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Motivation and challenges for e-commerce in e-waste recycling under "Big data" context: A perspective from household willingness in China

Bin Zhang[a,b,c,d], Zhanjie Du[a,b,c], Bo Wang[a,b], Zhaohua Wang[a,b,c,d,*]

[a] School of Management and Economics, Beijing Institute of Technology, Beijing 100081, China
[b] Center for Energy & Environmental Policy Research, Beijing Institute of Technology, Beijing 100081, China
[c] Sustainable Development Research Institute for Economy and Society of Beijing, Beijing 100081, China
[d] Collaborative Innovation Centre of Electric Vehicles in Beijing, 100081 Beijing, China

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ABSTRACT

With the emerging technology and consumption modes under "Big data" context, e-commerce has arisen as a new trend for e-waste recycling. This paper conducted a questionnaire survey from 896 residents living in the cities of China, to explore the development of e-commerce in e-waste recycling. An ordered logit regression model was employed to reveal the key drivers and barriers for residents to choose e-commerce for their e-waste recycling. The results show that e-commerce in e-waste recycling does not receive a universal acceptance from residents. The perceived convenience, attitude and subjective norm are positively related to the residential intensions towards employing e-commerce for e-waste recycling. The price disadvantage of e-waste collection by e-commerce is the major barrier for taking e-commerce for e-waste recycling. However, the relationship between e-commerce recycling willingness and perceived price disadvantage is moderated by e-waste disposal subsidy. Facility accessibility also plays a moderate role in the relationship between e-commerce recycling willingness and perceived convenience.

1. Introduction

Electrical and electronic waste (e-waste) is a world-wide problem. There are over 41.8 million tons of e-wastes generated all over the world, but < 20% of e-wastes were reported as formally treated by national take-back systems and schemes (Baldé, Wang, Kuehr, and Huisman, 2015). Large amounts of e-wastes even flowed to illegal disposal plants, and were extracted precious metals (e.g. gold and silver) with rough refinery and non-environmental friendly process. China faces even more serious problem of e-wastes. Beyond the second largest e-waste producer with the generation of > 6 million tons per year, China also processed almost of 70% of world's e-wastes each year (Wang, Zhang, and Guan, 2016). Many e-wastes generated in the developed countries exported to China in the name of second hand electrical or electronic appliances. People's lives and general health are threatened by the informal e-waste disposal, which is quite popular in China with simple treatments of disassembly, heating, acidification and incineration. A typical case of negative environmental impact is in Guiyu of Guangdong province, one of China's largest e-waste collection and distribution centers. Due to the long exposure to inappropriate disposal of e-waste, the lead content in the blood sampled from local children aged 1–6 is as high as 15.3 g/ml, which exceeds the advised warning standard by 50% (Ogunseitan, Schoenung, Saphores, and Shapiro, 2009).

China is engaging in the development of formal e-waste disposal system. There are 109 enterprises that have accessed to government certification for getting the e-waste disposal subsidies in China. The overall annual dismantling capacity of these enterprises exceeds 150 million sets. However, the actual dismantling amount is only 75 million sets.[1] Many disposal companies cannot collect enough e-wastes to fulfill their capacity. One of major reasons for the barrier between e-waste generation and demand of formal disposal company are attributed to the unwillingness of residents delivering their e-wastes to the formal disposed company. Residents often have to spend much time to deliver their e-wastes to the certified collection sites, which cause them inconvenience and uneasy feeling (Wang, Zhang, Yin, and Zhang, 2011). Thus, peddlers who provide on-site pick-up are preferred for e-waste recovery by many residents.

Big data is emerging as a new trend and impacts household daily consumption and life mode everywhere. Big data is a huge and complex data set in information Science (Lee, Han, and Sohn, 2015). It is difficult to store, process and analyze by traditional tools, and brings some

* Corresponding author.
E-mail address: wangzhaohua@bit.edu.cn (Z. Wang).

[1] The data is from *Industrial White Book of E-Waste Disposal and Reuse* (2015), which can be available at http://www.sohu.com/a/143406864_745358.

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smart changes in social lifestyles. Online travel recommendation system bring traditional travels with smart decision direction (Park and Kim, 2017). Shared bike system has been emerging in many big cities, after some big data technology such as GPS/GIS application can be installed in individual smart phones (García-Palomares, Gutiérrez, and Latorre, 2012). *E*-commerce is another changes for household shopping under big data context. Many consumers prefer online shopping to offline because of the convenience and time saving brought from big data technology (Salehi, Abdollahbeigi, Langroudi, and Salehi, 2012).

As e-commerce is increasingly popular in residents' daily lives, e-waste recovery through e-commerce is also emerging in China. Some e-companies such as "*Love Recycling*" and "*Yi Feng*" have been focusing on e-waste recycling with the application of Internet and mobile terminals. "*Love Recycling*" recovered over 5 million sets of e-wastes in the year 2016, 32.3% of which were collected by on-line Internet.[2] More and more residents prefer e-commerce to traditional e-waste recycling. However, traditional off-line e-waste recycling still plays dominant role particular in dumped household appliances. It is still not clear what impacts public acceptance of e-commerce in e-waste recycling. Very few studies have ever discussed the development of e-commerce in e-waste recycling and residential attitude towards it.

This paper empirically studies residential willingness in e-waste recycling through on-line e-commerce. We explore how different psychological and contextual variables influence residential acceptance for employing e-commerce in e-waste recycling. Questionnaire survey covering 895 samples in China was taken as the data source of our study. Through our study, we would like to answer the following questions:

- General acceptance of residents in e-commerce of e-waste recycling;
- What are the motivations and barriers behind public acceptance of e-commerce in e-waste recycling?

The reminder of this paper was organized as follows. The next section reviews the relevant literature to construct our hypothesis model. Then, we describe the data used for this study, specify our empirical tests, and report the results. In the last section, we conclude remarks including managerial implications.

