The Service Strategy and Influencing Factors of Online Recycling of Used Mobile Phones

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Abstract: Currently, many online platforms participate in the recycling of waste products, and the online recycling of used mobile phones is especially popular. We explore the service strategy for and the factors influencing customers’ willingness of online recycling (CWOR) of used mobile phones. We develop a game model of a reverse supply chain comprising a mobile phone manufacturer (MPM) and an online recycling platform (ORP) to analytically examine the influencing factors of CWOR. We show that the MPM’s profit is mainly affected by CWOR and the ORP’s offered recycling service. The impacts of customers’ preferences of the recycling price and recycling service on the MPM’s profit depend on the service cost coefficient. The ORP’s profit is independent of its service cost and customers’ preference of the recycling service. However, the impact of the recycling commission is restricted by customers’ preference of the recycling price. We also use structural equation modelling to empirically show that recycling service and environmental consciousness positively affect CWOR, and environmental protection publicity enhances environmental consciousness. In addition, customers’ age and income moderate the recycling service–CWOR link. Our findings reveal that improving the recycling service can directly and indirectly promote the recycling of used mobile phones. These findings provide guidance to the government and businesses related to used mobile phone recycling.

Keywords: supply chain management; game theory; empirical research; online recycling platform; customers’ willingness of online recycling; government environmental promotion

1. Introduction

Recent years have witnessed an increase in e-waste with rapid advances in electronic products. Global E-waste Monitoring 2020 reported that 53.6 million metric tons of e-waste were generated globally in 2019 (https://news.un.org/zh/story/2020/07/1061272 (accessed on 10 October 2021)). Recycling of used mobile phones has attracted great attention of society due to the corresponding economic and environmental benefits [1,2]. With accelerated replacement of mobile phones, massive quantities of used mobile phones are recyclable. An online report estimated the scrap volume of China’s mobile phones to be 303.933 million in 2018 (https://www.boolv.com/html/news/5452.html (accessed on 10 October 2021)). Incidentally, there is an urgent need to innovate the recycling channels for used mobile phones, encourage customers to actively participate in recycling, and realize the recycling and reuse of used mobile phones [3,4]. In this context, online recycling, which combines the used mobile phone recycling business with the Internet, is developing rapidly.

In the booming Internet economy, many online recycling platforms (ORPs) dedicated to the recycling business, e.g., European Recycling Platform, Aihuishou (China), and the ecoATM, have sprung up [5–7]. The recycling service covering inspection of the mobile phone’s conditions and house-call has become an important competitive advantage of
However, online recycling lacks standards and rules and has a low market share. In its Second-hand Mobile Phone Industry Research Report released in 2019 (https://www.199it.com/archives/822527.html (accessed on 1 October 2021)), 36kr.com (accessed on 1 September 2021) (an Internet media) estimated that only 20% of second-hand mobile phone transactions in China were completed online. The main reasons are: (1) it is difficult for customers to participate in recycling bargaining as the pricing power of used mobile phones is in the hands of the recycling firms, and (2) customers are reluctant to participate in online recycling due to a lack of convenient recycling scenarios and customers’ distrust of the recycling platforms (https://www.sohu.com/a/428062874_100014482 (accessed on 10 October 2021)). Thus, addressing the two problems of recycling pricing and recycling service is key to developing online recycling. Although the online recycling price is relatively open and transparent, customers have to make a quick decision whether or not to recycle their phones once the price is given, and they have no opportunity to negotiate with the recyclers. Without reasonable pricing of used mobile phones, customers are unwilling to recycle, which depresses the recycling rate. Moreover, the ORP, which directly interacts with customers, should provide customers with a satisfactory recycling service; otherwise, the recycling experience of customers will be adversely affected, leading to diminished recycling transactions. Thus, a better understanding of the pricing and the service strategy for online recycling will benefit the members of the online reverse supply chain.

Currently, most online recycling studies focus on the manufacturer’s choice of dual recycling channels [10,11], pricing strategies for the traditional and online recycling channels [12,13], and impacts of customer preferences of the choice of the dual recycling channel and recycling pricing strategy [9,14]. Meanwhile, customers’ willingness of online recycling (CWOR) is another driver of recycling of used mobile phones [15]. From the development law of the Internet economy, customers’ involvement is crucial for the success of the online economy. Different from the forward sales channels, used mobile phone recycling is not a solid demand of customers and the frequency of recycling is limited, and it is not worthy of attracting customers through the high-price recycling strategy. To stimulate customers’ participation in recycling, the influencing factors of CWOR must be explored. Additionally, Previous studies consider customers’ recycling behavior from the perspectives of information security, service convenience, and platforms’ transaction behavior [8,16–18]. However, these studies did not verify the relationship between recycling service and recycling willingness.

Therefore, in the context of online recycling, on the one hand, the paper develops a game model of a supply chain comprising a mobile phone manufacturer (MPM) and an ORP incorporating the recycling service as the decision variable, and analyzes the correlation between recycling service decisions and system operation. On the other hand, the study empirically explores the moderating effects of consumers’ demographic characteristics and mobile phone usage on the relationship of recycling service and CWOR. Notably, in terms of empirical researches, Yuan et al. [18] and Yin et al. [19] also explored the factors influencing CWOR to recycle used mobile phones. Among them, Yuan et al. [18] analyzed whether recycling facilities and services affect consumers’ reusable mobile phone transaction behavior, but did not further explore the impact of recycling services on the reverse supply chain or what factors affect recycling services. Yin et al. [19] examined the influence of consumers’ personal characteristics on CWOR and did not consider the possible influence of the market environment, including recycling services. In the study of the theoretical model, Wei et al. [20] consider recycling service costs in their theoretical model, but they do not explore the effect of recycler services on CWOR. Pourhejazy et al. [21] consider two types of waste electrical and electronic equipment (WEEE) recycling services in their model, but they focus on the trade-off between profit and service tubes for collectors. Giri et al. [22] examines pricing and product recycling strategies that include online channels, but they focus on the impact of recycling channels and dominant models on supply chain performance.

Developing a game model and an empirical model to study the influencing factors of CWOR, we seek to address three research questions as follows:

- How does the recycling service affect CWOR?
• What other factors affect CWOR?
• Do customers’ demographic characteristics and mobile phone usage pattern moderate the recycling service–CWOR link?

The innovation of our study lies in the game model we develop to analyze the service strategy for online recycling from the perspective of operations management. Based on the analytical findings, we apply structural equation modelling (SEM) to empirically examine the influencing factors of CWOR from the perspective of customers. We find that recycling services directly and indirectly affect CWOR of used mobile phones. Specifically, our major findings are as follows:

First, the MPM’s profit mainly depends on the quantity of mobile phones recycled. When the recycling commission changes, the MPM’s profit and recycling quantity are affected by customers’ preference of recycling and the ORP’s service cost coefficient. In addition, the impacts of customers’ preferences of the recycling price and recycling service on the MPM’s profit and recycling quantity depend on the service cost coefficient. The MPM can use a high recycling price to directly promote the recycling of used mobile phones. The MPM can offer a higher recycling commission to induce the ORP to provide customers with a better recycling service, which indirectly stimulates customers’ recycling activity. However, the effectiveness of these methods depends on the ORP’s service cost coefficient, and customers’ preferences of the recycling price and recycling service.

Second, the ORP’s profit is independent of the service cost coefficient and customers’ preference of the recycling service, but is associated with customers’ preferences of the external factors of the ORP. The ORP’s profit increases with customers’ voluntary recycling quantity and customers’ preference of the recycling price. Counterintuitively, increasing the recycling commission is not always beneficial to the ORP. The impact of the recycling commission on the ORP’s profit depends on customers’ preference of the recycling price. Therefore, instead of only considering its own cost constraints, the ORP should consider customers’ preference of the recycling price in deciding its recycling commission.

Finally, the recycling service level and customers’ environmental consciousness positively affect CWOR, and EP enhances environmental consciousness. Moreover, in terms of customers’ demographic characteristics and mobile phone usage pattern, we find that customers’ age, usage time of current mobile phones, and cumulative numbers of mobile phones owned are significantly related to their level of environmental consciousness. There are significant differences in CWOR of customers with different education levels and cumulative numbers of mobile phones owned. Customers’ age and income moderate the recycling service–CWOR link. The implication is that the online reverse supply chain should focus on improving the recycling service quality in view of the heterogeneity of customers and on strengthening recycling promotion.

