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Research on the Influence Mechanism of China's Waste Household Appliance Price Index

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Abstract

To accurately reveal the fluctuation logic and driving patterns of the waste household appliance price index and promote the standardized development of the recycling market, this paper adopts a full industrial chain perspective of waste household appliance recycling. It integrates transaction data from 64 formal recycling enterprises across 25 provincial-level regions in China and multi-dimensional public data, and systematically analyzes the influencing mechanism of the price index using the DEMATEL-ISM model and the VAR model. The results show that the influencing factors of the waste household appliance price index present a three-level hierarchical structure: the direct surface factors are the actual supply, actual demand of waste household appliances and the value of recycled materials; the intermediate transmission factors include 8 variables such as historical household appliance sales and willingness to participate in recycling; the deep-rooted fundamental factors cover 7 variables including industrial policy intensity and macroeconomic environment. 64.23% of the price index fluctuation comes from its own inertia, the contribution of household disposable income to the fluctuation reaches 17.97%, raw material prices exert a significant long-term driving effect, policy subsidies have a strong short-term impact but decay rapidly, and the negative impact of recycling volume on prices peaks in the second period and then gradually weakens. The findings provide a scientific basis for formulating precise regulatory strategies and optimizing resource allocation in the waste household appliance recycling market.

JEL classification numbers: Q40, Q58, R11, O13, P12.
Keywords: Waste household appliances, Price index, Influence mechanism, DEMATEL-ISM model, VAR model.

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1. Introduction

China is the world’s largest producer, consumer, and scrapper of household appliances. The total stock of household appliances in society has exceeded 3 billion units, with an annual theoretical scrappage volume of 200 to 250 million units. Waste household appliances have entered a peak period of large-scale elimination (Sun et al., 2024). As a key sector of the circular economy and the "dual carbon" strategy, the recycling and reuse of waste household appliances face prominent problems including chaotic pricing, sharp price fluctuations, weak competitiveness of formal channels, and severe information asymmetry (Wang et al., 2017). Price differentials for the same product category across regions and channels can reach 30%–50%, and price volatility is far higher than that of general industrial products. This not only disrupts market order but also restricts the development of the formal recycling system (Rosa and Terzi, 2018).

Establishing a scientific, continuous, and comparable price index for waste household appliances serves as a core tool for reflecting market conditions, stabilizing price expectations, and optimizing resource allocation. However, China has not yet formed a nationally unified, methodologically standardized, and authoritatively released price index for waste household appliances. Unclear price formation mechanisms, ambiguous impact pathways, and insufficient quantitative support have led to a lack of precise levers for policy regulation and exposed enterprises to considerable price risks in their operations.

Against this background, conducting a systematic study on the influence mechanism of the waste household appliance price index carries important theoretical and practical significance. Theoretically, this study improves the theory of price index compilation and volatility transmission for renewable resources, constructs a multi-level impact framework, and enriches interdisciplinary research on resource and environmental economics and the circular economy. In practice, it can provide a scientific basis for government regulation, enterprise pricing, and industry supervision, promote the standardized and efficient development of the recycling market, and enhance resource recycling efficiency and ecological and environmental benefits.

2. Literature Review

2.1 Research on the Recycling of Waste Household Appliances

Waste household appliance recycling is an important field in the circular economy and resource and environmental governance. Scholars at home and abroad have conducted extensive research on recycling systems, stakeholder behaviors, channel structures, and resource utilization efficiency.

Regarding recycling systems and models, foreign countries established relatively early recycling systems centered on the Extended Producer Responsibility (EPR) system, emphasizing that producers take responsibility for the entire life cycle of waste products (Andersen, 2022). Regulations such as the EU WEEE Directive and Japan’s Home Appliance Recycling Law have promoted the formation of standardized recycling networks, with related studies focusing on channel efficiency, cost allocation, and interest coordination mechanisms (Wilson et al., 2006). Domestic research has pointed out that waste household appliance recycling in China features a dual competitive structure of formal and informal channels. Informal channels account for approximately 40% of the market share by virtue of low costs and high quotations, squeezing the living space of formal enterprises (Liu et al., 2016). Existing models include government-led, enterprise-operated, Internet-plus-recycling, and trade-in programs. Most scholars argue that a multi-stakeholder collaborative model is more suitable for China's market characteristics (Wang et al., 2019).

In terms of residents' recycling behavior, studies have shown that household disposable income, environmental awareness, recycling convenience, price incentives, and policy perception are core factors affecting their willingness to recycle and channel choices (Bian et al., 2020). Rising incomes and stronger green preferences can significantly increase participation in formal recycling, whereas high-price attraction by informal channels leads to resource diversion, environmental pollution, and safety hazards (Wang et al., 2023).

On industrial chain and resource utilization research, the core value of waste household appliances derives from recycled materials such as copper, aluminum, iron, and plastics. Dismantling technology, treatment costs, and recycled material prices directly determine the profit margin of the industrial chain (Hou et al., 2020). The industrial chain is characterized by scattered upstream supply, disorderly midstream competition, and inefficient downstream value transmission, with the lack of effective price signals as a key constraint to collaborative efficiency.

Overall, research on the waste household appliance recycling industry is relatively mature, but studies on price formation mechanisms, price indices, and fluctuation patterns remain significantly insufficient.

2.2 Research Related to Price Index Construction

Price indices serve as a core tool for reflecting dynamic changes in market prices and have been widely applied in macroeconomic and segmented industrial sectors. In terms of index compilation methods, mainstream approaches include the Carli simple arithmetic mean index, Laspeyres index, Paasche index, Young index, and weighted average index (Xu et al., 2008). The Laspeyres index features fixed base-period weights and strong comparability, making it suitable for measuring long-term trends. Weighted indices, which assign weights based on transaction volume, value, amount, and other dimensions, better reflect market structures (Yang and Zhang, 2007).

In the field of renewable resources, existing studies have constructed price indices for single materials such as recycled copper, recycled aluminum, and recycled plastic using multi-dimensional weights including circulation volume, material value, and transaction value, verifying the rationality of weighted indices (Zhao, 2023). However, systematic, nationwide, and standardized research on price indices for recycled products such as waste household appliances, which are multi-category, highly heterogeneous, and centered on resource value, remains scarce. Only a few industry associations have issued pilot indices, lacking unified methodologies and authoritative conclusions.

Although current studies provide methodological references for index construction, a standardized index compilation paradigm suitable for waste household appliances has not yet been established, nor have indices been studied in conjunction with influence mechanisms and regulatory strategies.

2.3 Research on the Influence Mechanism of Price Fluctuations

Commodity price fluctuations are driven by multiple factors including supply and demand, costs, policies, and the macroeconomic environment. Recyclable resource prices exhibit strong cyclicality and high sensitivity.

Regarding influencing factors, the supply side is affected by scrappage volume, recycling volume, and formal recycling rate; the demand side depends on demand for recycled materials, dismantling capacity, and downstream industry prosperity; the core driver on the cost side is the price of primary raw materials; the policy side includes subsidies, treatment funds, and environmental regulation; at the macro level, prices are long-term driven by household income, economic growth, and technological level (Wu, 2024; Bai, 2024).

In terms of research methods, VAR models, impulse response functions, and variance decomposition are used to quantify dynamic shocks and contribution degrees (Gao, 2024); the DEMATEL-ISM model is applied to hierarchical classification of complex factors and analysis of transmission paths (Liang et al., 2022); system dynamics is used for long-term scenario simulation (Tian et al., 2020).

However, existing studies have obvious limitations: most focus on single factors and lack systematic analysis from the full industrial chain perspective; research on waste household appliance prices is mainly qualitative, with few empirical studies on the influence mechanism of price indices; and the chain transmission logic has not been clearly revealed.

2.4 Summary of the Literature

Based on existing literature, it can be concluded that:

(1) Research on the waste household appliance recycling industry is well-developed, but price formation, price indices, and fluctuation mechanisms remain prominent shortcomings, with the absence of authoritative indices, unclear influencing mechanisms, and imprecise regulatory strategies;

(2) The methodological system for price index compilation is mature, yet it has not been adapted to the characteristics of waste household appliances, including multi-category attributes, resource-dependence, and long industrial chains;

(3) Influencing factors of price fluctuations and corresponding econometric methods are well-established, but multi-level systematic decomposition and quantitative analysis of dynamic contribution degrees are lacking;

(4) Studies on policy regulation are abundant, but targeted regulatory design centered on price indices is insufficient.

In summary, existing research provides theoretical and methodological foundations, yet four major gaps remain: missing standardized indices, ambiguous transmission mechanisms, insufficient quantitative analysis, and disconnection from practical regulation. Taking these as the starting point, this paper systematically investigates the influence mechanism of the waste household appliance price index, so as to fill the gaps in current research.

3. Construction of China's Waste Household Appliance Price Index

3.1 Index Construction Methods and Comparative Analysis

A price index is a core indicator that reflects the trend and relative magnitude of price changes in commodities or services over a given period. Its compilation methods have formed a mature system centered on two key issues: weight selection and index form. According to whether differences in the importance of commodities are considered, mainstream methods can be divided into two categories: simple price indices and weighted price indices.

Simple price indices do not assign weights and mainly include the simple aggregate index and the simple arithmetic mean index (Carli index). The simple aggregate index directly sums prices of different measurement units for comparison, which lacks scientific rationality and is rarely applied in practice. The Carli index calculates price ratios first and then averages them, making it easy to compute. However, it fails to account for differences in transaction volumes and cannot reflect the relative importance of different commodities in the market (Li, 2003).

