Review on Dilemmas and Collaborative Governance Paths of Reverse Recycling of Waste Electronic Products in the "Internet +" Era

Xinjian Yu*

School of Economics and Management,Chongqing Jiaotong University, Chongqing 400074, China

*yuxinjian2024@126.com

Abstract. The scale of waste electronic products has been continuously climbing and has entered a peak period with an annual exceeding 50 million units and an annual growth rate of 20%. The toxic substances such as lead, cadmium, and mercury contained in them pose a severe threat to the ecological environment and public health. However, the coverage rate of the formal recycling channels is less than 10%, and a large number of products flow to the informal disassembly links, highlighting the structural defects of the traditional recycling system in terms of professionalism and scale. The "Internet +" recycling model provides a technically feasible path to solve the three obstacles of "unsmooth channels, insufficient trust, and weak incentives" through mechanisms such as online appointment, door-to-door pick-up, and time-space integration. This paper comprehensively review the realistic tensions in the implementation process of this model: on the one hand, although residents generally recognize the environmental risks and resource values, the actual participation rate is only 7%. The root cause is the disconnection between the concerns about personal information security and behavioral habits; on the other hand, the platform operation faces bottlenecks such as difficult profitability, weak supervision, and narrow coverage. Problems such as a single incentive structure, ambiguous main body responsibilities and rights, and fragmented policy implementation lead to an exacerbation of the supply-demand mismatch. On this basis, this paper further integrates frontier methods such as game theory modeling, multi-objective dynamic pricing, and closed-loop optimization, and proposes a tripartite collaborative governance framework with strong government supervision - credible enterprise performance - differential resident response as the core, and emphasizes the rigid constraints of information security, the combination of multiple incentive tools, and the collaborative scheduling of online and offline resources as the key fulcrums of institutional reconstruction.

Keywords: Internet + Recycling; Reverse Logistics; Waste Electronic Products

© The Author(s) 2026
V. Erokhin et al. (eds.), *Proceedings of the 6th International Conference on Internet Finance and Digital Economy (ICIFDE 2026)*, Advances in Economics, Business and Management Research 412,
https://doi.org/10.2991/978-94-6239-830-6_32

1 Introduction

Driven by the rapid iteration of consumer electronics, shortened product service life and massive household appliance replacement demand among residents, China has entered a peak period for the scrapping of waste electrical and electronic products. Calculated based on the latest statistical standards of the 2024 White Paper on Recycling, Treatment and Comprehensive Utilization of Waste Electrical and Electronic Products, early estimates only covered the five major traditional household appliances (TVs, refrigerators, washing machines, air conditioners and computers). In 2023, the theoretical total scrapping volume of these five categories reached 260 million units nationwide. When mobile phones, small household appliances and other electronic products are included, the annual scrapping scale of all categories of waste electronic products keeps rising, with an average annual growth rate of merely 6.8% from 2020 to 2025 (China Household Electrical Appliances Research Institute, 2025).

Beyond the huge scrapping volume, such waste carries severe hidden risks to the ecological environment and public health. Its components contain various toxic, corrosive and non-biodegradable hazardous substances including lead, cadmium, mercury, brominated flame retardants and diverse heavy metal compounds. Without standardized and professional harmless disposal and resource recovery procedures, toxic substances will gradually leach into soil and groundwater and diffuse into the atmosphere through random discarding and crude dismantling, posing long-term threats to regional ecological balance and residents' physical health.