We organize the rest of the paper as follows: In Section 2, we review the related studies to identify the research gap and position our study in the literature. In Section 3, we introduce the model of online recycling of used mobile phones, present the notation, and discuss the assumptions. In Section 4, we analyze the model and derive the analytical results. In Section 5, we present the empirical research and discuss the empirical findings. Finally, in Section 6, we conclude the paper, discuss the management insights of the research findings, and suggest topics for future research. We present the proofs of all the results in the Appendices A and B.

2. Literature Review

This study is closely related to three research streams, namely recycling strategies for waste products, online recycling, and influencing factors of customer online recycling. In the following we discuss the positioning of our work in relation to these research streams.

2.1. Recycling Strategies for Waste Products

Market competition and product heterogeneity affect enterprises’ recycling strategies. Toyasaki et al. [23] conducted a comparative analysis of competitive recycling and oligopoly
recycling. They found that although competitive recycling can reduce the recycling price and increase the recyclers’ profits, the recyclers are more in favour of oligopoly recycling when the product is highly replaceable or the economy scale for recycling is very efficient. Tian et al. [24] studied the recycling of waste products with different recycling structures and showed that when firms recycle separately, although recycling different products can benefit from economies of scale, the recycling of heterogeneous products can increase the cost. Mazahir et al. [25] found that product characteristics are very important when the government sets recycling policy goals, and different recycling goals should be set for different products. Esenduran et al. [3] explored the disposal of donated waste electronic appliances and showed that economies of scale can reduce the recycling cost, but recyclers may suffer profit losses due to economies of scale when there is channel competition. Zhu et al. [26] analyzed the dynamic decision-making process of recycling used batteries and studied the issue of cooperation between battery manufacturers and competitors. Focussing on the performance of recycling policies under the Extended Producer Responsibility framework, Zhou et al. [27] found that there is an upper bound on the government subsidy above which social welfare cannot be maximized or customer surplus cannot be reduced.

One of the commonly used methods for recycling WEEE is trade-in [28,29]. Zhang and Zhang [30] found that remanufacturing trade-in products may hurt customer surplus and social welfare when customers are strategic. Xiao and Zhou [31] focused on the recycling price of WEEE and the dynamic pricing of refurbished products. Considering trade-in as a way for recycling platforms to achieve price discrimination, Cao et al. [32] studied the pricing and sales strategies. Remanufacturing is a process to treat the used mobile phones. Esenduran et al. [33] showed that due to the remanufacturing cost, a higher recycling rate target is not conducive to remanufacturing. Moreover, they found that customers can benefit from strict recycling targets and less competition. Zhang et al. [34] found that a moderate recycling cost factor can help achieve Pareto improvements for OEMs and remanufacturers.

2.2. Online Recycling

The extant research on online recycling of waste products mostly focuses on the dual recycling channel consisting of online recycling and traditional recycling. Hahler and Fleischmann [37] studied the detection process of waste products and showed that the ORP can secure strong bargaining power by gaining the first-mover advantage. By comparing with the situation without recycling, Ren et al. [11] showed that when the cost of producing new products is more than that of remanufacturing, the manufacturer tends to choose an online sales platform to recycle waste products. Considering customers’ preference of the recycling channel, Feng et al. [12] compared four different recycling modes and found that online and offline dual-channel recycling is better than single-channel recycling because the online recycling channel can increase the offline recycling price. Subsequently, Li et al. [38] found that the dual recycling channel, i.e., online and offline, is not always better than the single recycling channel. However, they also found that online recycling can increase the recycling price, so it benefits the recycling of waste products. Taleizadeh and Sadeghi [13] focused on the competitive dual recycling channel and found that online recycling can take a large market share due to the lower cost and the higher recycling price. Chu et al. [10] suggested that multiple manufacturers cooperating with a third-party ORP to recycle is
better than a single manufacturer or a single retailer pursuing recycling on its own, and cooperating with a third-party ORP can yield higher social welfare.

Research on customers’ preference of the recycling channel has attracted increasing attention. Wang et al. [14] analyzed the impacts of customers’ channel preference on the recycling price and the recycling transfer payment by modelling a dual recycling channel in which a manufacturer cooperates with a retailer or a third-party ORP. Similarly, Wu et al. [9] modelled the dual recycling channel with an ORP and studied the impacts of customers’ channel preference on the recycling pricing and recycling service. They also designed a revenue sharing contract by adjusting the recycling transfer payment. However, while proposing improving the recycling service, Wu et al. [9] did not analyze the impact of recycling service on recycling pricing. Considering that the ORP should actively engage in marketing, Xiang and Xu [39] studied the ORP’s role in improving business reputation and showed that big data marketing is beneficial for recycling.

We summarize in Table 1 the main differences between our study and the literature on online recycling strategies. Specifically, we consider the recycling service as a decision variable and analyze the impacts of customers’ channel preference and the ORP’s service cost coefficient on the pricing and service strategies. In addition, we empirically find that the recycling service, an important factor affecting recycling, can indirectly promote online recycling by increasing CWOR.

| Literature                  | Model Structure                                                                 | Recycling Service (Effort) Is Considered? | Recycling Service (Effort) Is Endogenous? | Recycling Quantity Is Affected by Recycling Service (Effort)? | Decision Variable | Recycling Price | Recycling Service (Effort) |
|-----------------------------|---------------------------------------------------------------------------------|------------------------------------------|------------------------------------------|-------------------------------------------------------------|-------------------|----------------|-------------------|
| Giri et al. [22]            | Manufacturer, retailer, and a third party                                       | Y                                        | N                                        | N                                                            | Y                 | N              | N                 |
| Feng et al. [12]            | Recyclable dealer and recycler                                                  | N                                        | -                                        | N                                                            | Y                 | N              | N                 |
| Taleizadeh and Sadeghi [13] | Manufacturer, retailers, and thirty-party players, but online recycling is not considered | Y                                        | Y                                        | N                                                            | Y                 | N              | Y                 |
| Chu et al. [10]             | Multiple manufacturers and retailers, and a thirty-party online platform        | Y                                        | Y                                        | N                                                            | N                 | N              | Y                 |
| Wang et al. [14]            | Manufacturer, retailers, and a thirty-party collection platform                 | N                                        | -                                        | N                                                            | Y                 | N              | N                 |
| This Study                  | Manufacturer and an online recycling platform                                  | Y                                        | Y                                        | Y                                                            | Y                 | Y              | Y                 |

2.3. Influencing Factors of Customers’ Willingness of Online Recycling

We also conduct empirical research on CWOR in this study. The economic significance of recycling is that the manufacturer can reduce the production cost through the reuse of raw materials. For the customer, participation in recycling used mobile phones is more likely stimulated by their environmental consciousness, even with low economic returns. Only customers with lower incomes prefer higher recycling prices through online recycling [40]. Through interviews, questionnaires, and behavioral experiments, Simpson et al. [41] investigated customers’ recycling behavior and concluded that customers tend to recycle high-quality products to obtain higher monetary returns. However, it is not an economic way for recyclers to promote recycling simply by increasing the recycling price, so stimulating customers’ participation in online recycling by other means will promote online cycling. Studying the influencing factors of customers’ recycling of used mobile phones, Yin et al. [19] found that the factors affecting Chinese customers’ willingness to recycle are region, education level, and monthly income. Islam et al. [42] showed the importance of environmental protection education because many customers are not familiar with mobile phone recycling. However, Zhou et al. [43] found that environmental protection education is beneficial only under the circumstances where customers’ interest in environmental protection is low; otherwise, environmental education for customers may be detrimental.
Regarding online recycling, Dhanorkar [5] conducted a quasi-experimental study and empirically verified that online second-hand trading platforms can effectively reduce waste products. Bai et al. [8] explored the status quo of online recycling of used mobile phones in China through a questionnaire survey. Comparing OEM’s online collection and third-party online collection, Esenlan et al. [44] found that customers are more sensitive to price, payment arrival time, and ratings of third-party online collection. Conducting empirical research in seven regions of China, Wang et al. [40] found that perceived behavioral control, supervisory norms, customers’ attitudes, and economic motivations have positive impacts on online recycling, and convenient online recycling attracts customers to recycle household appliances online. Wang et al. [17] found that products’ green information and the ORP’s corporate social responsibility can increase customers’ willingness to recycle, and the ORP’s reputation moderates the impact of the platform’s corporate social responsibility on customer trust.