Weighted price indices introduce weights such as transaction volume, transaction value, and material value, significantly improving accuracy. They mainly include the Laspeyres index, Paasche index, Young index, and weighted arithmetic mean index. The Laspeyres index uses base-period quantities as weights, featuring strong comparability and suitability for long-term trend analysis. The Paasche index adopts current-period quantities as weights, aligning with the contemporary market structure but exhibiting weak intertemporal comparability (Sun and Sun, 1996). The Young index employs weights from a representative period, offering high flexibility and avoiding disturbances from abnormal fluctuations. The weighted arithmetic mean index adapts to multi-category scenarios with diversified weight settings, enabling a more scientific reflection of price changes.

Combined with the characteristics of the waste household appliance market, this study determines the basis for price index construction as follows:

1) Waste household appliances cover diverse categories with large disparities in transaction volume and material value, so the simple aggregate index is inapplicable and weighted methods must be adopted;

2) The recycling market covers a wide range of regions, involves numerous participants, and experiences frequent price fluctuations, requiring the index method to balance scientific rigor and simplicity;
3) To ensure the representativeness, comparability, and robustness of the index, the Carli index, Laspeyres index, Young index, and weighted arithmetic mean index are finally selected for compilation and comparative verification.

3.2 Index Sample Selection and Weight Setting

Weights are quantitative indicators that measure the importance of different samples to the overall price level and directly affect the representativeness and accuracy of the index. To ensure the scientific validity and representativeness of China's Waste Household Appliance Price Index, a multi-dimensional weighting system is adopted. This system integrates three key dimensions — market share by circulation volume, weight by circulation share of material value, and weight by transaction value — to comprehensively reflect the real situation of the waste household appliance market. Among them, circulation share reflects the market circulation scale of various types of waste household appliances and serves as an important indicator of market activity. Categories with larger circulation volumes usually occupy a more important position in the market and are therefore assigned higher weights in the price index. Material value weight reflects the economic value of recyclable materials derived from waste household appliances. Different types of waste household appliances vary greatly in the value of extractable materials after dismantling, such as copper, aluminum, iron, and plastics. Transaction value weight reflects the actual transaction value of waste household appliances in the recycling market. Categories with higher transaction values are generally more sensitive to market price fluctuations and thus receive higher weights in the price index.

Specifically, circulation volume weight is measured by the proportion of transaction volume of five types of waste household appliances in the total transaction volume; material value weight is measured by the proportion of the total value of four main recyclable materials — copper, aluminum, iron, and plastics — in the five types of waste household appliances to the overall material value; transaction value weight is measured by the proportion of transaction value of the five types of waste household appliances in the total recycling value. Detailed calculation formulas are presented in Table 1.

Table 1: Price index weight calculation formula

Categories of Waste Household Appliances	WQi	WVi	WSi	Comprehensive Weight λi
Refrigerator	$Q_{RF}/\sum Q_{RF}$	$V_{RF}/\sum V_{RF}$	$S_{RF}/\sum S_{RF}$	$\lambda 1$
Air conditioner	$Q_{AC}/\sum Q_{AC}$	$V_{AC}/\sum V_{AC}$	$S_{AC}/\sum S_{AC}$	$\lambda 2$
Washing machine	$Q_{WM}/\sum Q_{WM}$	$V_{WM}/\sum V_{WM}$	$S_{WM}/\sum S_{WM}$	$\lambda 3$
Television	$Q_{TV}/\sum Q_{TV}$	$V_{TV}/\sum V_{TV}$	$S_{TV}/\sum S_{TV}$	$\lambda 4$
Computer	$Q_{CP}/\sum Q_{CP}$	$V_{CP}/\sum V_{CP}$	$S_{CP}/\sum S_{CP}$	$\lambda 5$

Where Qi denotes the transaction volume of the i-th type of waste household appliance, Vi denotes the value of recycled materials from the i-th type of waste household appliance, and Si denotes the transaction value of the i-th type of waste household appliance.
$\sum Q_i$, $\sum V_i$, and $\sum S_i$ represent the total transaction volume, total value of recycled materials, and total transaction value in the waste household appliance market, respectively.
WQi, WVi and WSi represent the proportions of transaction volume, recycled material value, and transaction value of each type of waste household appliance in the total transaction volume, total recycled material value, and total transaction value, respectively.
λi is the weighted average of WQi, WVi and WSi, representing the weight of the price index of the i-th type of waste household appliance in the construction of the overall waste household appliance price index.
Detailed calculation results are shown in Table 2.

Table 2: Price index weight calculation results

Categories of Waste Household Appliances	Circulation Volume Weight	Material Value Weight	Transaction Amount Weight	Comprehensive Weight
Refrigerator	21%	21%	20%	21%
Air conditioner	27%	56%	51%	45%
Washing machine	25%	11%	18%	18%
Television	11%	7%	6%	8%
Computer	15%	5%	5%	8%

Following the analysis of price index construction methods in Section 3.1, this study selects three approaches—the Laspeyres index, the Carli index, and the Young index—to establish a price index framework for five types of waste household appliances: refrigerators, air conditioners, washing machines, televisions, and computers. Finally, a comprehensive waste household appliance price index is constructed using the weighted average index method.
The specific calculation steps are as follows:

Step 1: Calculate the average price of each appliance subcategory.
Recycling prices vary across regions, recycling enterprises, and collection batches even for the same type of appliance within the same period. Therefore, the average recycling price for each appliance subcategory is first calculated using the following formula:

$$\overline{p} = \frac{\sum p_j \times q_j}{\sum q_j} \tag{1}$$

where $\overline{p}$ is the average price of the appliance subcategory, *pj* is the recycling price of the j-th batch, and *qj* is the collection quantity of the j-th batch.

Step 2: Calculate price indices for the five types of waste household appliances.
Price indices for waste refrigerators, air conditioners, washing machines, televisions, and computers are constructed separately using the Carli, Laspeyres, and Young indices.

The Carli index is computed as:

$$K_C = \frac{1}{n}\sum\left(\frac{\overline{p}_1}{\overline{p}_0}\right) \tag{2}$$

The formula for the Laspeyres index is as follows:

$$\boldsymbol{K_L} = \frac{\sum \overline{\boldsymbol{p}}_{\boldsymbol{1}} \times \boldsymbol{q_0}}{\sum \overline{\boldsymbol{p}}_{\boldsymbol{0}} \times \boldsymbol{q_0}} \tag{3}$$

The formula for the Young index is as follows:

$$K_Y = \frac{\sum \overline{p}_1 \times q_r}{\sum \overline{p}_0 \times q_r} \tag{4}$$

Where $\overline{p}_1$ and $\overline{p}_0$ denote the average recycling prices in the current period and the base period, respectively; q_0 and q_r represent the transaction volumes in the base period and the representative period, respectively; and n stands for the number of household appliance subcategories.

Step 3: Calculate the waste household appliance price index.
Using the weighted average index method, the price indices of the five types of household appliances derived from the three index calculation approaches are weighted in accordance with the weight system constructed above. The calculation method for the waste household appliance price index is as follows:

$$PI_C = \lambda_1 RFPI_C + \lambda_2 ACPI_C + \lambda_3 WMPI_C + \lambda_4 TVPI_C + \lambda_5 CPPI_C \quad (5)$$

$$PI_L = \lambda_1 RFPI_L + \lambda_2 ACPI_L + \lambda_3 WMPI_L + \lambda_4 TVPI_L + \lambda_5 CPPI_L \quad (6)$$

$$PI_Y = \lambda_1 RFPI_Y + \lambda_2 ACPI_Y + \lambda_3 WMPI_Y + \lambda_4 TVPI_Y + \lambda_5 CPPI_Y \quad (7)$$

Where PI_C, PI_L, and PI_Y represent the comprehensive price index of waste household appliances obtained by weighting the price indices of five types of waste household appliances constructed using the Carli index, Laspeyres index, and Young index, respectively.
$RFPI_C$, $RFPI_L$, and $RFPI_Y$ represent the price index of waste refrigerators constructed using the Carli index, Laspeyres index, and Young index, respectively.
$ACPI_C$, $ACPI_L$, and $ACPI_Y$ represent the price index of waste air conditioners constructed using the Carli index, Laspeyres index, and Young index, respectively.
$WMPI_C$, $WMPI_L$, and $WMPI_Y$ represent the price index of waste washing machines constructed using the Carli index, Laspeyres index, and Young index, respectively.
$TVPI_C$, $TVPI_L$, and $TVPI_Y$ represent the price index of waste televisions constructed using the Carli index, Laspeyres index, and Young index, respectively.
$CPPI_C$, $CPPI_L$, and $CPPI_Y$ represent the price index of waste computers constructed using the Carli index, Laspeyres index, and Young index, respectively.
λi is the weight of the price index of the i-th type of waste household appliance in the construction of the overall waste household appliance price index.
In China’s waste household appliance market, transaction volumes and values vary significantly across different types of waste appliances. Meanwhile, the market involves a large number of participants and features complex price fluctuations.
The selected methods comprehensively consider computational simplicity, comparability, long-term trend analysis, and weight flexibility, enabling them to adapt to the complex conditions of the waste household appliance market.
The adoption of a multi-dimensional weighting system (including circulation volume proportion, material value weight, and transaction value weight) ensures the scientificity and representativeness of the price index.
Furthermore, by integrating the rapid responsiveness of the Carli index, the strong comparability of the Laspeyres index, the flexibility of the Young index, and the comprehensiveness of the weighted arithmetic average index, the constructed indices can reflect the price change trends in the waste household appliance market more comprehensively and scientifically.