Nevertheless, amid mounting pressure to advance standardized recycling, certified formal recycling and treatment enterprises only occupy a limited market share. Industrial surveys conducted in 2015 revealed that licensed waste electrical and electronic product treatment enterprises recovered merely 10% of all scrapped waste electronics nationwide, while nearly 90% of such waste was collected by unlicensed itinerant waste vendors and ultimately flowed into unregulated underground dismantling workshops (Wei, 2015). Thanks to the implementation of the Extended Producer Responsibility System and home appliance trade-in policies, the market structure has improved significantly. The 2024 White Paper on Recycling, Treatment and Comprehensive Utilization of Waste Electrical and Electronic Products indicates that the proportion of waste collected through formal recycling channels rose to 58.7% in 2024, with the remaining 41.3% still captured by unregulated itinerant recyclers (China Household Electrical Appliances Research Institute, 2025). Although the state has issued administrative measures governing the collection and utilization of the waste electrical and electronic product treatment fund, there remains room for optimization in policy implementation, and the expected regulatory effect of balancing market supply has not yet been fully achieved.

2 Pain Points of the Traditional System in the Reverse Recycling Industry of Waste Electronic Products

Relevant public questionnaire surveys targeting household electronic waste disposal behaviors demonstrate that environmental awareness among ordinary consumers has reached a relatively high level in China. Statistical results reveal that as high as 96% of surveyed residents clearly recognize the severe environmental pollution risks brought by improperly discarded waste electrical and electronic equipment, while 94% of respondents fully understand the recyclable economic and resource value contained in scrapped household appliances and digital products. Despite such widespread cognitive awareness among the public, actual green disposal behaviors fail to match people's environmental consciousness. Surveys find merely 7% of all consumers will actively deliver their end-of-life electronic products to officially certified formal recycling and dismantling enterprises. This stark contrast between high awareness and low compliance strongly signals that cumbersome, inaccessible recycling channels constitute the core bottleneck restricting the overall standardized recycling rate of waste electrical and electronic products. Against this backdrop, the innovative "Internet Plus" development concept provides a feasible technical and operational solution, which can build direct, convenient two-way links between individual household consumers and qualified formal recycling enterprises through digital online platforms (Wei, 2016).

In addition to the accessibility barrier for residents, the long-standing traditional offline recycling system inherently suffers from multiple prominent structural drawbacks that cannot be fundamentally resolved by conventional management approaches. For one thing, a complete, coordinated nationwide standardized recycling operation system has never been fully constructed and systematically optimized; individual itinerant waste collectors who dominate the grassroots recycling market lack unified industry training and professional operation norms, their waste sorting, classification and preprocessing techniques remain overly simplistic, and the overall operation scale of scattered offline recycling participants is too small to form intensive, large-scale resource recovery capacity (Zhao, 2017). For another, traditional offline recycling networks face persistent circulation blockages and extremely low operational efficiency due to information asymmetry between waste suppliers and recyclers. Without unified information matching and supervision mechanisms, most scrapped electrical and electronic goods bypass licensed processing factories and eventually flow into unregulated family-run small dismantling workshops or informal second-hand trading markets that lack official environmental and production qualifications, triggering continuous hidden pollution risks (Yan & Liu, 2022).

In contrast, the emerging "Internet + Recycling" integrated business model effectively addresses the above-mentioned pain points of the traditional recycling industry. Under this digital operation framework, ordinary users only need to submit a recycling reservation request on dedicated mobile mini-programs or web-based service platforms at any time according to their own schedules, and professional, certified recycling staff will provide free door-to-door waste collection services at the agreed time, which greatly reduces the time and transportation costs for residents to dispose of waste elec-

tronics and thoroughly eases the long-standing collection obstacles of the recycling industry (Gu et al., 2019). As an innovative circular economy model that combines online order submission and offline physical recycling services, this digital recycling mode breaks the limitations of time and geographical distance that shackle traditional recycling channels, eliminates the information isolation between consumers and formal recycling operators, injects new development momentum into the sluggish waste resource recovery industry, and serves as an irreplaceable core pathway to break through the current structural predicament of China's waste electrical and electronic product recycling system (Gong, 2019).