2. Conceptual model and hypotheses

In order to identify the key indicators that impact residential decision on choosing e-commerce for the e-waste recycling, we employed Theory of Planned Behavior (TPB) as well as Theory of Interpersonal Behavior (TIB) to construct our hypothesis model. According to TPB, individual behavioral intention is a function of personal attitudes, subjective norm and perceived behavioral control (Cordano and Frieze, 2000). Attitudes derive from the beliefs and evaluation about the outcomes of target behavior. Positive attitudes towards a behavior help strength the intention to act in the given behavior (Abrahamse, Steg, Gifford, and Vlek, 2009). Subjective norm derives from the beliefs of other people who are important or familiar to the individual. Perceived behavioral control reflects individual belief as to how easy or difficult performance of the behavior is likely to be. Moreover, the TIB highlights the role of habit and past behavior in the decision making of individual behavior. Sometimes, the actual performance of the task requires very little cognitive effort, but acts from habit and routine. Additionally, Expectancy-Value Attitude Theory assumes that individual behavioral intention results from an evaluation of expected utilities or values (Youjae, 1989). Higher benefits from e-commerce of e-waste recycling will attract more residents to join in the action. Comprehensively integrated the above theories, we develop the following framework for our further hypotheses (see Fig. 1).

[2] The data is available at http://tech.ifeng.com/a/20170105/44526871_0.shtml.

Convenience should be one of the major advantages of e-commerce in e-waste recycling. *E*-commerce provides easier channels for residents to get access to formal e-waste recycling. Comparing to the traditional ways, residents do not have to spend much time on finding formal e-waste collection sites. All the related information is available at the e-commerce website and easy to find. Moreover, on-site collection is often provided after residents make their e-waste recycling orders on the Internet or the Apps of cellphones. Residents can also choose to deliver their e-waste by post in the e-commerce of recycling. These convenient services by e-commerce make residents feel easy to conduct e-waste recycling. From the perspective of perceived behavioral control, residents will more likely to choose e-commerce in e-waste recycling due to the perceived convenience. Thus, we can conjuncture the following hypothesis:

H1. -1. Perceived convenience is positively related to residential willingness of e-commerce in e-waste recycling.

In the recent years, China is engaging in building formal e-waste recycling system. Many e-waste recycling facilities such as e-waste recycling bins have been built in residential communities. Many formal e-waste collection sites are also emerging nearby residential quarters. These e-waste collection facilities make the delivery of e-waste more convenient. Residents do not have to walk too far to conduct e-waste recycling. The convenience of e-commerce for e-waste recycling might be offset by the increasing e-waste recycling facility. Thus, the popularity of e-waste recycling facility, to some extent, would substitute certain demand of e-waste recycling through the e-commerce. From this point, we can conjuncture the following hypothesis:

H1. -2. The relationship between perceived convenience and willingness of e-commerce in e-waste recycling is weaken as there is a better facility of e-waste recycling.

E-commerce habit may play another important role in the willingness of e-waste recycling by an online order. Habit plays an important role in residential daily behavioral decision (Amoroso and Lim, 2017; Belanche, Flavián, and Pérez-Rueda, 2017). If an individual gets used to the online shopping, he/she will easily choose e-commerce for their e-waste disposal without much rational cognitive effect and heuristic cues. Otherwise, for those residents who barely use internet for shopping will hardly dispose their e-wastes by e-commerce. Habits lie close to the automatic end, because everyday lives are full of repetitive actions. Some e-wastes are often discarded as normal waste by residents' routine trash dumping. Thus, we conjuncture the following hypothesis:

H2. Habits of online shopping is positively related to residential willingness of e-commerce in e-waste recycling.

A broad class of studies are based on the idea that behavior is motivated by the expectations we have about the consequences of our behavior and the values we attach to those outcomes (Liobikienė and Juknys, 2016; Mencarelli and Lombart, 2017). *E*-waste recycling can bring economic revenue for residents, since there are valuable and reliable materials such as heavy metals contained in e-waste. At present in China, most e-waste collecting channels would offer a payment to residents for collecting their e-wastes. The relative price deviation between e-commerce and traditional e-waste collecting channels would impact the decision of residents, particularly for those who are price sensitive. In China, the price offered by informal e-waste collecting channels are often higher than formal channels including e-commerce channel (Qu, Zhu, Sarkis, Geng, and Zhong, 2013; Wang, Tian, Zhu, and Zhong, 2017). The price disadvantage of e-commerce in e-waste recycling would hinder the motivation of residents. Thus, we conjuncture the following hypothesis:

H3. The price disadvantage is negatively related to residential willingness of e-commerce in e-waste recycling.

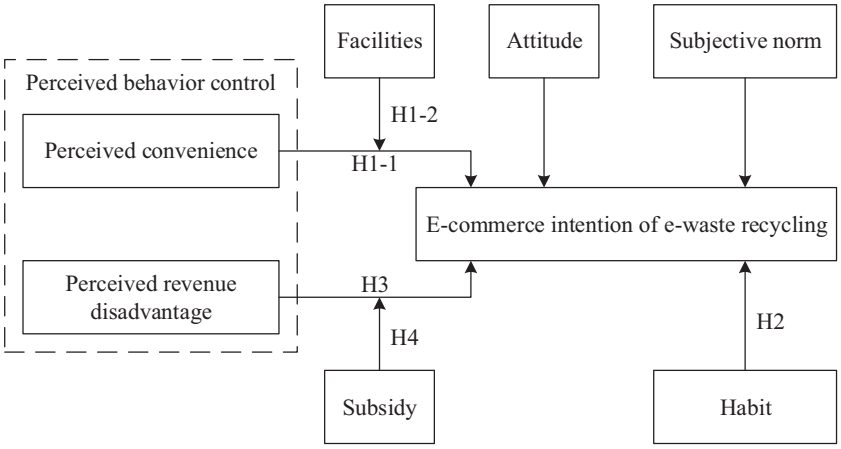

Fig. 1. The hypothesis framework in our study.