3.3 Index Calculation, Data Sources and Volatility Characteristics

The waste household appliance recycling price data used in this study are sourced from the China Renewable Resources Recycling Association. The data cover monthly recycling quantities and prices from 64 formal recycling and dismantling enterprises across 25 provinces and municipalities directly under the central government in China, spanning from January 2023 to November 2025, with as many as 21.5 million original transaction records. After data cleaning and screening, a total of 17 million around valid transaction data points were finally obtained, with their specific distribution shown in Table 3. The data cover the core product categories of "four types of appliances and one type of electronic product", providing solid data support for the construction of the price index.

Table 3: The amount of transaction data of waste household appliances market

Categories of Waste Household Appliances	2023	2024	2025	Total
Refrigerator	1620825	1408141	1503859	5133109
Air conditioner	1446232	1500458	1498204	5165747
Washing machine	946568	941730	829381	3138261
Television	251911	166581	183024	601516
Computer	542081	380504	420183	1633714
Total	4807617	4397414	4434651	16672347

Based on the transaction data of waste household appliances from January 2023 to November 2025, the price indices for waste air conditioners, waste refrigerators, waste washing machines, waste televisions, waste computers, as well as the comprehensive price index for waste household appliances can be obtained using three price index calculation methods, as shown in Figure 1.

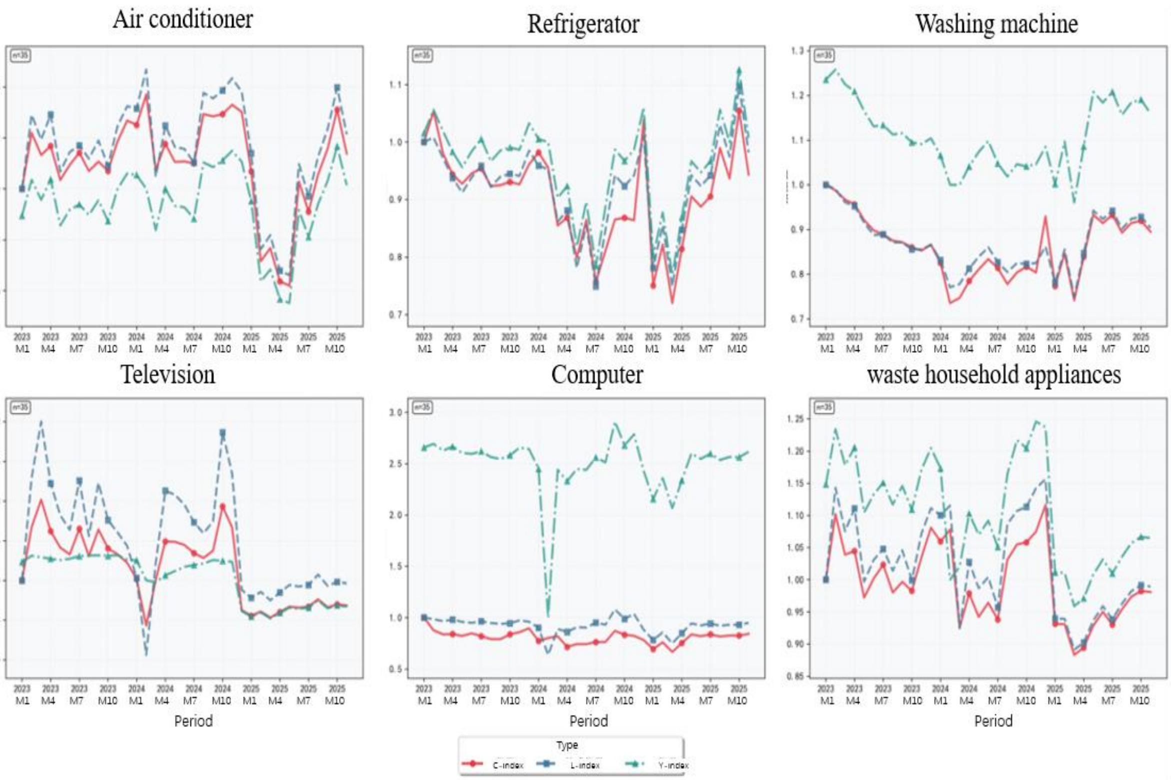

Figure 1: The calculation results of the price index of waste household appliances

From the calculation distribution of the three indices, the Carli index and the Laspeyres index are relatively close, while the Young index generally lies above or below the other two. The comprehensive price indices of waste household appliances calculated by the Carli index and the Laspeyres index tend to move consistently during downward trends. However, during upward movements, the Laspeyres index rises more sharply than the Carli index.

Based on the actual values of the waste household appliance price index from January 2023 to November 2025, the overall price index shows obvious phased volatility characteristics, with the fluctuation range and driving factors in different periods highly correlated.

From January to December 2023, the price index fluctuated repeatedly between 0.97 and 1.15, showing no clear unidirectional trend for the whole year. Volatility during this period was mainly driven jointly by rising raw material prices and phased growth in market demand. For instance, in February 2023, the index rose to an annual high of 1.15 due to concentrated demand for trade-in programs before the Spring Festival. In July, it fell to a phased low of 0.97 affected by a short-term correction in raw material prices and the off-peak recycling season. Meanwhile, increased recycling costs arising from stricter environmental compliance requirements restrained sharp price rises in some periods, keeping overall volatility within a reasonable range.

From January to June 2024, the price index experienced severe fluctuations, dropping to 0.82 in February and 0.83 in June, both reaching three-year lows. This volatility was mainly driven by the policy shock from the Announcement on Matters Related to the Suspension of the Waste Electrical and Electronic Equipment Treatment Fund issued in January 2024. The suspension of the fund directly reduced recycling and treatment costs. Coupled with the adjustment period during which market participants adapted to the new policy, prices declined substantially. The index briefly rebounded to 1.03 in March and 1.02 in May, representing phased corrections following short-term market supply-demand balance, reflecting the market's self-regulating capacity under policy shocks.

From July to December 2024, the price index gradually recovered and remained relatively stable, rising steadily from 1.04 in July to 1.13 in November and slightly falling to 1.01 in December, with a narrower overall fluctuation range. This change resulted from the market's gradual adaptation to policy adjustments, as recycling enterprises optimized their operational strategies to fit the new cost structure. Combined with the recovery in demand for downstream recycled materials and stable raw material prices, the price index returned to a reasonable range.

From January to November 2025, the price index maintained a moderate fluctuation pattern, staying mostly between 0.89 and 0.99 without extreme swings. During this period, the market formed a relatively stable supply-demand equilibrium, the policy environment became steady, and fluctuations in raw material prices diminished. Meanwhile, the expanded coverage of formal recycling channels and improved recycling efficiency further reduced price uncertainty, leading to stable overall index performance.

4. Theoretical Basis and Research Framework

4.1 Analysis of the Whole Industrial Chain for Waste Household Appliance Recycling

The whole industrial chain of waste household appliance recycling is a complex system involving multiple links and participants. It includes not only the collection, dismantling and reuse of waste household appliances, but also the interactions among the government, enterprises and consumers (Gong et al., 2020). The generation of waste household appliances marks the starting point of the industrial chain, and such appliances mainly come from households. With technological upgrading and product end-of-life, waste household appliances are collected and transported to recycling enterprises or entities, which conduct large-scale recycling and deliver them to dismantling enterprises for disassembly and refining. Dismantling enterprises disassemble waste household appliances, extract valuable materials such as metals and plastics, and carry out preliminary processing. Upstream manufacturing enterprises further process the raw materials provided by dismantling enterprises to produce new raw materials or semi-finished products. These materials are then used by downstream manufacturing enterprises to produce final products. Sales enterprises sell these final products to consumers, completing the closed loop of the industrial chain. After using the products, consumers may generate new waste household appliances, thus re-entering the recycling process. This circular process not only promotes resource reuse but also helps reduce environmental pollution and improve economic benefits (Bekker and Heidelbach, 2021). The whole industrial chain of waste household appliance recycling is shown in Figure 2.

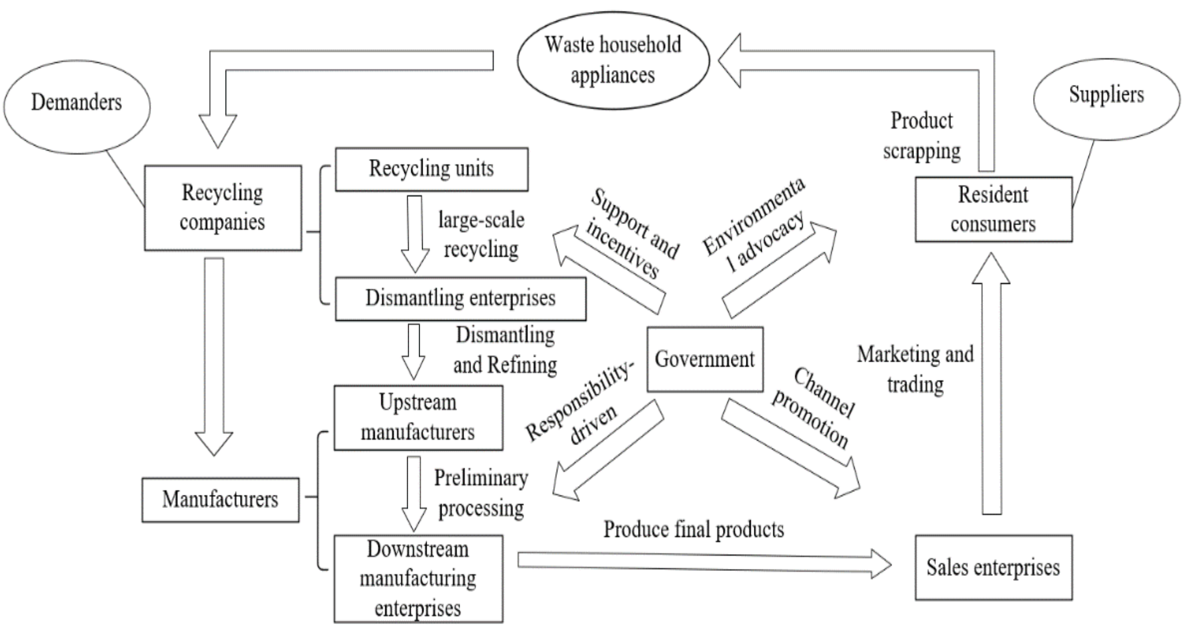

Figure 2: The whole industry chain of waste household appliances recycling

When the waste household appliance recycling industrial chain achieves closed-loop development, the efficiency of the entire system is maximized, resources are utilized most effectively, and environmental pollution is reduced to the lowest possible level. However, achieving this ideal state is confronted with numerous challenges.