3 Review of Research on Residents' Recycling Participation Behavior under the "Internet +" Recycling Model

3.1 Constraint Mechanism of Information Security Risks on Residents' Online Recycling

During the Internet+-enabled reverse recycling of waste electronic products, residents' concerns over personal information security act as a critical barrier to their decision-making and significantly curb their willingness to participate in online recycling. Existing studies verify that perceived risks of information security are significantly negatively correlated with residents' online recycling behavior; worries about information leakage greatly reduce residents' participation intention, which reflects a positive correlation between the level of information security and recycling engagement (Li & Wang, 2023). Meanwhile, the intensity of government supervision plays a central role in this mechanism. Strict government supervision can force enterprises to improve information security protection through heavy penalty mechanisms, boost the credibility of recycling platforms, and thereby ease residents' security concerns.

3.2 Summary of Empirical Research on Key Influencing Factors of Residents' Recycling Participation

Among the behavioral variables affecting residents' participation in the reverse recycling of electronic waste, the mastery of e-waste knowledge, environmental awareness, the replacement frequency of electronic products, sense of responsibility, familiarity with e-commerce platforms, and attitudes toward government intervention have been empirically identified as key influencing factors. Questionnaire survey data collected from residents in Hangzhou show that 69.1% of local respondents hold the willingness to conduct online recycling, yet 77.2% of them only possess a basic understanding of recycling platforms. This finding is only applicable to the sample of Hangzhou, and there are regional differences in the participation characteristics of residents nationwide (Li & Zhou, 2019). Meanwhile, the degree of e-waste knowledge exerts a significant impact on recycling willingness at the 1% significance level, while environmental awareness, product replacement frequency, sense of responsibility, platform familiarity

and attitudes toward government intervention are statistically significant at the 5% significance level.

4 Review of Research on the Operational Dilemmas of the "Internet+" E-Waste Recycling Model

The incentive mechanism of the current "Internet + Recycling" model suffers from systematic flaws. It overly relies on single financial subsidies and lacks the combined application of diversified incentive tools including information-based incentives, contractual incentives and spiritual incentives, resulting in loose interest linkages and ambiguous division of responsibilities among manufacturers, dismantling enterprises, platform operators and consumers.

Specifically, government supervision and supporting incentives are insufficient. Most Internet recycling enterprises are newly established private startups trapped in the dilemma of high operating costs and low profit margins. Heavy upfront investment in technological research and development as well as equipment maintenance hinders their ability to achieve sustainable profitability, which weakens their internal motivation to carry out standardized recycling. Meanwhile, residents show low willingness to participate. Without a rigorous market supervision system for information security, residents fear the risk of personal information leakage and tend to hoard waste electronic products at home instead of submitting them to formal recycling channels(Liu et al., 2023).

Furthermore, obvious loopholes exist in the layout of recycling channels. Taking campus e-waste recycling as an example, online platforms fail to provide full-category recycling services for all types of waste electronic products. In addition, this recycling model heavily relies on smart mobile devices and stable internet access. While it is widely accepted by young and middle-aged groups proficient in digital operations, it cannot deliver convenient services to the elderly and other groups with low internet literacy, which further undermines the universality and effectiveness of the incentive system (Zhang, 2020).

5 Frontier Research on Multi-agent Collaborative Governance and Reverse Logistics Optimization

5.1 Design of the Tripartite Game Equilibrium Mechanism among the Government, Enterprises, and Residents

In the multi-stakeholder collaborative governance of "Internet +" reverse recycling for waste electronic products, the design of a tripartite game equilibrium mechanism involving the government, enterprises and residents needs to focus on key intervention points. Strict supervision of information security and heavy penalty clauses for breaches constitute the core approaches to improving corporate credibility. Relevant studies indicate that rigorous government supervision can significantly boost the credibility of

Internet recycling enterprises in personal information protection, while imposing heavy penalties on information leakage incidents effectively drives enterprises to strengthen information security safeguards. Meanwhile, a lower risk of personal information leakage directly raises residents' willingness to engage in recycling activities (Li & Wang, 2023).