China government has constructed a subsidy system for formal and environmental friendly e-waste disposal (Awasthi and Li, 2017). Each certified disposal firm can get a subsidy according to its disposed quantity of e-waste. The e-waste disposal subsidy from government helps formal e-waste recycling firm build their competitive capacity in e-waste collection and disposal. Large amounts of e-wastes collected by e-commerce are remanufactured for donation or sold as second hand products. The disposal subsidy will attract more e-wastes from e-commerce platform flowing to final disposal firm. This subsidy policy may transfer the revenue increasing effect from e-waste disposal site to the upstream of e-waste collection. The price of e-waste collection by e-commerce will be increase due to the subsidy, which mitigate the disadvantage of e-commerce in e-waste collecting price. Thus, we conjuncture the following hypotheses:

H4. The relationship between price disadvantage and willingness of e-commerce in e-waste recycling is weaken as there is a subsidy for e-waste disposal.

3. Methodology

3.1. Modeling with ordered logit model

To test our hypotheses concerning the e-waste recycling willingness by e-commerce, we employ an Ordered Logit Model to do the estimation. Ordered Logit Model is a regression model employed for ordinal dependent variable (Bogue, Paleti, and Balan, 2017). It meets the proportional odds assumption that an arithmetic sequence is formed by the logarithms with each number added to the logarithms is the same to get the next in every case. The willingness of e-waste recycling by e-commerce is taken as dependent variable, which is measured in an ordinal set of responses in our study. Due to the ordinal nature of dependent variable in the studied dataset, an ordered-Logit model should be applied.

The basic model was shown as Formula (1). Integrating TPB with TIB, we employ attitude, subject norm, perceived behavioral control, and habits as the independent variables for the dependent variable of e-waste recycling willingness by e-commerce (ERWE). Since ERWE was measured by the preference order of e-waste recycling mode, an ordered logit model is suitable for the estimation. **H1-1** would suggest that ERWE has a positive relationship with perceived convenience, and $\alpha_3 > 0$ is expected. **H2** suggests that ERWE is negatively related to habit of off-line shopping, thus we expected $\alpha_4 < 0$.

$$ERWE^* = \alpha_0 + \alpha_1(\text{Attitude}) + \alpha_2(\text{SUNORM}) + \alpha_3(\text{PEC}) + \alpha_4(\text{Habit}) + \varepsilon_1 \quad (1)$$

Where $ERWE^*$ refers to latent and continuous measure of ERWE; SUNORM is the abbreviation of subjective norm; PEC is the abbreviation of perceived convenience; ε_1 is the random error term.

The observed and coded discrete willingness variable $ERWE_i$ is determined from the model as follows:

$$ERWE = \begin{cases} 1, & if -\infty < ERWE^* \le \mu_1 \ (\text{ERWE} would\ be\ the\ last\ choice) \\ 2, & if \mu_1 < ERWE^* \le \mu_2 \ (\text{ERWE} would\ be\ the\ last\ choice\ but\ one) \\ 3, & if \mu_2 < ERWE^* \le \mu_3 \ (\text{ERWE} would\ be\ the\ third\ choice) \\ 4, & if \mu_3 < ERWE^* \le \mu_4 \ (\text{ERWE} would\ be\ the\ \text{sec}ondary\ choice) \\ 5, & if \mu_4 < ERWE^* < \infty \ (\text{ERWE} would\ be\ the\ priority) \end{cases} \quad (2)$$

The probabilities of y_i in different coded value were defined as follows in our ordered logit model:

$$\begin{aligned} P(y_i = 1) &= F\left(\mu_1 - \alpha_i \sum_i x_i\right) \\ P(y_i = 2) &= F\left(\mu_2 - \alpha_i \sum_i x_i\right) - F\left(\mu_1 - \alpha_i \sum_i x_i\right) \\ P(y_i = 3) &= F\left(\mu_3 - \alpha_i \sum_i x_i\right) - F\left(\mu_2 - \alpha_i \sum_i x_i\right) \\ P(y_i = 4) &= F\left(\mu_4 - \alpha_i \sum_i x_i\right) - F\left(\mu_3 - \alpha_i \sum_i x_i\right) \\ P(y_i = 5) &= 1 - F\left(\mu_4 - \alpha_i \sum_i x_i\right) \end{aligned} \quad (3)$$

Where $P(y_i = k)$refers to the probability that the individual responds his/her attitude towards ERWE at the level of k; $F(\cdot)$ refers to the probability-distribution function; x_i refers to the independent variable i.

To test our hypothesis on the relationship between recycling facilities and ERWE, we incorporate the interaction term of recycling facilities and perceived convenience in the formula (2). Hypothesis **H1-2** which suggests better recycling facilities hinder the transfer of perceived convenience of e-commerce to ERWE, would be verified if $\alpha_6' < 0$.

$$ERWE^* = \alpha_0' + \alpha_1'(\text{Attitude}) + \alpha_2'(\text{SUNORM}) + \alpha_3'(\text{PEC}) + \alpha_4'(\text{Habit}) + \alpha_5'(\text{INFA}) + \alpha_6'(\text{INFA}\times\text{PEC}) + \varepsilon_2 \quad (2)$$

Where INFA is the abbreviation of recycling facility; α_j' is the estimated coefficients; ε_2 is the random error term.

Formula (3) was built for testing the hypotheses on revenue disadvantage and the effect of disposal subsidy policy, where *REVD* is the

abbreviation of revenue disadvantage and *Subsidy* is the subsidy for choosing formal e-waste recycling. Hypothesis 3 expecting $\alpha_7'' < 0$ suggests negative relations between ERWE and REVD. Hypothesis 4-1 and Hypothesis 4-2 would be verified if we have $\alpha_8'' < 0$ and $\alpha_9'' > 0$.

$$ERWE^* = \alpha_0'' + \alpha_1''(\text{Attitude}) + \alpha_2''(\text{SUNORM}) + \alpha_3''(\text{PEC}) + \alpha_4''(\text{Habit}) + \alpha_7''(\text{REVD}) + \alpha_8''(\text{Subsidy}) + \alpha_9''(REVD \times Subsidy) + \varepsilon_3 \quad (3)$$

Formula (4) is an integrative model including all the independent variables and interaction terms in the regression. It was built to check the robustness of the results from the above Models (1), (2) and (3).