It is evident from the above discussion that much of the literature up to now has focused on the factors affecting the recycling of used mobile phones and selection of the online recycling channel, while there is no research on the impact of customers’ heterogeneity on CWOR. In this study, we examine the moderating effects of customers’ demographic characteristics and mobile phone usage pattern on the recycling service–CWOR link. Additionally, this paper combines empirical and theoretical research to explore not only the factors influencing CWOR, but also to further explore the impact of CWOR on the reverse supply chain of used mobile phones. The specific differences between this study and the existing relevant literature are summarized in Table 2.

| Literature            | Method                | Major Contributions                                                                 | Influencing Factors                                               |
|-----------------------|-----------------------|--------------------------------------------------------------------------------------|-------------------------------------------------------------------|
| Wang et al. [17]      | Empirical research    | The impact of green messages on the willingness to participate in online recycling websites was studied | Green perceived value, green trust, and recycling platform reputation |
| Yuan et al. [18]      | Empirical research    | Factors affecting consumers’ used mobile phone transactions and their degree of influence were examined | Environmental awareness, information leakage sensitivity, transaction convenience and consumer transaction returns, etc. |
| Wang et al. [40]      | Empirical research    | Factors influencing residents’ willingness to participate in online e-waste recycling are explored | Perceived behavioral control, subjective norms, attitudes, and economic motivation |
| Simpson et al. [41]   | Experimental research | The influence of consumers’ psychological characteristics on product recall was investigated | Two psychological tendencies (attachment and frugality)            |
| Yin et al. [19]       | Empirical research    | Factors affecting consumer behavior, attitudes and willingness to pay for recycling used cell phones were addressed | Region, education level and monthly income                          |
| Zhou et al. [43]      | Theoretical research  | The relationship between consumer education and remanufacturing industry development was studied | Consumer education                                                |
| This Study            | Theoretical research and Empirical research | The influence of consumers’ willingness to recycle on the reverse supply chain of used mobile phones (theoretical research) and the factors influencing consumers’ willingness to recycle (empirical research) were examined | Recycling services, environmental awareness, environmental promotion, consumer age and income, etc. |
3. Model of Online Recycling of Used Mobile Phones

3.1. Model Description

We consider an online reverse supply chain comprising an MPM and an ORP, where the former relies on the latter to recycle used mobile phones with a certain residual value, as shown in Figure 1. The MPM focus on residual value of used mobile phones and publishes the information about recycling phones on the ORP, including the phone type, phone quality requirements, and recycling price. The customer browses the recycling information on the ORP and submits information about their used mobile phone (e.g., the shell condition and the mobile phone performance) that he wants to recycle. The customer can mail their used mobile phone to the ORP or wait for the staff from the ORP to pick up the phone. The customer’s recycling can be completed only after completion of the inspection of the used mobile phone. In this process, the MPM pays a commission to the ORP based on the quantity and quality of the recycled phones and benefits from the residual value of the used mobile phone. The ORP is responsible for the services during the recycling process.

Figure 1. The online reverse supply chain model of used mobile phones.

The MPM entrusts the ORP to recycle used mobile phones and the revenue of the ORP mainly depends on recycling, which disadvantages the ORP in the system’s decision-making process. So, we make the following major assumptions.

1. The MPM dominates the decision-making in the online reverse supply chain.
2. Both the MPM and ORP are rational and have symmetrical information.
3. The ORP strictly evaluates the recycled phone to ensure that it has the recycling value.

We use following notation throughout the paper.

$h$: Residual value of a used mobile phone.

$p$: Recycling price of used mobile phone. It is the decision variable of the MPM.

$\rho$: Recycling commission charged by the ORP. $h > \rho + p$ so that it is profitable for the MPM to recycle mobile phones. Given that aihuishou.com settles the commission payment with the MPM once a month, we take the recycling commission as an exogenous variable in this study in order to focus on the recycling service.

$s$: Recycling service level provided by the ORP for the MPM. It is a decision variable of the ORP. Following Bakal and Akcali [45], we assume that the service cost is $C(s) = ks^2/2$, where $k (k > 0)$ is the service cost coefficient.

$q$: Recycling quantity of used mobile phones, which is positively affected by the recycling price and recycling service level. Following Wu [46], we assume that the recycling quantity satisfies the following condition

$$q = \alpha + \beta p + \lambda s,$$

where $\alpha (\alpha \geq 0)$ represents the voluntary recycling quantity, i.e., the quantity of used mobile phones recycled for free due to customers’ environmental consciousness; and
\( \beta (\beta \geq 0) \) and \( \lambda (\lambda \geq 0) \) denote customers’ preferences of the recycling price and recycling service, respectively, i.e., the price and service elasticities of the recycling quantity.

It follows that the MPM’s profit is
\[
\pi_m = (h - \rho - p)(\alpha + \beta p + \lambda s),
\]
and the ORP’s profit is
\[
\pi_e = \rho(\alpha + \beta p + \lambda s) - ks^2 / 2.
\]

### 3.2. Model Solution

As independent economic entities, the MPM and ORP interact and make decisions to maximize their own profits, constituting a Stackelberg game. First, the MPM sets the recycling price \( p \), then the ORP determines the corresponding recycling service level \( s \).

We use the backward induction approach to derive the optimal decisions of the game players [47].

From Equation (3), we have
\[
\frac{\partial^2 \pi_e}{\partial s^2} = -k < 0,
\]
so \( \pi_e \) is a concave function in \( s \). Solving \( \frac{\partial \pi_e}{\partial s} = \lambda \rho - ks = 0 \) yields
\[
s = \frac{\rho \lambda}{k}. \tag{4}
\]

Substituting Equation (4) into Equation (2) yields
\[
\pi_m = (h - \rho - p)\left(\alpha + \beta p + \frac{\rho \lambda^2}{k}\right). \tag{5}
\]

From Equation (5), we have \( \frac{\partial^2 \pi_m}{\partial p^2} = -2\beta < 0 \), so \( \pi_m \) is concave in \( p \). Solving \( \frac{\partial \pi_m}{\partial p} = 0 \) yields
\[
p = \frac{k[\beta(h - \rho) - \alpha] - \rho \lambda^2}{2k\beta}. \tag{6}
\]

So, the optimal decisions are as follows: The recycling price is \( p^* = \frac{k[\beta(h - \rho) - \alpha] - \rho \lambda^2}{2k\beta} \), the recycling service level is \( s^* = \frac{\rho \lambda}{k} \), the recycling quantity is \( q^* = \frac{k[\beta(h - \rho) + \alpha] + \rho \lambda^2}{2k\beta} \), the MPM’s profit is \( \pi_m^* = \left\{\frac{k[\beta(h - \rho) + \alpha] + \rho \lambda^2}{2k\beta}\right\}^2 \), and the ORP’s profit is \( \pi_e^* = \frac{k[\beta(h - \rho) + \alpha]}{2} \).

Accordingly, we derive the following result.

**Lemma 1.** (1) The recycling commission should be reasonably set at \( 0 < \rho < \frac{k[\beta(h - \alpha)]}{k\beta + \lambda^2} \), and (2) The residual value of the used mobile phone should be \( h > \frac{\alpha}{\beta} \).

We derive Lemma 1 from the fact that the recycling price, recycling service level, recycling quantity, recycling quantity, MPM’s profit, and ORP’s profit are positive. Lemma 1 shows that the recycling commission should be in a proper range to ensure normal operations of the ORP. An excessive recycling commission is not conducive to cooperation between the MPM and ORP, and is detrimental to the ORP. The greater the voluntary recycling quantity is, the smaller is the range of the recycling commission for the ORP, i.e., the upper limit of the recycling commission is reduced. Therefore, increasing the voluntary recycling quantity enables the MPM to squeeze the recycling commission, raising the MPM’s recycling enthusiasm.