In terms of residents' sustained participation, deductions from game models demonstrate that differentiated subsidy strategies can optimize the tripartite benefit equilibrium and exert positive incentives on residents' recycling behavior. By constructing a Stackelberg game model, Qu et al. proposed a tripartite collaborative decision-making framework with consumer preferences, recycling efforts and government supervision as core variables. This framework reveals that government subsidy supervision can markedly raise the recycling enthusiasm of both consumers and enterprises. Furthermore, although reward-and-punishment regulatory mechanisms may generate short-term disruptions to the forward supply chain, they can improve the coordination of the reverse supply chain in the long run and force platforms to operate in compliance via dynamic reputation evaluation systems (Qu et al., 2022).

5.2 Online and Offline Dual-channel Dynamic Pricing and Resource Scheduling Model

In the field of reverse recycling of waste electronic products, the online and offline dual-channel dynamic pricing and resource scheduling model needs to effectively integrate multi-dimensional objectives such as price-sensitive demand, product quality differences, recycling incentive intensity, and carbon emission reduction benefits. Researchers need to construct a multi-objective optimization framework that takes into account maximizing economic profits, increasing carbon emission reduction, and enhancing resource circularity. This framework needs to fully consider the complex characteristics of multi-period operation, multi-product categories, and multi-level network structures. The model needs to accurately describe the dynamic relationships between key variables through non-linear functions: for example, the recycling incentive price G_mc and the recycling volume are described by the 1-e^(-λ×G_mc) function, and the second-hand sales price p_sm and the market demand are characterized by the e^(-Ω×p_sm) function, which is more in line with the actual market response law (Chen et al., 2024).

6 Research Summary and Outlook on Future Governance Implementation Paths

This study focuses on the core issue of "Internet +" empowering the reverse recycling of waste electronic products, and systematically summarizes the key findings in four dimensions: practical dilemmas, behavioral motivations, model failures, and governance reconstruction. The study finds that waste electrical and electronic products in China have entered the stage of large-scale scrapping, and the theoretical annual scrapping volume continues to rise. However, the formal recycling rate has been below 10%

for a long time. The main reason is that the traditional recycling system has structural defects such as unsmooth channels, loose organizations, and non-standard processing. The "Internet +" recycling, as an integrated model of online reservation and offline fulfillment, has the technical adaptability to break through time and space constraints and improve service accessibility, and has become the key path supported by policies and accelerated in practice.

There is a significant "high awareness - low action" paradox in residents' willingness to participate: although the awareness of environmental risks and the recognition of resource value are generally high, the proportion of actual transactions through formal channels is less than 10%. This paradox stems from two behavioral constraints - one is the lack of information security. The risk of personal information leakage constitutes a substantial threshold for online participation, and this risk perception highly depends on the coordinated construction of regulatory intensity and enterprise credibility. The other is the weakening of behavioral motivation. It has been confirmed that the mastery of e-waste knowledge, environmental awareness, sense of responsibility, proficiency in using platforms, and attitudes towards government intervention all have statistically significant effects, but the impact intensity of knowledge level is particularly prominent.

Further analysis shows that the "Internet +" recycling model has not achieved the expected effectiveness, and its operational failure is reflected in the simplification of the incentive structure and the imbalance of the coverage: the incentive mechanism dominated by economic subsidies is difficult to maintain the long-term cooperation of multiple subjects, and there is a lack of a composite incentive connection of information sharing, contractual restraint and reputation feedback among manufacturers, disassemblers, platform operators and consumers; at the same time, there is an obvious digital divide among the service objects, with the young and middle-aged groups becoming the main users, and the participation of the elderly group and people with low digital literacy being limited, weakening the inclusiveness and system resilience of the model.

To address the above problems, the construction of a multi-agent collaborative governance framework needs to rely on the dual perspectives of game equilibrium and closed-loop optimization. At the mechanism design level, the government can simultaneously enhance the compliance motivation of enterprises and the participation confidence of residents through strict information security supervision and differential reward and punishment arrangements; at the operation optimization level, the dynamic pricing and resource scheduling model must go beyond the linear assumption and use non-linear functions to describe the response relationship between the recycling incentive price and the recycling volume, and the exponential decay relationship between the second-hand sales price and the market demand, so as to achieve Pareto improvement among multiple goals of profit, carbon emission reduction and recycling efficiency.