First, from the perspective of residential consumers, the income generated from recycling waste household appliances through formal channels is lower than that offered by informal recyclers. Driven by economic interests, consumers tend to opt for the latter, which in turn affects the recycling volume of formal channels and hinders the maximization of their benefits.

Second, formal recyclers are required to comply with more stringent environmental regulations and safety standards in their operations, which inevitably increases their operating costs. In contrast, informal recyclers usually do not bear these additional costs, placing formal recyclers at a disadvantage in market competition. This cost disparity not only undermines the competitiveness of formal recyclers but also prevents them from competing with informal ones in terms of recycling prices, further reducing the attractiveness of the formal recycling system.

Furthermore, the recycling prices of waste household appliances often lack transparency and fluctuate significantly. Such price instability increases transaction uncertainty and impedes the conclusion of transactions between residents and formal recyclers.

Government participation in the waste household appliance recycling industrial chain helps alleviate the aforementioned problems. Through environmental publicity and other initiatives, the government guides residents to establish a correct understanding of waste household appliance disposal and enhances their environmental awareness. It provides policy support and financial subsidies to recycling and dismantling enterprises to encourage them to improve recycling efficiency and processing capacity. Additionally, the government promotes the implementation of the extended producer responsibility system among manufacturing enterprises, urging them to consider recyclability in product design and production processes. By leveraging the channel advantages of sales enterprises, the government facilitates the recycling of waste household appliances and promotes the development of programs such as trade-in incentives. Overall, the government plays a crucial role in ensuring the smooth operation of the entire waste household appliance recycling industrial chain.

The operation of the full waste household appliance recycling industrial chain exerts significant impacts on both the economy and the environment (Zhao et al., 2020). Economically, resource reuse helps reduce production costs and enhance economic efficiency. Environmentally, it reduces the pollution caused by waste household appliances, realizes the sustainable utilization of resources, and thus holds great significance for environmental protection. The efficient operation of this industrial chain is conducive to promoting the development of the circular economy and achieving the coordinated development of the economy, society, and environment.

In this process, the formation mechanism of the price index is a key factor. The price index not only reflects price fluctuations in the waste household appliance recycling market but also influences the operational efficiency and economic benefits of the entire industrial chain. Its formation is affected by a variety of factors, including supply and demand relations, cost structures, policy environments, and market competition. These factors interact jointly to determine the recycling price index of waste household appliances, which in turn exerts an impact on the operation of the entire industrial chain.

4.2 Theoretical Framework for the Influence Mechanism of Waste Household Appliance Price Indexes

To identify the influencing factors of the waste household appliance price index through industrial chain analysis, it is necessary to start from the whole industrial chain of waste household appliance recycling and gain an in-depth understanding of the operation mechanism of each link, the behavior of participants, and their interactions. The generation of waste household appliances marks the starting point of the industrial chain. Consumers' purchasing power, consumption habits, and environmental awareness directly affect the speed and volume of waste household appliance generation. Accelerated technological upgrading has shortened product life cycles, leading to more frequent generation of waste household appliances. The coverage and efficiency of the recycling network significantly influence the collection volume and costs of waste household appliances, while logistics costs are directly related to the level of recycling prices.

In the dismantling stage of waste household appliances, factors such as the sophistication of dismantling technology, labor costs, and equipment investment all affect recycling costs, which in turn influence the waste household appliance price index. Strengthening environmental protection requirements forces enterprises to adopt more environmentally friendly methods in recycling and processing, which undoubtedly increases their operating costs. Market demand plays a decisive role in the recycling value of waste household appliances, and market demand for recycled materials directly affects their recycling prices.

Government policies play a crucial role throughout the industrial chain. Recycling subsidy standards provided by the government can reduce the costs of recycling enterprises, while changes in environmental regulations affect enterprises' operation modes and cost structures. The intensity of market competition and the operational efficiency of recycling enterprises of different scales are also important factors affecting waste household appliance prices. At the macroeconomic level, macroeconomic factors such as economic cycles and inflation also exert an impact on the recycling prices of waste household appliances.

4.3 Research Methods and Model Applicability

4.3.1 DEMATEL-ISM Model

The Decision-Making Trial and Evaluation Laboratory-Interpretative Structural Modeling (DEMATEL-ISM model) is an integrated systematic analysis method constructed by combining the complementary advantages of the DEMATEL model and the ISM model. Its core function is to first quantify the direct and indirect influence intensities among multiple factors in a complex system via the DEMATEL model (Charles et al., 2020), identify core driving and driven factors as well as the priority of causal relationships, and then transform the quantified correlations into a clear hierarchical structure based on the ISM model. It is suitable for analyzing complex problems with closely correlated factors that require clarifying both causal intensities and hierarchical logic simultaneously, providing an accurate and systematic analytical tool for dissecting the causal mechanisms and sorting out the hierarchical transmission paths of the influencing factors of the waste household appliance price index in this study (Zhu et al., 2025).

Based on this integrated model framework, this study systematically explores the causal correlations and hierarchical transmission paths of the influencing factors of the waste household appliance price index. First, the DEMATEL model is used to quantify the influence intensities among factors and identify core driving and driven factors. Then, the reachability matrix of the ISM model is constructed on the basis of the quantified results, which is further decomposed to form a hierarchical structure. Finally, a complete influence mechanism of the waste household appliance price index is integrated, laying a theoretical foundation for subsequent empirical analysis and strategy design (Huo et al., 2023).

4.3.2 VAR Model

The Vector Auto-Regressive Model (VAR model), proposed by Christopher Sims in 1980, is a simultaneous multi-equation model that treats all endogenous variables in the system as linear functions of their own lagged terms and the lagged terms of other variables. Its core logic is to capture the dynamic interactive effects among variables through lagged terms without presupposing causal relationships between variables.

For a VAR(p) model containing k endogenous variables (where p is the lag order), its mathematical expression is:

$$Y_t = C + A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_p Y_{t-p} + \varepsilon_t \tag{8}$$

where $Y_t = [y_{1t}, y_{2t}, \cdots, y_{kt}]$ is a k-dimensional vector of endogenous variables; C is a k-dimensional constant vector; $A_1, A_2, \ldots, A_p$ are k×k-dimensional coefficient matrices reflecting the influence intensities of lagged variables on current values; $\varepsilon_t = [\varepsilon_{1t}, \varepsilon_{2t}, \ldots, \varepsilon_{kt}]$ is a k-dimensional random disturbance vector satisfying $E(\varepsilon_t)=0$ 、$E(\varepsilon_t \varepsilon_t')$ being a positive definite covariance matrix.

Although the DEMATEL-ISM model can clarify the static structure and hierarchical transmission paths among factors, it fails to quantify the dynamic impact intensity, duration, and feedback effects of factor fluctuations on the price index. The VAR model can exactly compensate for this limitation. Without presupposing unidirectional causal relationships between variables, it can incorporate the price index and core influencing factors into an endogenous system simultaneously. Through the impulse response function, it accurately portrays the dynamic impact path, peak effect, and attenuation trend of a unit standard deviation fluctuation of a single factor on the price index. With variance decomposition, it quantifies the contribution proportion of various factors to price fluctuations in different periods, clearly identifying the influence priority and time-effect differences of four types of factors: market supply and demand, economic costs, policies and institutions, and social technologies.

5. Identification and Hierarchical Analysis of Influencing Factors on the Waste Household Appliance Price Index

5.1 Construction of the DEMATEL-ISM Model

Based on the theoretical analysis of the formation mechanism of the waste household appliance price index in Section 4.2, combined with existing literature reviews, 21 influencing factors affecting the waste household appliance price index are identified. Let S0 denote the waste household appliance price index; the corresponding 22 factors are as follows: Actual supply of waste household appliances (S1), actual demand for waste household appliances (S2), theoretical supply volume (S3), formal recycling rate (S4), market demand intensity (S5), historical sales volume of household appliances (S6), willingness to participate in recycling (S7), recycling infrastructure (S8), policy subsidy intensity (S9), average product lifespan (S10), value of recycled materials (S11), residents' purchasing power (S12), public environmental awareness (S13), industrial policy intensity (S14), industrial technological level (S15), price of primary raw materials (S16), macroeconomic environment (S17), social and cultural environment (S18), policy and regulatory environment (S19), technological development level (S20), and raw material market environment (S21), as shown in Table 4.

Based on relevant literature and scholarly analyses, the influence relationships between the waste household appliance price index S0 and its influencing factors Si (i = 1, 2, …, 21) are determined. According to these influence relationships, the adjacency matrix A is constructed, as presented in Table 4.