On the other hand, Lemma 1 signifies that not all used mobile phones have recycling value, and the MPM should identify the types of acceptable used mobile phones and publishing the corresponding recycling information. This also explains the phenomenon in real practice that the MPM is more willing to recycle recent mobile phone models than old models. This is because the parts of old mobile phones are obsolete and cannot be utilized
in the development and production of new mobile phones. This also reminds the customer
that they should recycle their used mobile phone as soon as possible to secure the returns.

Lemma 2. (1) When \( s \leq \frac{\rho \lambda}{2} \), \( \pi_e \) increases with \( s \), but the increasing trend becomes flat, and
(2) when \( s > \frac{\rho \lambda}{2} \), \( \pi_e \) decreases with \( s \) and the decrease becomes more evident.

We derive Lemma 2 from the ORP’s profit function, i.e., Equation (3). The ORP’s profit
is concave in the recycling service level. When the recycling service level is low, the ORP
can improve its service to increase the recycling quantity and increase its profit, but the
marginal effect will gradually decrease with the improvement of the service level. When
the service level is high, e.g., \( s > \frac{\rho \lambda}{2} \), although a better service can promote the recycling of
used mobile phones, the ORP will incur a higher service cost, so the profit decreases with
the improvement of service.

4. Model Analysis

4.1. Theoretical Analysis

Proposition 1. (1) The optimal recycling service level \( s^* \) is positively related to customers’ prefer-
ces of the recycling service \( \lambda \) and recycling commission \( \rho \). (2) The optimal recycling price \( p^* \) is
negatively related to the recycling commission \( \rho \).

(Proposition is obtained by finding \( \lambda \) partial derivative for \( s^* \) and the partial derivative
of \( \rho \) for \( s^* \) and \( p^* \), respectively.)

With an increase in \( \lambda \), the customer becomes sensitive to the recycling service. To im-
prove the recycling quantity and recycling profit, the ORP should provide a better recycling
service to attract more customers. An increase in the recycling commission means that the
ORP can obtain more commission income, which offsets the recycling service cost, so the
recycling service will be improved. Moreover, an improvement in the recycling service can
attract more customers to participate in recycling, so the MPM will reduce the recycling
price to cope with the cost pressure caused by the increased recycling commission.

As the recycling commission increases, the MPM’s pricing strategy and the ORP’s
service strategy show opposite changes. This is mainly because the two strategies are
mutually substituting in terms of attracting customers to recycle used mobile phones.
The MPM as the dominant player can change its pricing strategy in the opposite direction
of the ORP’s service to maximize the MPM’s profit.

Proposition 2. (1) The optimal recycling quantity \( q^* \) and the MPM’s optimal profit \( \pi_{m}^* \) are
positively correlated with the voluntary recycling quantity \( \alpha \), and customers’ preferences of the
recycling price \( \beta \) and the recycling service \( \lambda \). When \( \lambda > \sqrt{\frac{h}{2}} \), the recycling quantity and the
MPM’s profit are positively correlated with the recycling commission \( \rho \); when \( \lambda < \sqrt{\frac{h}{2}} \), the
recycling quantity and the MPM’s profit are negatively correlated with the recycling commission.
(2) Customers’ preferences of the recycling price and recycling service \( \beta \) and \( \lambda \) have different degrees
of impact on the optimal recycling quantity \( q^* \) and the MPM’s optimal profit \( \pi_{m}^* \). When \( k > k_s \),
where \( k_s = \frac{2\rho \lambda}{k - \rho} \), the recycling quantity is more affected by costumers’ preference of the recycling
price; when \( k < k_s \), the recycling quantity is more affected by customers’ preference of the recycling
service. Similarly, when \( k > k_{ss} \), where \( k_{ss} = \frac{\rho \lambda (4B + \lambda)}{\beta (h - \rho) - \rho} \), the MPM’s profit is more affected by
costumers’ preference of the recycling price; when \( k < k_{ss} \), the MPM’s profit is more affected by
customers’ preference of the recycling service.

Proof. See Appendix A. □

It is noted that the MPM’s profit is mainly decided by the quantity of recycled phones. Both
the MPM’s profit and the quantity of recycled phones are affected by system param-
eters. Specifically, the higher the customers’ voluntary recycling quantity is, the higher
are the recycling quantity and the MPM’s profit. When customers’ recycling behavior is more susceptible to the recycling price and recycling service, the MPM and ORP gain more flexibility in adjusting their recycling pricing and service strategies. Therefore, the recycling quantity and the MPM’s profit increase with customers’ preferences of the recycling price and recycling service.

Although customers’ preferences of the recycling price and recycling service can increase the recycling quantity and the MPM’s profit, their effects are different. When the service cost coefficient is large \((k > \max(k_s, k_{ss}))\), the recycling quantity and the MPM’s profit are more affected by the preference of the recycling price; but when the service cost coefficient is small \((k < \min(k_s, k_{ss}))\), the recycling quantity and the MPM’s profit are more affected by the preference of the recycling service. Therefore, the MPM can directly stimulate the customer to recycle their used mobile phone by increasing the recycling price. The MPM can also encourage the ORP to provide a higher recycling service level by accepting a higher recycling commission to indirectly increase the recycling quantity.

Since increasing the recycling commission can increase the recycling service level and reduce the recycling price, the impacts of the recycling commission on the recycling quantity and the MPM’s profit are uncertain. When the customer has a higher preference for the recycling service, e.g., \(\lambda > \sqrt{k\beta}\), it is effective to indirectly increase the recycling quantity through a higher recycling commission because the recycling quantity and the MPM’s profit increase with the recycling commission. However, when customers preference of the recycling service is low, e.g., \(\lambda < \sqrt{k\beta}\), the indirect method of a higher recycling commission is not helpful because the recycling quantity and the MPM’s profit decrease with the recycling commission.

**Proposition 3.** The ORP’s profit \(\pi^*_e\) is positively related to customers’ voluntary recycling quantity \(\alpha\) and preference of the recycling price \(\beta\). When \(\beta < \beta_s\), the ORP’s profit is positively related to the recycling commission \(\rho\); when \(\beta > \beta_s\), the ORP’s profit first increases and then decreases with the recycling commission, and maximum profit is obtained when \(\rho = \frac{\alpha + h\beta}{2\beta}\), where \(\beta_s = \frac{3\alpha + 2h\lambda^2 + \sqrt{9\alpha^2\lambda^2 + 108\alpha\lambda^2 + h^2\lambda^4}}{2\alpha}\).

**Proof.** See Appendix B. □

The ORP’s profit is independent of the service cost coefficient \(k\) and customers’ preference of the recycling service \(\lambda\), but depends on customers’ voluntary recycling quantity \(\alpha\) and preference of the recycling price \(\beta\). With an increase in preference of the recycling price, the recycling service remains unchanged, but an increase in the recycling price helps improve the recycling quantity, so the ORP’s profit increases. Similarly, when the voluntary recycling quantity increases, the ORP obtains additional recycling quantity and profit.

Besides, an increase in the recycling commission \(\rho\) inevitably causes the MPM to reduce the recycling price, while also stimulating the ORP to improve the recycling service level and increase the service cost. Therefore, the impact of the recycling commission on the ORP’s profit is not certain. When the customer is not sensitive to the recycling price, i.e., \(\beta < \beta_s\), although an increase in the recycling commission reduces the recycling price, the recycling quantity is less affected. An improvement in the recycling service helps increase the recycling quantity, so the ORP profits more as the recycling commission increases. When the customer is sensitive to the recycling price, i.e., \(\beta > \beta_s\), although an increase in the recycling commission brings a short-term increase in the ORP’s profit, the decline in the recycling price makes the recycling quantity decrease and the service cost rises due to the higher recycling service level, ultimately reducing the ORP’s profit as the recycling commission increases. Therefore, in real practice, the ORP needs to consider customers’ recycling preference when setting the recycling commission.
4.2. Numerical Studies

We conducted numerical studies to verify the analytical findings and ascertain the impacts of different model parameters on the optimal decisions. The values of the parameters should match the model description and fit the conditions in the lemmas and propositions. Setting \( \alpha = 10, \ h = 20, \ k = 2, \) and \( \beta = 5, \) we analyze the impacts of the recycling commission on the MPM’s profit in two cases where we set customers’ preference of the recycling service as \( \lambda_1 = 4 \) and \( \lambda_2 = 2 \) to denote the customer with a strong and a weak preference for the recycling service, respectively. We show in Figure 2 changes in the MPM’s profit with the recycling commission in the two cases (the ranges of the recycling commission are different in the two cases and we round down the upper limit).