To sum up, if we want to comprehensively improve the operational efficiency of the reverse recycling system of waste electronic products, relying solely on digital technology empowerment is far from enough. We also need to rely on a complete institutional design to coordinate the recycling behavior logic of residents and the system architecture of the entire industrial chain. On the basis of strictly observing the bottom line of user information security, build a long-term participation system that deeply integrates

and collaborates among the four dimensions of recycling awareness, participation motivation, recycling channels and multiple incentives.

References

1. China Household Electrical Appliances Research Institute. (2025). 2024 white paper on recycling, treatment and comprehensive utilization of waste electrical and electronic products. Resources Recycling, 8, 13–23.
2. Wei, J. (2015). New conception of waste electrical and electronic products recycling strategy based on "Internet +". Jinri Keji, (11), 54–56.
3. Wei, J. (2016). Construction of "Internet +" recycling model for waste electrical and electronic products. Keji Guanli Yanjiu, 36(21), 230–234.
4. Zhao, Y. (2017). Recycling decision conception and operation mode of waste electrical and electronic products under "Internet +". Zhongguo Ziyuan Zonghe Liyong, 35(11), 69–70, 86.
5. Yan, S., & Liu, K. Q. (2022). Literature review on reverse logistics of electronic products recycled via the Internet. Zhongguo Chuyun, (4), 137–138. https://doi.org/10.16301/j.cnki.cn12-1204/f.2022.04.061.
6. Gu, F., Zhang, W., Guo, J., & Hall, P. (2019). Exploring “Internet+Recycling”: Mass balance and life cycle assessment of a waste management system associated with a mobile application. Science of the Total Environment, 649, 172–185. https://doi.org/10.1016/j.scitotenv.2018.08.298.
7. Gong, Y. D. (2019). Innovation of incentive mechanism for Internet + recycling model—A case study of Baidu Recycling Station. Zhongguo Liutong Jingji, 33(4), 65–75. https://doi.org/10.14089/j.cnki.cn11-3664/f.2019.04.007.
8. Li, X., & Wang, S. (2023). Achieving a win-win situation by promoting internet recycling of waste electronics and preventing information leakage in a multi-party game. Heliyon, 9(8), e19903. https://doi.org/10.1016/j.heliyon.2023.e19903.
9. Li, Z. N., & Zhou, L. H. (2019). Research on residents’ participation willingness in e-waste recycling under the background of “Internet +”: Evidence from survey data in Hangzhou. Jingji Yanjiu Daokan, (9), 125–128. https://doi.org/10.xxx.
10. Liu, T. T., Zhu, K., Wen, Z. C., Wu, S. Y., Zheng, Z. C., & Xue, J. (2023). Development trends and challenges of waste electrical and electronic equipment internet recycling. Huanjing Baohu, 51(8), 66–71. https://doi.org/10.14026/j.cnki.0253-9705.2023.08.016.
11. Zhang, L. N. (2020). Waste electronic products treatment and recycling model based on Internet+. Dianzi Jishu yu Ruangan Gongcheng, (7), 3–4. https://doi.org/10.20109/j.cnki.etse.2020.07.002.
12. Qu, Y., Zhang, Y., & Guo, L. (2022). Decision strategies for the WEEE reverse supply chain under the “Internet+recycling” model. Computers & Industrial Engineering, 169, 108532. https://doi.org/10.1016/j.cie.2022.108532.
13. Chen, W., Liu, Y., & Han, M. (2024). Designing a sustainable reverse logistics network for used cell phones based on offline and online trading systems. Journal of Environmental Management, 354, 120417. https://doi.org/10.1016/j.jenvman.2024.120417.

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (http://creativecommons.org/licenses/by-nc/4.0/), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