Table 4: Symbols and meanings of variables

Symbol	Meaning	Symbol	Meaning
S0	Waste Household Appliance Price Index	S11	Value of Recycled Materials
S1	Actual Supply of Waste Household Appliances	S12	Residents' Purchasing Power
S2	Actual Demand for Waste Household Appliances	S13	Public Environmental Awareness
S3	Theoretical Supply Volume	S14	Industrial Policy Intensity
S4	Formal Recycling Rate	S15	Industrial Technological Level
S5	Market Demand Intensity	S16	Primary Raw Material Prices
S6	Historical Sales Volume of Household Appliances	S17	Macroeconomic Environment
S7	Willingness to Participate in Recycling	S18	Social and Cultural Background
S8	Recycling Infrastructure	S19	Policy and Regulatory Environment
S9	Policy Subsidy Intensity	S20	Technological Development Level
S10	Average Product Service Life	S21	Raw Material Market Environment

First, a matrix of direct influence relationships among factors is established to clarify the intensity of interactions between factors, with diagonal elements set to zero. The matrix is then standardized to obtain the comprehensive influence matrix. Finally, the influencing degree, affected degree, causal degree and centrality degree of each factor are calculated to distinguish core causal factors from resultant factors and clarify the importance and interrelationships of the factors. The calculation results are shown in Table 5.

Table 5: The comprehensive influence relationship of the influencing factors of the price index of waste household appliances

Factor	Factor Name	Influence Degree	Affected Degree	Causality Degree	Centrality	Factor Attribute
S0	Waste Household Appliance Price Index	0.483	2.875	-2.392	3.358	Result
S1	Actual Supply of Waste Household Appliances	0.409	1.236	-0.827	1.645	Result
S2	Actual Demand for Waste Household Appliances	0.506	1.384	-0.878	1.890	Result
S3	Theoretical Supply Volume	0.352	0.891	-0.539	1.243	Result
S4	Formal Recycling Rate	0.427	1.158	-0.731	1.585	Result
S5	Market Demand Intensity	0.385	1.026	-0.641	1.411	Result
S6	Historical Sales Volume of Household Appliances	0.218	0.573	-0.355	0.791	Result
S7	Willingness to Participate in Recycling	0.512	0.987	-0.475	1.499	Result
S8	Recycling Infrastructure	0.625	0.832	-0.207	1.457	Result
S9	Policy Subsidy Intensity	1.023	0.586	0.437	1.609	Cause
S10	Average Service Life of Products	0.327	0.715	-0.388	1.042	Result
S11	Value of Recycled Materials	0.721	1.368	-0.647	2.089	Result
S12	Residents' Purchasing Power	0.685	0.723	-0.038	1.408	Result
S13	Public Environmental Awareness	0.452	0.897	-0.445	1.349	Result
S14	Industrial Policy Intensity	1.158	0.492	0.666	1.650	Cause
S15	Industrial Technological Level	0.573	0.685	-0.112	1.258	Result
S16	Primary Raw Material Prices	0.987	0.612	0.375	1.599	Cause
S17	Macroeconomic Environment	1.072	0.536	0.536	1.608	Cause
S18	Social and Cultural Environment	0.528	0.713	-0.185	1.241	Result
S19	Policy and Regulatory Environment	0.895	0.502	0.393	1.397	Cause
S20	Technological Development Level	0.632	0.698	-0.066	1.330	Result
S21	Raw Material Market Environment	0.857	0.563	0.294	1.420	Cause

A Cartesian coordinate system is constructed with centrality as the horizontal axis and causality as the vertical axis to show the causal relationships and importance of each indicator, as shown in Figure 3.

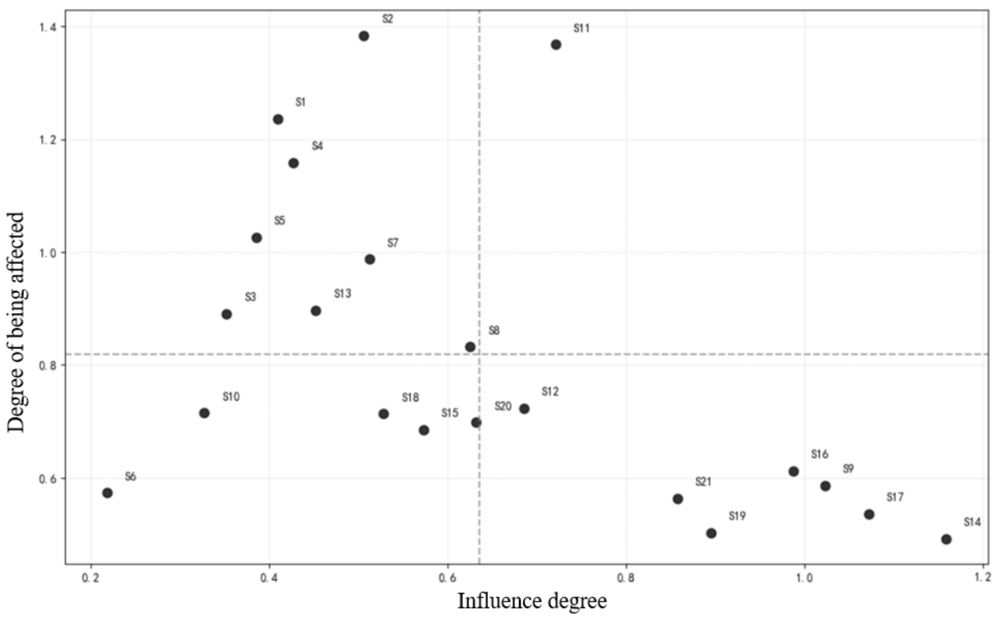

Figure 3: The relationship between the influencing factors of the price index of waste household appliances

Next, the overall influence matrix T is constructed. Since the aforementioned matrix cannot reflect the degree of a factor's influence on itself, an identity matrix is introduced to form the overall influence matrix, so as to cover all the correlations among factors. To establish the reachability matrix, a threshold λ is first determined based on the comprehensive influence matrix to screen the correlation intensity between factors, balancing the elimination of redundant relationships and the retention of key connections. To avoid subjective bias, the threshold is set as the sum of the mean and standard deviation of the elements in the comprehensive influence matrix. Boolean operations and iterative calculations are then carried out using relevant software tools, and the final reachability matrix is obtained.

Construct a multi-level hierarchical structure model. The reachable set, antecedent set, and common set of each factor are calculated based on the reachability matrix M, and then gradually screened according to hierarchical decomposition rules. Finally, the hierarchy table of influencing factors of the waste household appliance price index is obtained, as shown in Table 6. The influencing factors are divided into six levels. Among them, the waste household appliance price index is at the first level; the actual supply and actual demand of waste household appliances are at the second level; the theoretical supply volume, formal recycling rate, and market demand intensity are at the third level; historical household appliance sales, willingness to participate in recycling, recycling infrastructure, policy subsidy intensity, average product lifespan, and value of recycled materials are at the fourth level; residents purchasing power, public environmental awareness, industrial policy intensity, industrial technological level, and primary raw material prices are at the fifth level; and social and cultural background, policy and regulatory environment, technological development level, and raw material market environment are at the sixth level.

Table 6: level decomposition summary

Layer	Si
L1	S0
L2	S1,S2
L3	S3,S4,S5
L4	S6,S7,S8,S9,S10,S11
L5	S12,S13,S14,S15,S16
L6	S17,S18,S19,S20,S21

5.2 Analysis of the Hierarchical Structure of Influencing Factors

According to the hierarchical division and logical relationships of the influencing factors, directed arrows are used to connect the relevant factors between different levels, yielding the hierarchical structure diagram of the influencing factors of the waste household appliance price index, namely the influence mechanism of the index, as shown in Figure 4.

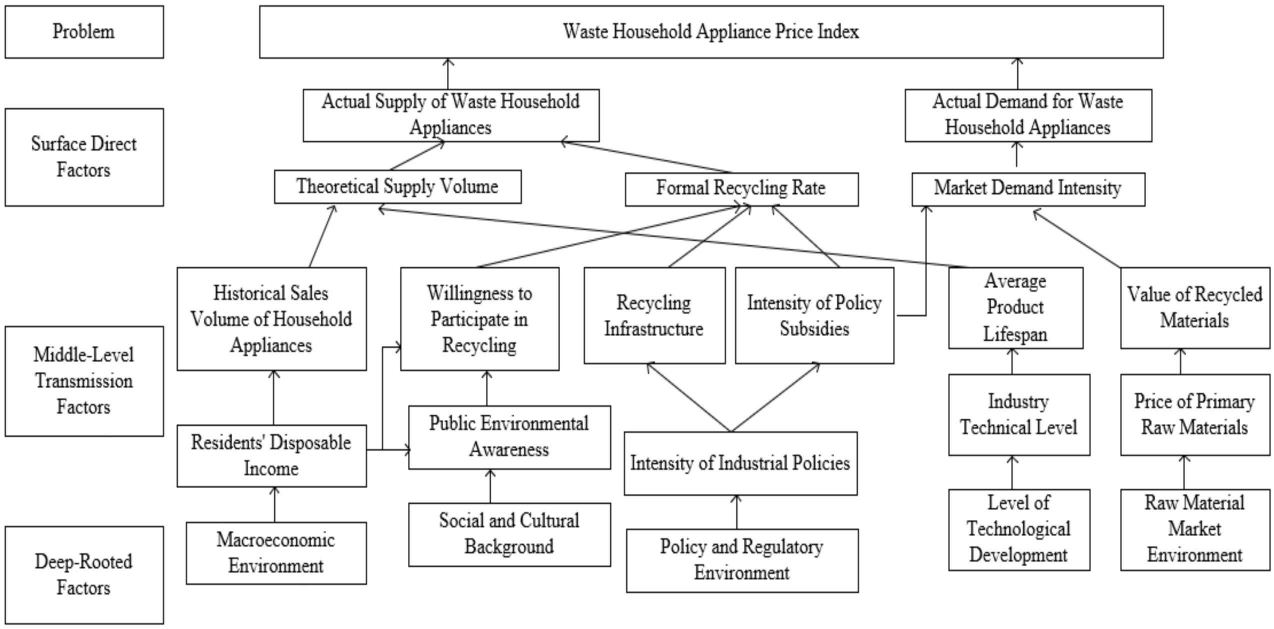

Figure 4: Hierarchical structure diagram of the influencing factors of the waste household appliance price index

The system of influencing factors on the waste household appliance price index can be divided into three levels: surface direct factors, intermediate transmission factors, and deep-rooted factors.