![Figure 2](image1)

**Figure 2.** Impact of the recycling commission on the MPM’s profit under different customers’ preference of the recycling service: (a) When \( \lambda \) is strong \( (\lambda_1 = 4) \); (b) When \( \lambda \) is weak \( (\lambda_2 = 2) \).

Then, we set \( \alpha = 10, \ h = 20, \ k = 2, \) and \( \lambda = 3 \) to analyze the impacts of the recycling commission on the MPM’s profit under different customers’ preference of the recycling price. When \( \beta_1 = 6, \) it denotes that the customer has a weak preference for the recycling price, while \( \beta_2 = 14 \) denotes that the customer has a strong preference for the recycling price. We show in Figure 3 the relationships between the ORP’s profit and the recycling commission in the two cases (the ranges of the recycling commission are different in the two cases and we round down the upper limit).

![Figure 3](image2)

**Figure 3.** Impact of the recycling commission on the ORP’s profit under different customers’ preference of the recycling price: (a) When \( \beta \) is weak \( (\beta_1 = 6) \); (b) When \( \beta \) is strong \( (\beta_2 = 14) \).

Figures 2 and 3 show that the recycling commission, the setting of which involves customers’ preferences of the recycling price and recycling service, is an important factor.
affecting the MPM’s and ORP’s profits. For the MPM, the impact of the recycling commission on profit depends on customers’ preference of the recycling service. A higher recycling commission will produce more profit when the customer has a high preference for the recycling services while it hurts the profit if customers’ preference is low. For the ORP, the impact of the recycling commission mainly depends on customers’ preference of the recycling price. When customers’ preference of the recycling price is low, increasing the recycling commission helps increase the ORP’s profit, but the growth gradually decreases. When customers’ preference of the recycling price is high, an increase in the recycling commission does not always help improve the ORP’s profit, which renders the ORP’s profit decrease if the recycling commission exceeds a particular value, i.e., $\rho = 10$ in Figure 3b.

Although the above analysis shows that customers preferences of both the recycling price and recycling service have impacts on the MPM’s profit, understanding of the differences between these two types is limited. In this subsection, we conduct a comparative analysis through numerical studies. Letting $\alpha = 10$, $h = 20$, and $k = 2$, we assume that $\rho = 5$, $\beta = [5, 10]$, and $\lambda = [5, 10]$. Suppose the service cost coefficient satisfies $k_1 = 2$ and $k_2 = 20$ for the two cases where the service cost coefficient is small and large, respectively. We show in Figure 4 changes in the MPM’s profit under different service cost coefficients.

![Figure 4](image)

**Figure 4.** Impact of customers’ preferences of the recycling price and recycling service on the MPM’s profit under different service cost coefficients: (a) When $k$ is small ($k_1 = 2$); (b) When $k$ is big ($k_2 = 20$).

We see that customers’ preferences of the recycling price and recycling service have different degrees of impact on the MPM’s profit. When the service cost coefficient is small, customers’ preference of the recycling service has a greater impact on the MPM’s profit than customers’ preference of the recycling price. The main reason is that the recycling service is better when the service cost coefficient is small, which is conducive to promoting the recycling of used mobile phones. However, when the service cost coefficient is large, customers’ preference of the recycling price has a greater impact on the MPM’s profit because the recycling service is worse, and the online reverse supply chain cannot effectively respond to customers’ service demand.

In addition to the above model parameters, customers’ voluntary recycling quantity also affects the process of recycling used mobile phones. Setting $h = 20$, $k = 2$, $\beta = 5$, $\lambda = 2$, and $\rho = 9$, we show in Figure 5 the impacts of the voluntary recycling quantity on the recycling quantity, and the MPM’s and the ORP’s profits.

The recycling quantity of used mobile phones increases with the voluntary recycling quantity. Moreover, an increase in the voluntary recycling quantity increases the MPM’s and ORP’s profits, which means that it is always beneficial to increase customers’ voluntary recycling quantity from the perspectives of environmental protection and the online reverse supply chain.

The voluntary recycling quantity, and customers’ preferences of the recycling price and recycling service are related to customers and reflect customers’ attitude towards online recycling and their recycling behaviors, so we refer to them as parameters of CWOR.
We see that an increase in any of the parameters of CWOR increases the quantity of recycled mobile phones (arrowheads with solid lines in Figure 6).

Figure 4. Impact of customers’ preferences of the recycling price and recycling service on the MPM’s profit under different service cost coefficients: (a) When \( k \) is small (\( k^1 = 2 \)); (b) When \( k \) is big (\( k^2 = 20 \)).

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Note: The superscript * means that the variables are optimal solutions.

Figure 5. Impact of the voluntary recycling quantity: (a) Change in the recycling quantity; (b) Changes in the MPM’s and ORP’s profits.

The voluntary recycling quantity, and customers’ preferences of the recycling price and recycling service are related to customers and reflect customers’ attitude towards online recycling and their recycling behaviors, so we refer to them as parameters of CWOR. We see that an increase in any of the parameters of CWOR increases the quantity of recycled mobile phones (arrowheads with solid lines in Figure 6).

Figure 6. The connection between the game model and empirical research.

In Figure 6, the direct impact of the recycling service level as well as CWOR (including \( \alpha \), \( \beta \), and \( \gamma \)) on recycling is straightforward. As the main factor studied in the theoretical model, the service level can be regulated by ORP, and it is easy to achieve the optimal service strategy given by the model. However, consumer intention, also a major factor, on the one hand, cannot be analyzed in depth as an exogenous variable in the theoretical model. On the other hand, it is difficult for MPM and ORP to regulate it to a level beneficial to the reverse supply chain. Therefore, based on the theoretical model, this paper constructs a structural equation model to further explore CWOR and mainly answer the following questions. What factors affect CWOR? How can MPM and ORP effectively contribute to CWOR? The empirical analysis is presented in the next section as a further extension of the theoretical analysis and numerical studies.

5. The Influencing Factors of CWOR

5.1. Research Model and Hypotheses

Grounded in Theory of Reasoned Action, Theory of Planned Behavior, and the Service Quality Model, we examine the influencing factors of customers willingness to recycle are customers’ perceptions and attitudes, including cognition of the ORP’s recycling service level and their attitudes towards environmental protection. Accordingly, we propose the research model. As shown in Figure 7, the chapter explores the impact of service level and environmental consciousness on CWOR. Among them, the service level is decomposed
from five perspectives: tangibility, reliability, responsiveness, assurance, and empathy. The effects of demographic characteristics and mobile phone usage on environmental consciousness and CWOR are explored. Among them, demographic characteristics are decomposed from four perspectives: gender, age, income, and education level, while mobile phone usage is measured by the length of time spent on mobile phones and the number of mobile phones owned. Furthermore, the role of environmental protection publicity on consumer environmental consciousness is also explored.

Figure 7. The research model of the influencing factors of CWOR.

(1) Impact of recycling service level on CWOR

Service level is one of the fundamental factors that affect customers’ decision-making. According to the SERVQUAL Model, the service level can be measured by tangibility, reliability, responsiveness, assurance, and empathy. Many empirical studies have shown that these are driving factors for customers to choose online services [48]. For example, Águila-Obra et al. [49] found that service level positively affects customers’ use of online postal services. Li et al. [50] found that service level positively affects customers’ use of online shopping sites. Priporas et al. [51] showed that service level also positively affects customers’ usage of Airbnb.

Combining the operation characteristics of online recycling in China, we analyze in this study the influencing factors of CWOR based on the Service Quality Model. Tangibility mainly relates to the service facilities, equipment, and service personnel appearance. Since Chinese ORPs (e.g., Aihuishou and JD Recycling) provide recycling services through the website and door-to-door service, tangibility is further divided into website tangibility and personnel tangibility, which refer to the quality of the website pages and personnel’s appearance and equipment, respectively. Reliability refers to the ORP’s ability to accurately fulfill its service promises, such as ensuring data removal. Reliability affects CWOR because customers are usually concerned about the security risk of incomplete data removal when recycling mobile phones [18]. Responsiveness means that the ORP is willing to help customers recycle and provide timely services. A timely response to demand will have an impact on customers’ attitudes. Assurance means that the ORP’s employees have the corresponding knowledge and ability to help customers complete online recycling, which also has an important impact on CWOR. Finally, empathy refers to the personalized care provided by the ORP to customers, which also affects CWOR.