$$ERWE^* = \alpha_0''' + \alpha_1'''(\text{Attitude}) + \alpha_2'''(\text{SUNORM}) + \alpha_3'''(\text{PEC}) + \alpha_4'''(\text{Habit}) + \alpha_5'''(\text{INFA}) + \alpha_7'''(\text{REVD}) + \alpha_8'''(\text{Subsidy}) + \alpha_6'''(\text{INFA}\times PEC) + \alpha_9'''(REVD \times Subsidy) + \varepsilon_4 \quad (4)$$

3.2. Questionnaire design

To measure each latent variable in our model of Fig.1, we developed a questionnaire based on the literature. There were three parts comprising our questionnaire: (1) “Residential intentions and behavior towards e-waste recycling”, (2) “Perceived features of e-commerce in e-waste collection” which is designed for evaluating the influential determinants of e-waste collection with e-commerce, and (3) “Demographic information”. The example of measurement for each item in the questionnaire was shown in Table A-1 of Appendix.

For residential intention towards e-waste disposal, we provided five ways for the respondents to give a rank according to their future choice of e-waste disposal. They are e-commerce, on-site collection by peddlers, delivery to professional collection site, discarding and keep in the house. We evaluated the choice of first rank with the score of 5, and the last rank with the score of 1. The residential intention towards e-commerce of e-waste collection was measured by its final ranked scores.

TPB influential variables including personal attitudes and subjective norm were measured following the literatures (Wang et al., 2011a; Webb et al., 2013). Perceived behavioral control was subdivided into *perceived convenience* and *perceived revenue disadvantage*. Each variable was measured with two questionnaire items except *Attitudes* (measured with three items). Respondents are asked to show their views on the statements with a 5-point scale (labelled end-points of 1 = “not at all” and 5 = “very much”).

Habit was measured by asking respondents their approval towards their experience of e-commerce. Only one item was employed for the measurement on a 5-point scale with labelled end-points of 1 = “not at all” and 5 = “very much”. It was developed based on the study of TIB (Moody and Siponen, 2013).

Facilities (INFA) was developed with three measurement items. Respondents were asked to evaluate the facility accessibility of e-waste recycling around their living community. There were also three items for measuring this variable, and a five-point scale (labelled end-points of 1 = “not at all” and 5 = “very much”) was also employed for the measurement.

Subsidy was also developed with only one item. Respondents were asked their approval towards the adequacy of e-waste recycling subsidies from local government. This item was evaluated using a 5-point scale with labelled end-points of 1 = “not at all” and 5 = “very much”.

Although the questionnaire items were adopted from, or developed based on the previous literature, we further took a pilot test before the formal questionnaire survey to ensure the meaning of the questionnaire was clear in the presented context. According to the pilot test, we did minor modifications on the wording of items. After that, some experts in waste recycling were invited to further examine the revised version to ensure content validity.

Our questionnaire showed acceptable measurement reliability. According to the pilot test, the values of Cronbach's alpha were all above 0.7 for each independent variable. The factor loading of each measurement item and average variance extracted of each construct variable were all above 0.5. The discriminatory validity of our questionnaire was also good. The correlation between each two construct variable was all smaller than their square root of average variance extracted.

For common-method bias which was due to common measurement methods employed in questionnaire survey, we took several measures to reduce the potential bias. An introduction was given before the survey to guarantee confidentiality of the response information. This would make the respondents feel comfortable to give their real responses towards our question. As the common-method bias may raise if the collected data from single source, we separated our questions into three different sections. A cover story was given between each two sections. The separated sections would reduce the feeling of correlation between each questions. The respondents would give their direct response towards each question with less influence from other questions. Moreover, a Harman's single-factor test was employed to further examine the possibility of common-method bias. According to Podsakoff, MacKenzie, Lee, and Podsakoff (2003), we loaded all the items into an exploratory factor analysis, where the first emerging factor without rotation is the proxy of common method variance. The first factor accounts for < 50% in this research, which indicates no single factor was dominant in the covariance among the measures. Thus, the common-method bias was not found in our survey.

3.3. Data collection

The formal survey was conducted from January 15th to February 28th, 2017. We trained 92 college students about our questionnaire survey, and asked them to do the data collection in their hometown during their winter vacation. During the train of survey, we asked each investigator to understand every questionnaire items, and teach them onsite survey skills and how to deal with all kinds of problems during survey. During the survey, we ask each investigator have to choose at least 5 different residential communities in their city with each community no > 10 respondents. Face to face investigation was asked during the survey. Misunderstanding and false responses can be timely solved by the explanation from our investigators. Finally, we received 940 questionnaires, but only 895 responses were acceptable after a technical check for missing items, repetitive answers and self-contradictory responses. All acceptable responses covered 30 provinces of China except Hainan and Taiwan. We did not include Hainan province because that there are no investigators from Hainan province. It is one of our disadvantages that selective biases might exist due to miss of Hainan sample. However, Hainan is a small island province with small population in China. The living style of residents is not significantly different with other nearby south coast provinces. The missing of Hainan province in our sample would not be important for our main results.

Fig.2 showed the regional distribution of our sample. China can be divided into eight economic regions, namely the economic zones of the Yellow River, Northeast, Yangtze River, North Coast, South Coast, East Coast, Southwest, and Northwest.[3] Our samples were major from North Coast and Yangtze River, which accounted for > 70% of total sample.

[3] The Yellow River economic zone includes four provinces of China, namely Shanxi, Inner Mongolia, Shaanxi, and Henan. The Northeast economic zone includes three provinces of China, namely Heilongjiang, Jilin, and Liaoning. The Yangtze River economic zone includes four provinces of China, namely Hubei, Hunan, Anhui, and Jiangxi. The North Coast economic zone includes two cities and two provinces of China, namely Beijing, Tianjin, Hebei, and Shandong. The South Coast economic zone includes three provinces of China, namely Fujian, Guangdong, and Hainan. The East Coast economic zone includes one city and two provinces of China, namely Shanghai, Jiangsu, and Zhejiang. The Southwest economic zone includes one city and four provinces of China, namely Chongqing, Sichuan, Yunnan, Guizhou, and Guangxi. The Northwest economic zone includes five provinces of China, namely Gansu, Ningxia, Tibet, Qinghai, and Sinkiang.