(1) Surface Direct Influencing Factors of the Waste Household Appliance Price Index.

Actual supply of waste household appliances, actual demand for waste household appliances, and the value of recycled materials are the three main surface direct factors driving fluctuations in the waste household appliance price index. From the perspective of market economics theory, the supply and demand of waste household appliances jointly determine their market price level. Generally speaking, when the actual supply of waste household appliances increases, the market experiences oversupply, leading to a decline in the price index; when actual demand rises, market shortage pushes up the price index. In addition, changes in the value of recycled materials directly affect market demand intensity. When the value of recycled materials increases, downstream enterprises become more willing to recycle and reuse waste household appliances, boosting actual demand and thereby driving up the price index, and vice versa. These three factors work together to directly determine the fluctuation of the waste household appliance price index.

(2) Intermediate Transmission Influencing Factors of the Waste Household Appliance Price Index.

Historical sales volume of household appliances, willingness to participate in recycling, recycling infrastructure, policy subsidy intensity, average product lifespan, primary raw material prices, residents' purchasing power, and public environmental awareness are the main intermediate transmission factors affecting the waste household appliance price index. On the supply side, historical household appliance sales restrict the actual supply level by influencing the theoretical supply volume; willingness to participate in recycling, recycling infrastructure, and policy subsidies jointly affect the formal recycling rate, which in turn influences actual supply; the length of average product lifespan directly affects the calculation of theoretical supply volume. On the demand side, primary raw material prices adjust market demand intensity by affecting the value of recycled materials; residents' purchasing power and public environmental awareness indirectly influence the formal recycling rate by shaping recycling participation willingness. These factors jointly affect the market supply-demand relationship of waste household appliances through different transmission paths.

(3) Deep-Rooted Influencing Factors of the Waste Household Appliance Price Index.

Industrial policy intensity, industrial technological level, macroeconomic environment, social and cultural background, policy and regulatory environment, technological development level, and raw material market environment are the deep-rooted factors driving fluctuations in the waste household appliance price index. Industrial policy intensity directly determines the investment scale of recycling infrastructure construction and the level of policy subsidies; industrial technological level affects product lifespan and recycled material extraction efficiency; the macroeconomic environment indirectly influences market demand by affecting residents' purchasing power and primary raw material prices; social and cultural background shapes public environmental awareness and recycling participation willingness; the policy and regulatory environment provides institutional support and a development framework for the entire recycling industry; technological development level promotes industrial technological progress; and the raw material market environment adjusts the value of recycled materials by influencing primary raw material prices. These deep-seated factors ultimately affect the supply-demand relationship and price index in the waste household appliance market through complex transmission mechanisms.

The 21 influencing factors can be classified into four categories: market supply-demand factors, economic cost factors, social-technological factors, and policy-institutional factors. Among them, market supply-demand factors include actual supply, actual demand, market demand intensity, and formal recycling rate; economic cost factors include the value of recycled materials, primary raw material prices, and the macroeconomic environment; social-technological factors include recycling infrastructure, industrial technological level, public environmental awareness, recycling participation willingness, technological development level, and per capita purchasing power; policy-institutional factors include policy subsidy intensity, industrial policy intensity, policy and regulatory environment, and raw material market environment.

6. Analysis of the Dynamic Impact Effects of the Waste Household Appliance Price Index

6.1 Variable Selection and Data Processing

To empirically test the influence mechanism revealed by the DEMATEL-ISM model and quantify the effects of core factors on the waste household appliance price index, this study takes the waste household appliance price index as the dependent variable, and selects representative indicators from four categories—market supply and demand, economic cost, social technology, and policy institution—as core explanatory variables. The specific selection reasons and data sources are as follows.

The dependent variable, the waste household appliance price index, is represented by the Laspeyres price index constructed in Chapter 3, mainly for two reasons. First, scientificity: the fixed-weight feature of the Laspeyres index effectively avoids disturbances caused by fluctuations in the structure and volume of recycled categories, accurately reflecting the real changing trend of price levels, which conforms to academic norms for price index compilation. Second, systematicness: it covers five core categories including air conditioners, refrigerators, washing machines, televisions, and computers, comprehensively reflecting the overall market price level rather than partial fluctuations of a single category. The data source is consistent with that in Section 3.3.

The representative indicator for market supply and demand is the total recycling volume of waste household appliances (Nelen et al., 2014). The total recycling volume is obtained by weighted summation of monthly recycling volumes of five typical waste household appliances—air conditioners, refrigerators, washing machines, televisions, and computers—using the same weights as the price index (set based on the proportion of dismantled resource value of the five appliances, as shown in Table 2), with the unit of “10,000 units”. As a core direct surface factor of market supply and demand, the recycling volume directly reflects the supply strength of the waste household appliance market, and its changes immediately affect the supply-demand balance, fully matching the direct influence path of “actual supply → price index” in the ISM model. In addition, the DEMATEL model results show that the affected degree of recycling volume reaches 3.42, ranking among the top three of all factors. As a core target of various driving factors, it can fully represent the short-term impact of market supply-demand factors on prices. The data source is consistent with that in Section 3.3.1.

The representative indicator for economic cost is the composite price index of major raw materials (Xu et al., 2025). The core renewable resources from dismantling waste household appliances are iron, copper, aluminum, and plastics (Horta et al., 2020). Therefore, three high-frequency indices—the steel price index (representing iron), non-ferrous metal price index (representing copper and aluminum), and China Plastic City PP index (representing plastics)—are selected and synthesized into a composite index of major raw material prices according to the proportion of recycled volume of each resource after dismantling five types of appliances (35% iron, 8% copper, 12% aluminum, 45% plastics), and used after dimensionless processing. As a core driving factor of economic cost, raw material prices directly determine the resource value of waste household appliances. Higher prices of renewable resources strengthen the willingness of dismantling enterprises to purchase, thereby pushing up the recycling price of waste household appliances, which conforms to the intermediate transmission logic of “raw material price → recycled material value → price index”. In the DEMATEL model, the influencing degree of raw material prices reaches 3.56, ranking second among all factors, with a direct influence intensity of 4 on recycled material value, which can accurately represent the medium and long-term trend-driven effect of economic cost factors on prices. Data are obtained from MySteel and Shanghai Metals Market as daily data, processed into monthly averages to be consistent with the frequency of other variables. Index data have excluded inflation interference and are horizontally comparable.

The representative indicator for social technology is per capita disposable income of national residents. Quarterly data released by the National Bureau of Statistics are disaggregated into monthly per capita disposable income data (unit: yuan/person) with reference to existing studies, based on the proportion of monthly total retail sales of consumer goods, to meet the model’s monthly analysis requirements. Resident disposable income indirectly acts on the price index through the transmission path: “income increase → enhanced environmental awareness → improved willingness to participate in formal recycling → optimized recycling efficiency → stable price”, which has been supported by many domestic and foreign studies. The DEMATEL model shows that the centrality of resident disposable income reaches 5.58, ranking top three among all factors. It is both driving (causality degree 0.84) and transmissive, comprehensively representing the long-term supporting effect of social and technological factors on prices, while effectively solving the problem of unavailability of indicators such as recycling infrastructure.

The representative indicator for policy institutions is policy subsidy intensity. Focusing on the Waste Electrical and Electronic Equipment Treatment Fund, the most direct and influential policy in the field of waste household appliance recycling, the policy subsidy intensity is calculated by weighted summation of the per-unit subsidy standards for five appliances (air conditioners, refrigerators, washing machines, televisions, computers) using the same weights as the price index (as shown in Table 2), with the unit of “yuan/unit”. The DEMATEL model shows its causality degree reaches 2.15, ranking first among all factors, making it the most effective core driving factor for regulation. Compared with abstract indicators such as “industrial policy intensity” and “regulatory environment”, the subsidy standard of the treatment fund is directly quantifiable, and the continuous implementation of the policy can accurately reflect the dynamic effect of policy intervention, avoiding measurement deviations caused by qualitative policy variables.

6.2 Test of Short-Term Dynamic Correlation of the Price Index

The first step in constructing the VAR model is to conduct a stationarity test for each variable series in the model. This paper adopts the ADF unit root test to judge the stationarity of each variable, and the specific test results are shown in Table 7. At the 5% confidence level, the p-values of the ADF test for the original series of the waste household appliance price index and the policy variable are 0.279 and 0.780 respectively, both greater than the significance level of 0.05, indicating that the original series of these two variables are non-stationary. By contrast, the p-values of the original series of recycling volume, major raw material prices, and residents' disposable income are all less than 0.05, meaning they are stationary at the level of the original series. To further analyze the characteristics of the non-stationary series, all variables are processed by first-order difference and subjected to the ADF test again. The results show that the first-order difference series of all variables are stationary, meeting the stationarity requirement of the VAR model and passing the unit root test.