Considering that a better recycling service is conducive to improving the recycling quantity, we hypothesize that:

**Hypothesis 1 (H1). The recycling service level positively affects CWOR.**
(2) Impact of environmental consciousness on CWOR

Environmental consciousness represents the degree of an individual’s concern for the environment and positively affects the individual’s green behavior [52–54]. According to the psychological law that consciousness determines behavior, individuals often consciously maintain an ecological balance and oppose environmental pollution under the positive impact of environmental consciousness. For instance, Xu et al. [48] showed that environmental consciousness significantly positively affects customers’ purchase behavior of green furniture. The empirical analysis of Ting et al. [53] indicated that environmental consciousness positively affects customers’ choice of green tourism. So, we hypothesize that:

Hypothesis 2 (H2). Environmental consciousness positively affects CWOR.

(3) Impact of environmental protection publicity on environmental consciousness

Publicity helps the audience form cognition of social norms or subjective norms, so affecting their attitudes and behaviors. Through publicity, customers develop normative awareness of participating in online recycling of used mobile phones and form environmental consciousness. Wang et al. [40] showed that subjective norms and attitudes positively affect online recycling. Yin et al. [19] found that environmental protection education helps the consumers develop good environmental behaviors. Islam et al. [42] also pointed out the necessity of providing EP and education to customers. So, we hypothesize that:

Hypothesis 2 (H3). Environmental protection publicity positively affects environmental consciousness.

(4) Impacts of demographic characteristics and mobile phone usage pattern on environmental consciousness and CWOR

Researchers believe that demographic characteristics such as gender, age, income, and education level also affect people’s environmental consciousness [55–57]. Yin et al. [19] surveyed recycling used mobile phones in China, and found that region, monthly income, and education level affect recycling mobile phones. In addition, according to Okada et al. [58], other factors such as the number of mobile phones owned and the length of time the phone has been used may also affect environmental consciousness.

Therefore, we further analyze environmental consciousness and CWOR among customers with different demographic characteristics and mobile phone usage pattern, and examine the moderating effects of personal characteristics and mobile phone usage pattern on the recycling service–CWOR link.

5.2. Research Design and Data Analysis
5.2.1. Measurement Variables

We design a questionnaire to collect data to test the research model proposed in Section 5.1. We show in Table 3 the measurement metrics developed based on the pertinent literature. All the measurement items in Table 3 use a 7-point Likert scale with 1 denoting strongly disagree and 7 denoting strongly agree.

5.2.2. Data Collection

We received 245 completed questionnaires through an online survey. There were 227 valid questionnaires with an effective rate of 92.65%. Table 4 shows the demographic characteristics. From the perspective of online recycling platforms, Xianyu, Aihuihui, and JD Recycling are the most used, with more than 85% of the users. There are more female respondents. Most of the participants hold a bachelor’s degree and have a monthly income between RMB 4500 and 8000. Most of them have used their current phone for 1–2 years and have owned three mobile phones on average. Most of the participants are under the age of 40 and more than two-thirds of them are well educated, which means that they have recycling awareness and understand the operations of online recycling. Therefore, the sample is representative and suitable for our study.
| Constructs                          | Codes | Items                                                                                     | Sources                                      |
|------------------------------------|-------|-------------------------------------------------------------------------------------------|----------------------------------------------|
| Environmental Consciousness (EC)   | EC1   | I am very concerned about environmental issues.                                            | Xu et al. [48] and Xu et al. [54]             |
|                                    | EC2   | I believe that humans and nature should live in harmony to ensure sustainable development.  |                                              |
|                                    | EC3   | I am willing to start from my own consumption to achieve sustainable development.           |                                              |
| EP                                 | EP1   | I like most of the environmental promotion methods.                                        | Wang et al. [40] and Wang et al. [17]        |
|                                    | EP2   | In most cases, I think the content of environmental protection promotion is appropriate.   |                                              |
|                                    | EP3   | I often see publicity of environmental protection.                                         |                                              |
| Recycling Service Level (RSL)      | RSL1  | Easy operation of online recycling platform (ORP) (Tangibility).                           | Priporas et al. [51] and Hapsari et al. [59] |
|                                    | RSL2  | Advanced equipment for network recycling platform employees (Tangibility).                  |                                              |
|                                    | RSL3  | The promises that ORP made to customers can be completed in time (Reliability).            |                                              |
|                                    | RSL4  | ORP can provide the promised service on time (Reliability).                                |                                              |
|                                    | RSL5  | ORP can handle various problems in time (Responsiveness).                                  |                                              |
|                                    | RSL6  | Online customer service can respond to customers in time (Responsiveness).                 |                                              |
|                                    | RSL7  | The employees of ORP are trustworthy (Assurance).                                          |                                              |
|                                    | RSL8  | I feel safe in the contact with ORP providing recycling service (Assurance).               |                                              |
|                                    | RSL9  | ORP understands my special needs and pays attention (Empathy).                            |                                              |
|                                    | RSL10 | ORP always insists on interests of customers first (Empathy).                              |                                              |
| CWOR                               | CWOR1 | I am willing to recycle used mobile phones through this ORP now.                          | Sun and Jayaraj [60], and Wang et al. [40]  |
|                                    | CWOR2 | I will recycle used mobile phones through this platform in the future.                     |                                              |
|                                    | CWOR3 | Even if the recycling price is unsatisfactory, I am willing to recycle used mobile phones through this platform. |                                              |
|                                    | CWOR4 | I am willing to let this ORP to dispose of my used mobile phones.                         |                                              |

5.2.3. Data Analysis

(1) Model reliability and validity analyses

Model reliability mainly refers to the consistency of the measurement variables, which is generally judged by Cronbach’s alpha, composite reliability (CR), and average variance extracted (AVE). Validity mainly refers to whether the measurement metrics reflect the latent variables, which is usually tested by convergent validity. Convergent validity is generally verified by factor loadings, CR, and AVE. According to Hair et al. [61], Cronbach’s alpha > 0.7, CR > 0.7, factor loadings > 0.5, and AVE > 0.5 for the measurement model to maintain reliability and validity. According to the test results shown in Table 5, the measurement model has good internal consistency and convergent validity.

(2) Analysis of SEM

We show in Figure 8 the results of the model fit test, where e1-e20 denote the measured residuals of each observed variable. According to Hair et al. [61], a larger chi-square value (CHI) represents a better model fit. The ratio of the chi-square value to the degree of freedom (DF) should be five, and it is excellent if the ratio is less than three; the values of goodness-of-fit index (GFI) and adjusted goodness-of-fit index (AGFI) should be as large as possible, and not being less than 0.7. The value of root mean square error of approximation (RMSEA) should be less than 0.1, and being less than 0.08 is fine. The test results are: CHI = 470.647, DF = 167, CHI/DF = 2.818, GFI = 0.830, AGFI = 0.787, and RMSEA = 0.097, indicating that our proposed research model is acceptable.

(3) Hypothesis testing

Hypotheses 1–3 proposed in Section 5.1 examine the impact of the recycling service level on CWOR, the impact of environmental consciousness on CWOR, and the impact
of EP on environmental consciousness, respectively. We test the three hypotheses by the path coefficients, as illustrated in Figure 8. The results show that recycling service level positively affects CWOR, environmental consciousness positively affects CWOR, and EP positively affects environmental consciousness. Thus, these hypotheses are all supported.