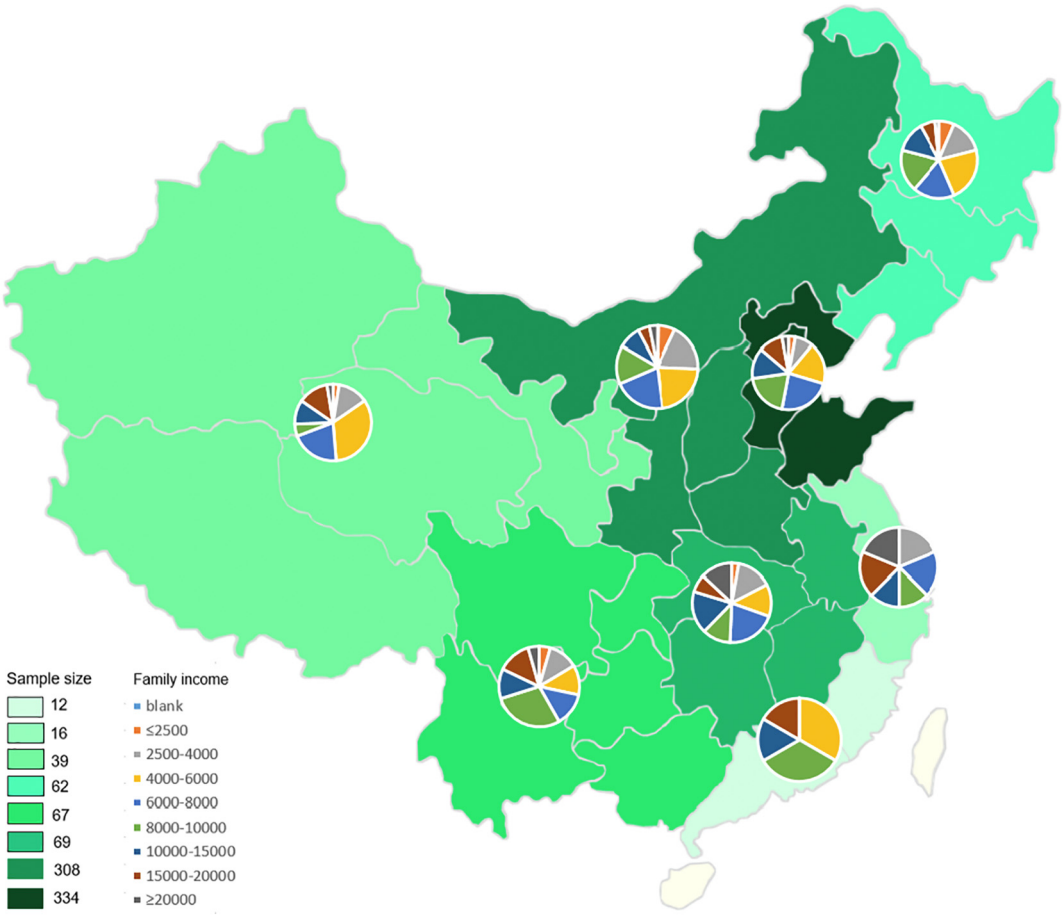

Fig. 2. The sample distribution of regions and family income.

The following were Yangtze River and southwest. The distribution of family income in each region was also shown in Fig.1. The family income of most respondents was distributed from 4000 to 10,000 Yuan RMB. The family income exceeding 15,000 Yuan was majorly located in the area of East Coast and South Coast.

4. Results and discussion

4.1. Statistical analysis for e-waste recycling in China

According to our survey, e-commerce in e-waste recycling is far less popular in comparison to on-site collection by peddlers in most regions of China. Fig. 3 showed the household e-waste disposal modes in China. Residents were asked how many e-wastes had been disposed in the last five years by each of the following five ways, namely peddlers, e-commerce, professional collection site, storage in the house and discarded directly. Most respondents sell their e-waste to peddlers in our survey. Quite a few respondents took e-commerce for their e-waste disposal. Professional recycling site was the choice of some respondents, but the ratio was also very low. Over 43% of e-waste were reported to be collected by peddlers in our survey; e-waste recycling by e-commerce only accounted for 3%. It was indicated that on-site collection by peddlers was still the dominant way for e-waste recycling in China, and e-commerce and professional recycling site were far less competitive. Other large amounts (around 32%) of e-waste were kept storage at home. Many respondents could not find proper ways to dispose their e-waste. Some of them could not find convenient channels for e-waste collection, otherwise feel that the recycling price was not satisfied.

Residents with different household incomes showed different behavior in e-waste recycling. The poorest residents with household income < 2500 RMB/month hardly had e-waste to dispose. For one thing, these respondents used fewer electrical and electronic products in their daily life. For another thing, these respondents might be reluctant to change with new electrical and electronic products even if their old ones reaches the producer suggested end of life. Sometimes, they could not afford to change the new ones. In contrary to other traditional e-waste disposal modes like collection by peddlers, e-commerce attracts more respondents with house income above 10,000 RMB/month. It indicated that high income residents were easily access to e-commerce mode for e-waste recycling. This finding is constant with the literature that income level is important predictors of e-waste recycling behavior (Dwivedy and Mittal, 2013).

According to the age distribution, we found that young respondents < 30 years old were more activating in e-waste recycling using e-commerce. There were hardly any respondents with the age of > 60 using e-commerce for their e-waste recycling. It was also shown that the ratio of young respondents in using professional recycling sites was also comparatively larger than other e-waste recycling modes. Young residents were often easily get access to the information of recycling site location, and had more time and various carriers for e-waste delivery.

According to the distribution of education level, we found that high educated respondents were more likely to choose e-commerce for their e-waste recycling. The ratio of bachelor and postgraduate of respondents choosing e-commerce was relatively higher than other traditional e-waste recycling modes. These residents were often well educated and familiar with e-commerce in their daily lives.

