. The reasonable recovery price formulation requires a reasonable classification of the recycled products. Therefore, relevant laws and regulations and the recycling industry should develop a reasonable classification list of recycled products, this not only provides a basis for the recovery price, but also improves the recovery rate and recovery efficiency of waste electronic products, and improves the recycling value of recycled products.

(3) Manufacturer's recycling behavior: The construction of recycling standards should fully consider the technical level of the manufacturer and the superior technical level, which will make the recycled electronic products fully utilized and save the product cost for the enterprise. At the same time, it will bring a good environmental image to the company and enhance the intangible wealth of the company.

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