The lag order of the VAR model is comprehensively determined according to four information criteria: FPE, AIC, HQIC, and SBIC, with the results presented in Table 8. When the lag order is 2, three indicators, namely FPE, AIC, and HQIC, reach the optimum simultaneously (marked with *), and the SBIC value is relatively small, indicating that the VAR(2) model ensures goodness of fit while maintaining satisfactory parsimony. Therefore, this study selects the VAR(2) model for subsequent analysis.

Table 7: ADF test results of each variable

Variables	Original sequence		First-order difference	
	ADF	P	ADF	P
Waste Household Appliance Price Index	-2.02	0.28	-4.30	0.000
Recycling Volume	-4.00	0.00	-8.49	0.000
Prices of Major Raw Materials	-3.64	0.00	-5.78	0.000
Disposable Income of Residents	-3.03	0.03	-5.94	0.000
Policy Variables	-0.92	0.78	-6.16	0.000

Table 8: lag order information criterion statistical table

Lag	LL	LR	FPE	AIC	HQIC	SBIC
0	28.64	NA	1.90E-07	-1.31	-1.24	-1.09
1	153.59	249.90	7.30E-10	-6.87	-6.41	-5.55*
2	186.59	65.99	5.1E-10*	-7.31	-6.47*	-4.89
3	207.70	42.22	8.00E-10	-7.09	-5.87	-3.57
4	249.40	83.40*	5.20E-10	-8.02*	-6.41	-3.40

Table 9: Johansen Cointegration Test Parameter Table

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.72	101.80	68.52	0
At most 1 *	0.55	53.04	47.21	0.01
At most 2	0.32	22.50	29.68	0.29
At most 3	0.18	8.05	15.41	0.51
At most 4	0.02	0.64	3.76	0.42

Since the model contains five variables that may have a long-run equilibrium relationship, a cointegration test is required. This study adopts the Johansen cointegration test, and the results are shown in Table 9. The trace statistic test indicates that at the 5% significance level, the null hypotheses of “None” and “At most 1” are rejected, while those of “At most 2” and above are not rejected. This suggests that there exist at least two cointegration relationships among the five variables, satisfying the conditions for establishing a vector error correction model and indicating a long-term stable equilibrium relationship between the variables. This result provides a theoretical basis for the subsequent impulse response analysis and variance decomposition, ensuring the reliability of the empirical findings.

To verify the stability and validity of the constructed VAR(2) model, this study performs an AR unit root test. This test is a necessary and sufficient condition for judging the stability of a VAR model, based on the principle that the model is stable if the reciprocal moduli of all characteristic roots lie within the unit circle; otherwise, it is unstable. The test results are shown in Figure 5, where all characteristic roots fall within the unit circle, indicating that the VAR(2) model satisfies the stability condition. This implies that the model constitutes a stationary system, its impulse response functions will converge, and the variance decomposition results are valid.

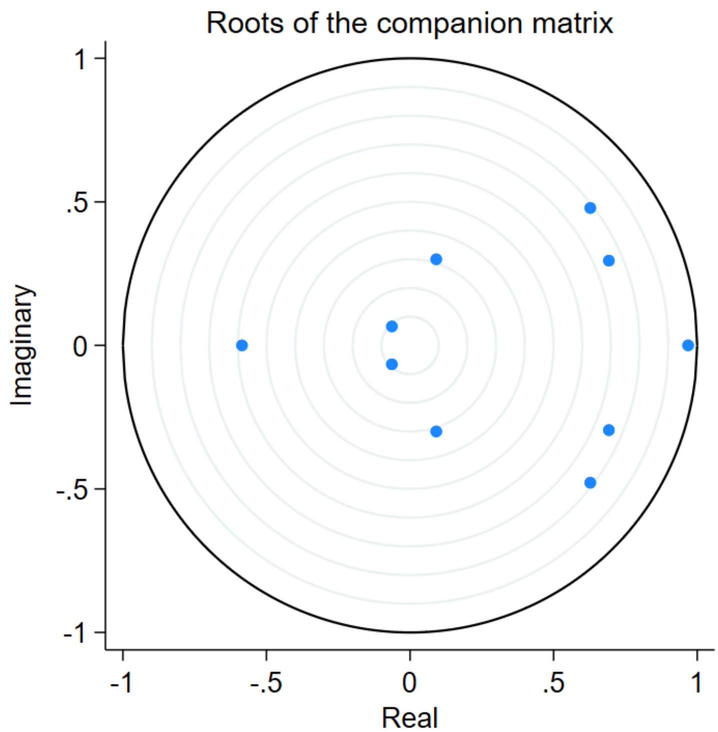

Figure 5: Unit root test results

6.3 Index Impulse Response and Decomposition of Volatility Contribution

The impulse response function is one of the core analytical tools of vector autoregression (VAR), which is used to depict the dynamic influence path on all variables in the system after an endogenous variable is subjected to an external shock of one standard unit. Its core idea is that in an interconnected system, an unexpected change in any variable will not only affect itself but also transmit to other variables in the system through the dynamic links among variables. Mathematically, the impulse response function is derived from the vector moving average representation of the VAR model. By the Wold decomposition theorem, a stable VAR model can be transformed into a VMA(∞) model:

$$Y_t = \mu + \varepsilon_t + \Psi_1\varepsilon_{t-1} + \Psi_2\varepsilon_{t-2} + \cdots \quad (9)$$

Among them, the element in the i-th row and j-th column of the coefficient matrix Ψ_s is the impulse response value of a unit shock to variable j on variable i in period s. By observing the sequence of Ψ_s as s changes, the complete impulse response path can be obtained.

Based on the impulse response function derived from the VAR model, this paper conducts an in-depth analysis of the dynamic influence paths of a standard unit positive shock from recycling volume, major raw material prices, residents' disposable income, and policy variables on the waste household appliance price index. The analysis period covers the next 20 periods, and the results are shown in Figure 6, revealing the direction, intensity, duration, and lag effect of the influences of various factors.

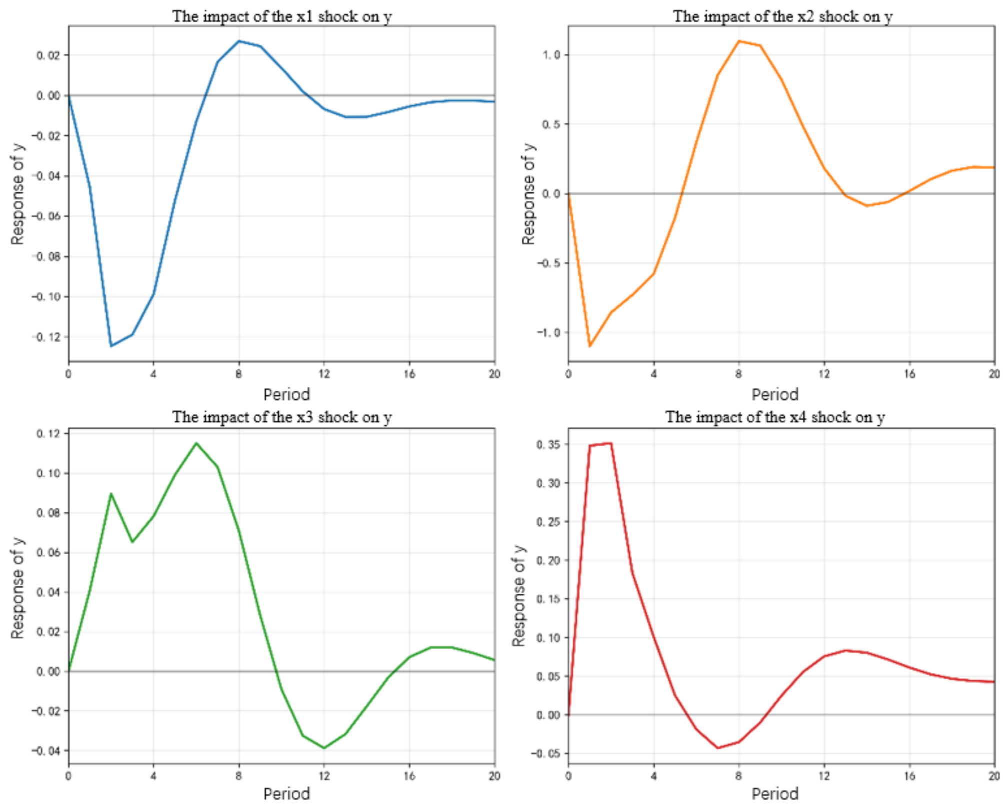

Figure 6: Impulse response results

The impact of recycling volume shocks on the waste household appliance price index reflects short-term suppression and market self-regulation. An unexpected increase in recycling volume exerts a negative effect on the price index. The negative impact peaks in the second period after the shock, with a one-unit increase in recycling volume causing the price index to drop by 0.12 units, indicating significant short-term downward pressure on the price index due to excess supply. However, this restraining effect does not intensify continuously; it begins to weaken after the third period and turns from negative to positive after the sixth period. This dynamic trajectory reveals the self-regulating mechanism of the waste household appliance recycling market: the initial excess supply is gradually absorbed by the market, easing price pressure and potentially leading to a slight rebound. This indicates that recycling volume is an important factor triggering short-term price fluctuations, yet market mechanisms can effectively correct such deviations.

Shocks to major raw material prices exhibit the most significant and complex influence path, highlighting their role as a fundamental driving force. A strong negative effect appears in the initial stage (Periods 1–5), which may reflect the time lag in cost transmission to downstream recycled products. Nevertheless, the impact strongly shifts from negative to positive starting from Period 6 and rises rapidly, reaching a positive peak in Period 8, where a one-unit shock to raw material prices pushes the waste household appliance price index up by 1.08 units. Although its impact weakens slowly thereafter, it maintains a strong positive effect throughout the 20-period analysis. This clearly demonstrates that rising raw material prices fundamentally enhance the intrinsic value and market demand of waste household appliances as resource products, thereby forming the strongest and most persistent upward momentum for their price index.