We categorized the career of respondents with environment related career and non-environment related career. The ratios of environmental

Fig. 3. Statistical analysis for e-waste recycling under demographic distribution.

Table 1
Estimation results of e-waste recycling by e-commerce.

	Model (1)	Model (2)	Model (3)	Model (4)
Dependent variable: *ERWE*				
Independent variable:				
Attitude	0.444** (0.918)	0.480** (0.093)	0.453** (0.117)	0.463** (0.118)
	[0.264, 0.624]	[0.298, 0.661]	[0.224, 0.682]	[0.232, 0.695]
SUNORM	0.304** (0.055)	0.398** (0.064)	0.349** (0.059)	0.420** (0.065)
	[0.196, 0.412]	[0.272, 0.522]	[0.234, 0.682]	[0.292, 0.548]
PEC	0.301** (0.065)	0.969** (0.177)	0.365** (0.071)	0.968** (0.182)
	[0.172, 0.429]	[0.623, 1.316]	[0.227, 0.504]	[0.612, 1.325]
Habit	−0.150** (0.050)	−0.122** (0.050)	−0.148** (0.050)	−0.124** (0.050)
	[−0.247, −0.052]	[−0.221, −0.243]	[−0.246, −0.050]	[−0.222, −0.025]
INFA		0.745** (0.232)		0.705** (0.239)
		[0.290, 1.200]		[0.237, 1.173]
REVD			−0.559** (0.279)	−0.412 (0.288)
			[−1.105, −0.013]	[−0.977, 0.153]
Subsidy			−0.518** (0.174)	−0.376** (0.178)
			[−0.859, −0.177]	[−0.725, −0.027]
INFA × PEC		−0.253** (0.622)		−0.233** (0.064)
		[−0.374, −0.131]		[−0.358, −0.108]
Subsidy × REVD			0.188** (0.081)	0.127** (0.083)
			[0.028, 0.347]	[−0.037, 0.290]
μ_1	1.604 (0.457)	3.964 (0.787)	0.400 (0.927)	2.803 (1.217)
	[0.707, 2.500]	[2.423, 5.506]	[−1.407, 2.206]	[0.418, 5.189]
μ_2	2.517 (0.461)	4.891 (0.792)	1.319 (0.922)	3.734 (1.220)
	[1.613, 3.422]	[3.339, 6.444]	[−0.489, 3.126]	[1.343, 6.125]
μ_3	3.446 (0.468)	5.835 (0.799)	2.253 (0.925)	4.680 (1.224)
	[2.528,4.364]	[4.269, 7.400]	[0.441, 4.066]	[2.282, 7.078]
μ_4	4.594 (0.477)	6.999 (0.807)	3.412 (0.928)	5.850 (1.228)
	[3.658, 5.530]	[5.418, 8.580]	[1.593, 5.231]	(3.443, 8.257)
Log-likelihood	−1384.55	−1374.16	−1379.24	−1371.27
N	895	895	895	895

** $p < 0.05$.

related career in e-commerce and professional recycling site were higher than that in e-waste recycling by peddlers. Residents who occupy in environment related jobs often had higher awareness of environmental protection. Thus, environmental friendly e-waste disposal would be the priority for these residents. *E*-commerce and professional recycling sites were the certified channels to dispose the

collected e-waste in a harmless way. However, large amounts of e-waste collection by peddlers were flowed to illegal e-waste disposal with negative environmental impacts. Residents taking environment related jobs had more opportunities to understand the negative environmental impacts of e-waste recycling by peddlers, and were reluctant to choose peddlers for their e-waste.

4.2. Ordered logit regression for the determinants of e-waste recycling with e-commerce

We estimated Eq. (1), (2) and (3) using the hierarchical ordered Logistic estimation techniques. We used the Stata 12.0 software to run the estimation and obtain samples for posterior distributions for parameter estimation. The parameter α, α' and α''were given slightly informative priors, and all variance parameters of ε_1, ε_2 and ε_3 were given slightly informative priors as logic distribution. Both dependent variable and independent variables were standardized in order to increase the interpretability of the estimation. Eq. (4) was an integrative model including all related independent variables mentioned in the above three models.

Table 1 reported our empirical results regarding the e-waste recycling by e-commerce using the above models shown in Section 3.

The coefficient of *PEC* was significantly positive in all models from Model (1) to Model (4). Hence, hypothesis **H1-1** was supported that perceived convenience is an important indicator for individuals to choose e-commerce as the channels for their e-waste recycling. *E*-commerce often provides on-site pick-up service for e-waste recycling. Individuals do not have to carry e-wastes to the recycling site as long as they take e-commerce for e-waste recycling. E-commerce is also more convenient for collecting e-waste recycling information, such as e-waste recycling price, disposal methods and pick-up time. It will save much time and energy to find e-waste recycling sites and contact information of e-waste collectors. Due to the advantage of convenience in the online e-waste recycling, residents would prefer e-commerce for their e-waste recycling if other indicators are constant.

The coefficient of *Habit* was also statistically significant in all models from Model (1) to Model (4). Hence, hypothesis **H2** was supported that habit is an important indicator for individuals to choose e-commerce as the channels for their e-waste recycling. This result is also constant with the literature that habit is important for household waste recycling (Abd'Razack, Medayese, Shaibu, and Adeleye, 2017). Individual with few online shopping experience or unfamiliar with online shopping would be less likely to take e-commerce in their e-waste recycling. Shopping habit is often unconscious and hardly to change. If an individual prefers online shopping, it is normally subconscious for him/her to choose e-commerce for the e-waste recycling.

Model (2) was set to test the moderate effect of *INFA* which denotes the accessibility of e-waste collecting facility. The results showed that *INFA* did play a moderate role at the 5% significant level, which is consistent with Hypothesis **H1-2**. The relationship between *PEC* and *ERWE* was weaken when the *INFA* increased. This result suggested that, controlling for other indicators, perceived convenience would be less important for an individual to choose e-commerce for his/her e-waste disposal if there are accessible facilities for e-waste recycling.