Table 4. Demographic characteristics.

| Item                      | Sample Distribution | Sample size | Percentage (%) |
|---------------------------|---------------------|-------------|----------------|
| Gender                    | Male                | 89          | 39.21          |
|                           | Female              | 138         | 60.79          |
| Age                       | <18                 | 7           | 3.08           |
|                           | 18–25               | 60          | 26.43          |
|                           | 26–30               | 65          | 28.63          |
|                           | 31–40               | 76          | 33.48          |
|                           | 41–50               | 10          | 4.41           |
|                           | >51                 | 9           | 3.96           |
| Education Level           | Post-secondary      | 61          | 26.87          |
|                           | Bachelor’s degree   | 146         | 64.32          |
|                           | Master’s degree     | 17          | 7.49           |
|                           | Doctoral degree     | 3           | 1.32           |
| Income                    | <RMB 2000           | 27          | 11.89          |
|                           | RMB 2000–4500       | 46          | 20.26          |
|                           | RMB 4500–8000       | 76          | 33.48          |
|                           | RMB 8000–10,000     | 40          | 17.62          |
|                           | >RMB 10,000         | 38          | 16.74          |
| Usage Time of Current     | Within half a year  | 14          | 6.17           |
| Mobile Phone              | Half a year–one year| 36          | 15.86          |
|                           | One–two years       | 88          | 38.77          |
|                           | Two–three years     | 53          | 23.35          |
|                           | Three–four years    | 23          | 10.13          |
|                           | >Four years         | 13          | 5.72           |
| Cumulative Number of      | 1                   | 7           | 3.08           |
| Mobile Phones Owned       | 2                   | 17          | 7.49           |
|                           | 3                   | 63          | 27.75          |
|                           | 4                   | 50          | 22.03          |
|                           | 5                   | 43          | 18.94          |
|                           | 6                   | 11          | 4.85           |
|                           | >6                  | 36          | 15.86          |
| ORP                       | aihuishou.com       | 47          | 20.70          |
|                           | JD Recycling        | 46          | 20.26          |
|                           | Weibo Recycling     | 18          | 7.93           |
|                           | Xianyu              | 104         | 45.81          |
|                           | Zhaoliangji.com     | 9           | 3.96           |
|                           | lehuiso.com         | 3           | 1.32           |

(4) The impacts of demographic characteristics and mobile phone usage patterns

We use the independent-samples t-test to check whether customers with different demographic characteristics and mobile phone usage patterns have significant differences in their impacts on environmental consciousness and CWOR. Then, we use the AMOS multi-group analysis to test whether demographic characteristics and mobile phone usage pattern moderate the recycling service–CWOR link. Results are shown in Table 6.

Customers of different ages, current mobile phone usage times, and cumulative numbers of mobile phones owned have significant differences in their impacts on environmental consciousness. Customers under the age of 30 may receive more publicity and education on environmental protection, so they have stronger environmental consciousness. Customers who have used their current mobile phones for less than two years and those who have a
cumulative number of mobile phones not fewer than four are more environmentally conscious. Customers with shorter usage times of their current phones replace their phones more frequently, so they have owned more phones. These customers often pay attention to the information on the recycling of used mobile phones and are more familiar with online recycling. They are more likely to receive EP and have stronger environmental consciousness.

Table 5. Reliability and validity analyses.

| Constructs | Item | Standard Factor Loading |  | Cronbach’s Alpha | CR | AVE |
|------------|------|-------------------------|-------------------|-----------------|---|-----|
| EC         | EC1  | 0.723                   | ***               | 0.784           | 0.788 | 0.554 |
|            | EC2  | 0.717                   |                   |                 |     |     |
|            | EC3  | 0.79                    | ***               |                 |     |     |
| EP         | EP1  | 0.771                   | ***               | 0.758           | 0.764 | 0.521 |
|            | EP2  | 0.746                   | ***               |                 |     |     |
|            | EP3  | 0.641                   | ***               |                 |     |     |
| CWOR       | CWOR1| 0.777                   | ***               | 0.849           | 0.815 | 0.525 |
|            | CWOR2| 0.779                   | ***               |                 |     |     |
|            | CWOR3| 0.677                   | ***               |                 |     |     |
|            | CWOR4| 0.657                   | ***               |                 |     |     |
| RSL        | RSL1 | 0.683                   | ***               | 0.912           | 0.913 | 0.513 |
|            | RSL2 | 0.727                   | ***               |                 |     |     |
|            | RSL3 | 0.787                   | ***               |                 |     |     |
|            | RSL4 | 0.717                   | ***               |                 |     |     |
|            | RSL5 | 0.660                   | ***               |                 |     |     |
|            | RSL6 | 0.724                   | ***               |                 |     |     |
|            | RSL7 | 0.699                   | ***               |                 |     |     |
|            | RSL8 | 0.695                   | ***               |                 |     |     |
|            | RSL9 | 0.737                   | ***               |                 |     |     |
|            | RSL10| 0.726                   | ***               |                 |     |     |

Note: *** denotes $p < 0.001$.

Figure 8. Results. (Note: ***$p < 0.001$).

In terms of CWOR, customers with higher education levels learn more information about environmental protection and they are more likely to use the ORP, so they have stronger CWOR. The more mobile phones owned, the larger the voluntary recycling quantity and the stronger the CWOR.

Age and income moderate the relationship between the recycling service–CWOR link. Recycling service has a greater impact on older customers’ CWOR. This is because older customers are unfamiliar with online operations and lack trust in the ORP. Accurate and convenient recycling services are crucial to attracting such customers. Customers with lower incomes do not emphasize the recycling service as they want higher monetary compensation through recycling.
Table 6. Results of AMOS multi-group analysis.

| Variable                                  | EC Is There a Significant Difference? | Group Mean | CWOR Is There a Significant Difference? | Group Mean | The Relationship between Recycling Service Level and CWOR Is There a Significant Difference? | Group Mean |
|-------------------------------------------|---------------------------------------|------------|------------------------------------------|------------|-----------------------------------------------------------------------------------------------|------------|
| Gender                                    | No (0.144)                            |            | No (0.106)                               |            | No (0.505)                                                                                     |            |
| Age (Higher group ≥ 30; Lower Group < 30) | Yes (0.069)                           | Lower: 5.72; Higher: 5.49 | No (0.756)                               | Yes (0.001) | Lower: 0.32; Higher: 0.53.                                                                   |            |
| Education Level (Higher group ≥ Bachelor; Lower group < Bachelor) | No (0.109)                            |            | Yes (0.010)                               | Lower: 5.18; Higher: 5.59 | No (0.327)                                                                                     |            |
| Income (Higher Group ≥ 8000 RMB; Lower Group < 8000 RMB) | No (0.426)                            |            | No (0.253)                               |            | Yes (0.053)                                                                                     | Lower: 0.51; Higher: 0.56. |
| Usage Time of Current Mobile Phone (Higher Group ≥ 2 years; Lower Group < 2 years) | Yes (0.065)                           | Lower: 5.72; Higher: 5.49 | No (0.534)                               |            | No (0.450)                                                                                     |            |
| Cumulative Number of Mobile Phones Owned (Higher Group ≥ 4; Lower Group < 4) | Yes (0.021)                           | Lower: 5.44; Higher: 5.74 | Yes (0.001)                               | Lower: 5.19; Higher: 5.66. | No (0.245)                                                                                     |            |

Note: *p*-value is in parentheses.

5.3. Results and Discussion

All the three proposed hypotheses are supported. As demonstrated by the theoretical analysis in Sections 3 and 4, as a decision variable for online recycling of used mobile phones, recycling service not only directly affects recycling but also indirectly influences recycling by affecting CWOR. Recycling service is mainly composed of tangibility, reliability, responsiveness, assurance, and empathy. The ORP should provide a reliable recycling service, increase customers’ trust in the platform, pay attention to customers’ demand, and function under the customer-centric operating model.

Moreover, EP positively affects environmental consciousness, which positively affects CWOR. Therefore, it is necessary to strengthen the promotion of online recycling of used mobile phones, enrich the content and methods of promotion, and attract more people to participate in online recycling.

Finally, customers’ age and usage time of their current mobile phones have significant impacts on their environmental consciousness. Customers of different ages, cumulative numbers of mobile phones owned, and education level have significant differences in their impacts on CWOR. Customers’ age and income level moderate the impact of the recycling service level on CWOR, which shows that customers of different ages and income levels should be provided with different recycling services to increase CWOR. Before the recycling of used mobile phones, the MPM or ORP should conduct a market survey to understand customers’ CWOR by investigating customers’ education levels and cumulative numbers of mobile phones owned, and provide a more targeted online recycling service.

6. Conclusions

Currently, many ORPs participate in recycling and the online recycling of used mobile phones is especially popular. We constructed a game model of online recycling of used mobile phones to explore the MPM’s and ORP’s recycling decisions. We also examined the influencing factors of CWOR from the perspective of customers. We observed the following findings.