Increases in residents' disposable income generate a steady and moderate positive boost to the price index. The impact rises steadily after the shock, reaches a high level in Period 6, then enters a long stable plateau, and only begins to decline slowly after Period 10. This pattern shows that improved resident purchasing power effectively strengthens environmental consumption willingness and willingness to pay for formal recycling channels, providing solid and sustained demand-side support for waste household appliance prices. Unlike the rapid decay of policy shocks, demand growth driven by income is more resilient and serves as a robust fundamental factor influencing the price index.

Policy shocks (such as increased subsidies) exert an immediate but rapidly diminishing effect on the waste household appliance price index. They quickly reach a high point in Period 1, with a one-unit policy shock lifting the price index by 0.348 units, and this peak effect persists into Period 2, proving that policy instruments are highly efficient in stimulating the formal recycling market and rapidly raising prices. However, such strong effects cannot be sustained; they enter a rapid decline from Period 3 onward and become negligible after Period 10. This typically reflects the short-term nature of administrative or economic subsidy policies, whose effects dissipate as the market fully responds and forms a new equilibrium, requiring policymakers to pay attention to the persistence of policy outcomes.

Based on the above analysis, the waste household appliance price index is subject to intertwined dynamic influences from multiple factors with varying time sequences. Its fluctuations result from the combined effects of short-term forces and long-term trends. Recycling volume and policy variables dominate short-term volatility, while raw material prices and resident income determine the fundamental direction and baseline level of long-term trends, respectively.

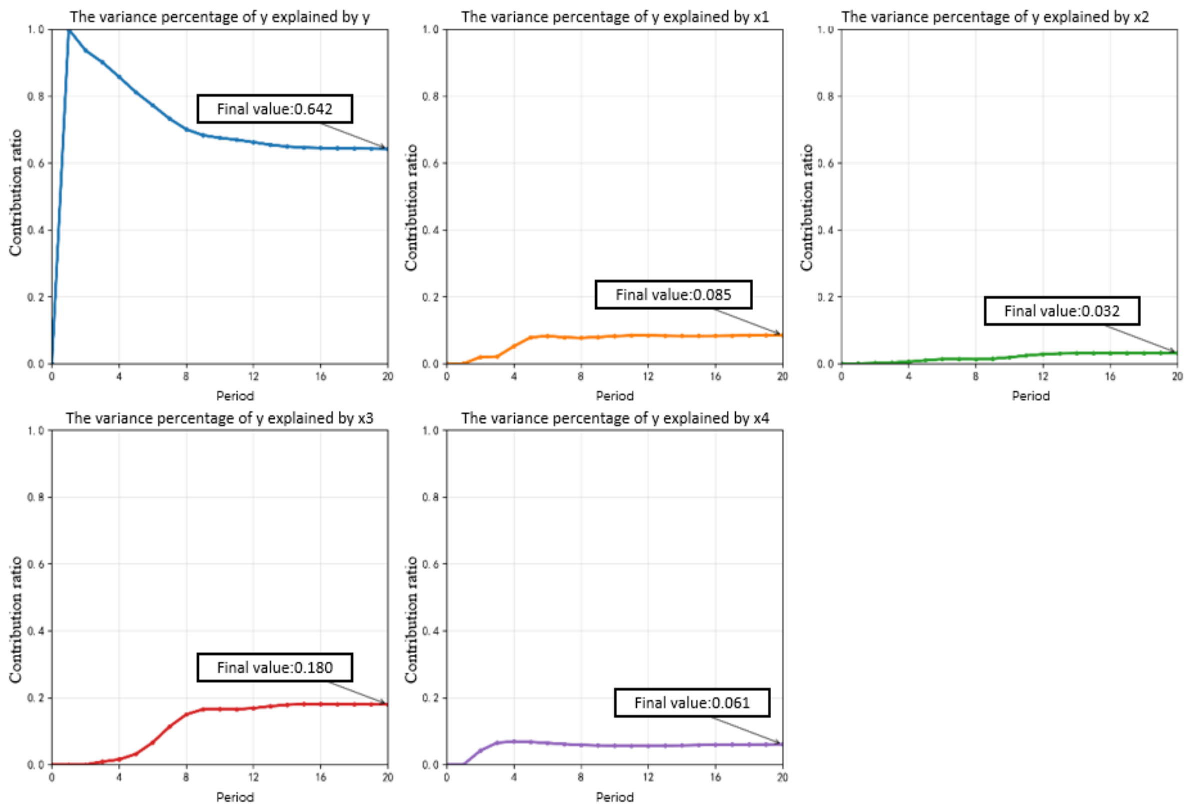

Figure 7: The result of variance decomposition

According to the variance decomposition results in Figure 7, this study identifies the contribution degrees of various influencing factors to the fluctuation of the waste household appliance price index and their dynamic evolution characteristics as follows:

First, the fluctuation of the waste household appliance price index mainly stems from its own historical inertia. The analysis shows that in the first period, the fluctuation of the price index is entirely explained by its own shock. Although this contribution rate gradually declines over time, it remains at a relatively high level of 64.23% in the 20th period. This indicates that price changes feature significant self-sustaining characteristics, and historical price trends are the most important basis for predicting future movements, reflecting strong path dependence in the process of market price formation.

Second, residents' disposable income is the most important influencing factor apart from the index itself. Its contribution degree shows a rapid upward trend, rising from nearly zero in the second period to 16.64% in the 10th period, and finally stabilizing at around 17.97% in the 20th period. This trajectory suggests that the impact of residents' purchasing power on the price index is a continuously strengthening medium- and long-term process. Income level gradually becomes a key external factor driving price changes by affecting consumption structure and recycling willingness.

Third, the contribution degree of recycling volume remains stable but relatively limited. Its contribution rate rises gradually from the initial stage, basically stabilizes after reaching 8.27% in the 10th period, and finally maintains at 8.52%. This indicates that, as a direct reflection of the market supply side, changes in recycling volume do exert a sustained influence on price fluctuations, but its effect intensity is significantly lower than that of price inertia and residents' income.

Fourth, the impact of policy variables exhibits a pattern of rapid initial growth followed by stabilization. It reaches a contribution degree of 4.17% in the second period, indicating that policy shocks can be transmitted to the market relatively quickly. However, subsequent growth is slow, and the final contribution degree stabilizes at 6.07%. This result shows that although policy intervention can produce noticeable effects in the short run, its explanatory power for price fluctuations is relatively limited in the long run, weaker than fundamental factors such as residents' income.

Finally, the contribution degree of raw material prices is the lowest among all factors. Although its contribution rate grows slowly over time, it finally stabilizes at only 3.21%. This finding differs from theoretical expectations, suggesting that while changes in raw material prices elicit responses in price levels, their importance is relatively low in explaining the overall magnitude of price index fluctuations.

7. Conclusions and Policy Recommendations

This paper takes the waste household appliance price index as the core, based on transaction data from 64 formal recycling enterprises across 25 provinces in China, and uses the DEMATEL-ISM method and VAR model to systematically analyze the influencing mechanism of the price index. The main conclusions are as follows:

First, the waste household appliance price index shows obvious phased fluctuations. Driven by raw material prices, it trends upward; policy adjustments trigger sharp short-term shocks, and the index gradually stabilizes after market adaptation. The index responds sensitively to market supply and demand, costs, and policies.

Second, the influencing factors of the price index present a three-level transmission structure. At the surface level, it is directly driven by actual supply, actual demand, and the value of recycled materials; at the intermediate level, it is transmitted by historical household appliance sales, willingness to participate in recycling, infrastructure, subsidy intensity, and other factors; at the deep level, it is fundamentally determined by industrial policies, technological levels, the macroeconomy, the regulatory environment, and other factors.

Third, dynamic empirical results show that 64.23% of the price index fluctuation comes from its own inertia, featuring strong path dependence; residents' disposable income contributes 17.97%, making it the most important external influencing factor; raw material prices exert a long-term stable driving effect; recycling volume generates a short-term negative impact; policy subsidies take effect quickly but decay rapidly, with limited long-term contribution.

To stabilize waste household appliance prices, smooth the transmission mechanism, increase the proportion of formal recycling, and promote the standardized development of the industry, hierarchical regulation suggestions are proposed:

(1) Short term: Improve price monitoring and early warning to stabilize abnormal fluctuations

Establish a monthly monitoring and early warning system centered on the waste household appliance price index to issue timely price signals; regulate recycling pricing and clear price labeling, and crack down on grade depression, price undercutting, and malicious competition; use tools such as temporary subsidies and reserve regulation to quickly hedge against sharp shocks from supply, demand, and raw material prices, so as to stabilize market expectations (Zhao et al., 2025).

(2) Medium term: Improve the policy linkage mechanism and optimize resource allocation efficiency

Construct a dynamic adjustment mechanism that links subsidy standards to the price index to enhance policy accuracy; strengthen the construction of recycling outlets and sorting infrastructure to reduce collection costs and promote efficient matching of supply and demand; promote data sharing and coordinated pricing across the industrial chain to reduce information asymmetry and lags in price transmission.

(3) Long term: Strengthen institutional support and promote high-quality industrial development

Strictly implement the extended producer responsibility system, and promote green design and high-value utilization of recycled materials; increase investment in technological R&D and environmental publicity to improve dismantling efficiency and residents' willingness to use formal recycling channels; establish a multi-department collaborative governance system, incorporate the price index into industry assessment and policy evaluation, and form a long-term mechanism for price stabilization, quality improvement, emission reduction, and efficiency enhancement.

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