Model (3) was set to test the moderate effect of *Subsidy* which denotes the national subsidy for cleaner e-waste disposal. The results showed that the coefficient of *REVD* denoting perceived revenue disadvantage of e-commerce recycling is -0.559 ($p < 0.05$), which suggested a significantly negative relationship between *REVD* and *ERWE*. It indicated that lower price provided by e-commerce recycling refrained an individual's willingness to choose e-commerce, which is consistent with Hypothesis **H3**. However, the negative relationship between *REVD* and *ERWE* would be weaken if there was a growth of e-waste disposal subsidy. The conjecture was supported by our results that a coefficient of interaction *Subsidy* × *REVD* is significantly positive at 5% significance level. The Hypothesis **H4** was supported.

Model (4) is an integrative model including all the independent variables and interaction terms in the regression. It provided a robust result that the significance of coefficients was consistent with our previous Models (1), (2) and (3).

4.3. Implications and limitations

Although e-commerce is increasingly popular in residents' daily life in recent years, its development in e-waste recycling is relatively slow. There have been some e-commerce companies such as "*Love Recycling*" and "*Yi Feng*" emerging for e-waste collection in many cities of China. However, most residents hardly employ e-commerce for their e-waste recycling, particularly for the low-income and aged residents. There are some possibly reasons for the unpopular e-commerce in e-waste recycling according to our analysis.

First, perceived convenience is a key indicator impacting on residents' decision in e-waste recycling modes. This finding is constant with the literature that convenience is one of the main reasons for waste recycling (Klaiman, Ortega, and Garnache, 2017). Although e-commerce is convenient for making orders and collecting information of e-waste recycling, some residents feel difficult to get access to the e-commerce service. As e-commerce for e-waste collection is in an initial stage for many cities of China, its on-site collection service only covers urban aeration of the city. The residents in suburb of the city also have to deliver their e-waste to the collection site even if they choose e-commerce for e-waste recycling. Thus, the advantage of e-commerce in convenience is watered down for these residents. They would choose peddlers rather than e-commerce as the peddlers can pick up their e-waste on the house.

Particularly, the aged residents would not be likely to take e-commerce for e-waste recycling. They are accustomed to the traditional off-line commerce. According to our analysis, habit is important for residents to choose their e-waste recycling modes. *E*-commerce is often new to the aged residents. Few of them would like to try the unfamiliar mode for their e-waste recycling. Additionally, taking e-commerce for e-waste recycling should use the computer or install an *APP* in the computer, in order to place an order. It is too troublesome for the aged residents, and brings inconvenience for using the e-commerce. On-site e-waste collection by peddlers is a more simple and convenience way for aged residents.

Second, the comparatively lower price offered by e-commerce is another barrier for its development. The e-wastes collected by e-commerce are either flowed to the second hand market for resale, or disposed in the formal disposal company. Both of these two are higher costed in comparison to the informal e-waste disposal which often collects e-waste from peddlers (Orlins and Guan, 2016). Thus, the collected price by e-commerce is commonly lower than peddlers, and is hardly to bargain as e-commerce is often built upon an open and public platform. E-commerce platform does not often accept all kinds of e-wastes. Mobile phone is most welcomed e-waste for e-commerce, because it is easily to be resold in the second hand market after simple refurbishment. However, few e-commerce platform would like to pay high price for old washing machine, air-conditioner and refrigerator. Some old household appliances such as water heater, rice cooker and coffee maker are even refused to be recycled by most e-commerce platform. The price disadvantage make residents prefer to choose peddlers for their e-waste recycling.

Moreover, residents' attitude towards the environmental benefits of e-waste recycling by e-commerce is not strong in China. Many residents do not think proper e-waste recycling such as e-commerce will help improve our environment. Thus, few residents feel responsible for taking formal e-waste collection channels. The atmosphere of using e-commerce for e-waste recycling has not taken shape. The positive effect of subjective norm plays limited role in household e-waste recycling with e-commerce, because the friends and relatives around the resident also have little experience in using e-commerce for e-waste recycling.

Residents could not get positive comments about taking e-commerce for e-waste recycling. Accordingly, government should attach importance to propagandize the benefits of e-waste recycling to the environment and society, and give detailed information about the proper ways to deal with household e-wastes. The guidance of household e-waste recycling would help residents form positive attitude towards e-commerce in e-waste recycling.

Additionally, e-commerce is an economic option to replace traditional formal e-waste recycling sites. Its development will help to reduce the flow of e-waste to peddlers and other illegal e-waste collection channels. However, Chinese government has not given a clear direction for the future development of e-waste collection. It still provides great investments in the physical e-waste recycling facility. However, most these physical recycling facilities are operated in a low efficiency. According to our results, the development of physical e-waste recycling facility will weaken the attractive of e-commerce in e-waste recycling. It is a kind of waste for the government to excessively focus on the e-waste facility. *E*-commerce could largely replace the role of physical recycling facility with a better efficiency.

E-waste disposed by the certified disposal company in China will get a subsidy from the national government. According to our analysis, e-waste disposal subsidy negatively moderate the disadvantage of e-waste collection price of e-commerce. It indicates that e-commerce is more sensitive to the subsidy. The subsidy would be reflected in the e-waste collection price more quickly and significant than other traditional e-waste collection modes. Peddlers will be less influenced by the subsidy because their collected e-wastes are majorly flowed to informal e-waste disposal site rather than certified e-waste disposal firm. Increasing the rate of subsidy in formal e-waste disposal will be an effective way for the popularity of e-commerce in e-waste recycling. It will also attract more e-wastes collected from e-commerce flowed into the certified disposal companies, instead of resold as second hand products.

Although there have been some interesting findings in our paper, some limitations also exist during the analysis. One of the major problem is a relative small sample employed in our research. Although we collected nearly 900 questionnaires as our sample, it is still too small for a national distribution. Particularly for some western provinces of China, we collected < 30 questionnaires for each province. In the future study, we have to focus on one or two cities, and explore the development of e-commerce in e-waste recycling and the acceptance of public residents. Another limitation is that all the variables in our analysis are from respondents' perceived strong or weak responses, including the variable of e-waste recycling facility and subsidy. Although it can directly evaluate respondents' feelings towards a measurement item, it may not reflect the actual situation of facility or subsidy. In the future study, it would be better to embed actual data of policy or investment data with the survey data. Integrating data from multi-sources will make the study more reliable and convincing.