First, from the perspective of the MPM, the profit mainly depends on the recycling quantity of mobile phones. Both the recycling quantity and the MPM’s profit increase with the voluntary recycling quantity and customers’ preferences of the recycling price and
recycling service. Moreover, the impacts of customers’ preferences of the recycling price and recycling service on the MPM’s profit and recycling quantity depend on the service cost coefficient. A larger service cost coefficient represents a greater impact of customers’ preference of the recycling service, while a smaller service cost coefficient corresponds to a greater impact of customers’ preference of the recycling price.

Second, the ORP’s profit is independent of the service cost coefficient and customers’ preference of the recycling service. The ORP can benefit more from increases in customers’ voluntary recycling quantity and customers’ preference of the recycling price. When customers’ preference of the recycling price is low, the ORP should increase the recycling commission to guarantee its profit. When customers have a high preference for the recycling price, since the recycling quantity decreases due to the negative correlation between the recycling price and recycling commission, the ORP’s profit increases first and then declines with the recycling commission. Therefore, the ORP should set an appropriate recycling commission according to customers’ preference of the recycling price.

The empirical research on the influencing factors of CWOR illustrates that the recycling service and customer environmental consciousness have significant positive impacts on CWOR, and EP has a significant positive impact on customers’ environmental consciousness. Customers of different ages, current mobile phone usage times, and cumulative numbers of mobile phones owned have significant different impacts on environmental consciousness. Customers with different education levels and cumulative numbers of mobile phones owned have significant differences in CWOR. Age and income moderate the relationship between the recycling service–CWOR link.

For supply chain firms, the recycling of used mobile phones is not only a pathway to reduce their production costs but also a manifestation of their corporate social responsibility. Online recycling has shown promising development prospects, so cooperation between the MPM and ORP should be strengthened to encourage customers to actively participate in online recycling. Specifically, the management implications of our research findings are as follows:

(1) The MPM can encourage customers to recycle used mobile phones in two ways: directly increase the recycling price or indirectly encourage customers to recycle by accepting a higher recycling commission to improve the recycling service level. The MPM needs to find the most effective method and make rational decisions based on the ORP’s service cost coefficient and customers’ preferences of the recycling price and recycling service.

(2) Playing an important role in online recycling of used mobile phones, the ORP should not be constrained by its service cost coefficient but should have an overall view and pay attention to customers for long-term development. The ORP should analyze customers’ preferences of the recycling service and recycling price through market research, and the ORP should set a reasonable recycling commission to strengthen cooperation with the MPM. Moreover, the recycling service positively affects CWOR, which can indirectly increase the recycling quantity. Therefore, the ORP should focus on providing a high-quality and reliable recycling service.

(3) From the perspective of customers, raising customers’ awareness of environmental protection is conducive to increasing CWOR, thereby promoting recycling and sustainability development. Therefore, the MPM, ORP, and relevant government departments involved in used mobile phones recycling need to strengthen the publicity of online recycling of used mobile phones, innovate the publicity methods, and enrich the publicity content.

We conducted a theoretical analysis of the recycling service strategy for the online reverse supply chain for used mobile phones and an empirical analysis of the influencing factors of CWOR. There are still some limitations in this paper, and we will explore the following three perspectives in the future: (1) in the reverse recycling process of used mobile phones, ORP and the MPM may have a cooperative relationship that shares the recycling revenue, similar to a revenue-sharing contract. This contract will affect the recycling service level and the recycling motivation of supply chain participants. In the future, we will reflect this cooperative relationship in our theoretical model and further
explore the service strategy of the reverse recycling supply chain. (2) In the real reverse recycling supply chain, ORP often cooperate with multiple MPMs, and there may be MPMs with greater channel power, and we will consider this situation in our future research. (3) This paper demonstrated the influence of CWOR on the recycling volume of used mobile phones. How the government can make use of CWOR’s influencing factors for subsidies or policy settings to regulate the used mobile phone recycling industry and reduce the environmental pollution caused by mobile phone disposal is also a question we would like to explore in the future.

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Abbreviations

AGFI adjusted goodness-of-fit index;  
AVE average variance extracted;  
CHI chi-square value;  
CR composite reliability;  
CWOR customers’ willingness of online recycling;  
DF degree of freedom;  
EC Environmental Consciousness;  
EP Environmental protection publicity;  
GFI goodness-of-fit index;  
MPM mobile phone manufacturer;  
ORP online recycling platform;  
RMSEA root mean square error of approximation;  
RSL Recycling Service Level;  
SEM structural equation modelling;  
WEEE waste electrical and electronic equipment.

Appendix A

Proof. (1) Solve the first derivatives of the recycling quantity and the MPM’s profit as follows:

\[
\frac{\partial q_*}{\partial k} = -\lambda^2 \frac{2k}{2k^2} < 0, \quad \frac{\partial q_*}{\partial \lambda} = -\lambda^2 \left\{ k\beta(h - \rho) + a \right\} + \rho^2 > 0, \quad \frac{\partial \sigma^*}{\partial k} = \frac{1}{2}, \quad \frac{\partial \sigma^*}{\partial \lambda} = \frac{k\beta(h - \rho) + a + \rho^2}{2k^2} > 0, \quad \frac{\partial \pi^*_m}{\partial k} = \frac{k\beta(h - \rho) + a + \rho^2}{2k^2} > 0, \quad \frac{\partial \pi^*_m}{\partial \lambda} = \rho \left\{ k\beta(h - \rho) + a \right\} + \rho^2 > 0.
\]

when \( \lambda > \sqrt{\frac{k\beta}{2k^2}} \), \( \frac{\partial q_*}{\partial \rho} = \frac{\lambda^2 - k\beta}{2k^2} > 0 \) and \( \frac{\partial \sigma^*}{\partial \rho} = \left( \lambda^2 - k\beta \right) \left\{ k\beta(h - \rho) + a \right\} + \rho^2 \left\{ k\beta(h - \rho) + a \right\} + \rho^2 > 0 \); similarly,

when \( \lambda < \sqrt{\frac{k\beta}{2k^2}} \), \( \frac{\partial q_*}{\partial \rho} = \frac{\lambda^2 - k\beta}{2k^2} < 0 \) and \( \frac{\partial \sigma^*}{\partial \rho} = \left( \lambda^2 - k\beta \right) \left\{ k\beta(h - \rho) + a \right\} + \rho^2 \left\{ k\beta(h - \rho) + a \right\} + \rho^2 < 0.

(2) Compare the first derivatives of the recycling quantity and the MPM’s profit as follows:
Appendix B

\textbf{Proof.} \( \frac{\partial \pi^*}{\partial \alpha} = \frac{\rho}{2} > 0, \frac{\partial \pi^*}{\partial \beta} = \frac{\rho(h - \rho)}{2} > 0, \) and \( \frac{\partial \pi^*}{\partial \rho} = \frac{\beta(h - 2\rho) + \alpha}{2}. \)

Solving \( \frac{\partial \pi^*}{\partial \alpha} = 0 \) yields \( \rho = \frac{h}{2} + \frac{\alpha}{2\rho}. \) Considering Lemma 1, we have

(1) By \( \frac{k(\beta(h - a))}{k} < \frac{h}{2} + \frac{\alpha}{2\rho} \), we have \( \beta < \beta_s \), where \( \beta_s = \frac{2k\alpha + h\lambda^2 + \sqrt{9k^2\lambda^4 + 10k\alpha\lambda^2 + h\lambda^4}}{2k}. \)

Since \( \beta_s > \frac{2k\alpha + 2k\lambda^2}{2k} > \frac{k(\beta(h - a))}{k} \), when \( \beta < \beta_s \), we have \( \frac{\partial \pi^*}{\partial \alpha} > 0. \)

(2) By \( \frac{k(\beta(h - a))}{k} > \frac{h}{2} + \frac{\alpha}{2\rho} \), we have \( \beta > \beta_s. \) If \( 0 < \rho < \frac{h}{2} + \frac{\alpha}{2\rho} \), then \( \frac{\partial \pi^*}{\partial \rho} > 0; \) if \( \frac{h}{2} + \frac{\alpha}{2\rho} < \rho = \frac{h}{2} + \frac{\alpha}{2\rho} \), then \( \frac{\partial \pi^*}{\partial \beta} < 0. \) □

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