5. Conclusion

Now we are moving into a “big data” era. New and intelligent technology has been emerging in residents' daily life under the “big data” context. Residents' consumption modes are constantly changing due to the newly applied technology, particularly the increasing application of internet technology. A new way, namely e-commerce, has also arisen in e-waste recycling. *E*-commerce platform like *Love Recycling* and *Yifeng* has offered e-waste recycling service in many cities of China. To the best of our knowledge, this paper contributes to explore the development of e-commerce in e-waste recycling from the perspective of residential attitudes and behavior. We conducted a questionnaire survey from 896 residents in China, and investigated their intentions, perceived feelings and behavior towards e-waste recycling with application of e-commerce. Our empirical analysis with an ordered logit regression, reveal several important determinants of residents' e-waste recycling behavior as the Internet has evolved.

First, we find that e-commerce in China has not attracted a universal acceptance for e-waste recycling. Most aged or low-income residents still prefer to take peddlers for their e-waste collection. E-commerce for e-waste recycling is more welcomed by the residents who are accustomed to online shopping. As e-commerce for e-waste recycling majorly covers big cities at present, it is more popular for residents living in big cities.

Second, we found that perceived convenience is an important motivation of taking e-commerce for e-waste recycling. E-commerce is easier for residents to search e-waste recycling information, and often provides delivery service for e-waste collection. The major barrier for residents' willingness to take e-commerce for e-waste recycling is the perceived disadvantage of e-waste collecting price. Peddlers often offer higher price because the majority of their collected e-waste flowing to more profitable illegal e-waste disposal.

Finally, moderate effect is found for e-waste disposal subsidy and accessibility of collection facility. *E*-waste disposal subsidy will be more efficiently transferred to e-commerce collection from disposal firm with an effectively marketing mechanism. This will offset the price disadvantage of e-waste collection from e-commerce. The accessibility of collection facility will also dilute the advantage of e-commerce in convenience for e-waste recycling. Some residents will be attracted to use the collection facility instead of e-commerce.

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Appendix A

Table A-1. Measurement items.

Constructs	Items	Item contents
Attitude (AT)	AT1	I think taking e-commerce for e-waste recycling is helpful for environmental protection.
	AT2	I think e-commerce is important for e-waste recycling.
	AT3	I think taking e-commerce for e-waste recycling will make living environment better.
Subjective norm (SUNORM)	SN1	Many people who are close to me choose e-commerce for e-waste recycling.
	SN2	Most people who are important to me suggest me choose e-commerce for e-waste recycling.
Perceived convenience (PEC)	PEC1	E-commerce is convenient for e-waste recycling because of the onsite pick-up service.
	PEC2	E-commerce reduces time for searching information of e-waste collection channels.

Perceived revenue disadvantage (REVD)	REVD1	The price of e-waste collection is cheap for e-commerce.
	REVD2	Onsite peddlers provides higher e-waste collection price than other e-waste collection channels.
Habit (HA)	HA1	I do not often employ e-commerce for shopping.
Facilities (INFA)	FA1	It is easy for me to deliver my e-waste to collection site.
	FA2	It will not take much time to deliver the e-waste to collection site.
	FA3	There are many e-waste collection facilities around my house.
Subsidy	SUB1	Local government provides enough subsidies for formal e-waste disposal.

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.techfore.2018.03.001.

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Dr. Bin Zhang is an Assistant Professor of School for Management and Economics, Beijing Institute of Technology, China. He worked as a "Hong Kong Scholar" at Business School of Hong Kong Polytechnic University from 2015 to 2016. His research interests are low carbon behavior, environmental & sustainable management, and environment & low carbon policy, aiming to understand evolutionary mechanism of household low carbon behavior and contribute to national level environmental management.

Miss Zhanjie Du is a master student of School for Management and Economics, Beijing Institute of Technology, China. She received her Bachelor of Management degree from Lanzhou University. Her research interests are environmental management and household low carbon behavior.

Dr. Bo Wang is a postdoctor of School for Management and Economics, Beijing Institute of Technology, China. She research interests are low carbon behavior, environmental & sustainable management, and environment & low carbon policy, aiming to understand evolutionary mechanism of household low carbon behavior and contribute to national level environmental management.

Zhaohua Wang is a Distinguished Professor at School of Management and Economics, Beijing Institute of Technology (BIT). He is also the Associate Director of the Center for Energy and Environmental Policy Research at BIT (Ranking 111, Top 4% institutions in the field of Environmental Economics at IDEAS). Zhaohua Wang has more than 15 years of experience in clean production and sustainable consumption, including academic, research, and consulting. He is the Executive Committee of China Management Science Research, President of Beijing Research Association of Higher Education Management in Colleges and Universities, Vice President of the Chinese Society of Optimization, Overall Planning and Economic Mathematics (OOPEM), and the committee member of Chinese Society for Sustainable Development. Owing to his outstanding efforts in research work, he was awarded by the National Natural Science Fund for Distinguished Young Scholars (2016), the honor of National-level Candidates of New Century Talents Program (2013), the honor of Young and Middle-aged Expert with Outstanding Contributions (2013), the honor of Excellent Researcher of China (2012), and the honor of New Century Excellent Talents in University. His recent research and teaching focus on Clean Production, Sustainable Consumption, Energy Policy and Energy Economics, CO_2 emission and Climate Policy. He has performed over 20 research projects for various China governmental agencies including NDRC, Ministry of Education, and NSFC. He published 3 books and over 200 papers in peer review Journals including Energy Economics, Energy Policy, Applied Energy, Renewable and Sustainable Energy Reviews, Energy, Journal of Cleaner Production, Journal of Industrial Ecology, and Ecological Indicators. 7 papers are ESI high indexed papers.