The Impact of the Financial Fund on the Efficiency of Waste Electrical and Electronic Products Processing in China

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Abstract. With the support of the fund, the recovery and dismantling volume of WEEE in China have been greatly improved, but it is far away from the provisions of the long term planning for the construction of renewable resources recovery system. In the paper, the development of waste electrical and electronic products processing field is analyzed, from which we find the shortcomings of the existing electronic waste fund operation in China. First of all, the paper analyzes the influence of household appliances dismantling fund on household appliances production industry by using partial equilibrium model, and finds that expropriation fund is not the main reason for enterprises to adjust their production and operation strategies and adopt ecological design. Through further analysis, it finds that the main reason for enterprises to adopt ecological design is firstly attributed to the public’s increasing attention to health, and secondly to the environmental standards and sections issued by the government subsidy and other policies directly related to ecological design. In terms of the fund subsidies, DEA model is used to analyze the impact of fund subsidies on the dismantling and treatment industry. The model results show that fund subsidies are effective for the dismantling and treatment of 5 major electronic waste products. On one hand, they alleviate the loss of enterprises; on the other hand, they promote energy conservation and emission reduction, and improve the efficiency of dismantling. The economic benefit, environmental and resource benefit and social benefit of the fund of dismantling and processing enterprises are all affected by the fund subsidy. Finally, it gives policy implications. In order to improve the financial efficiency of the fund, it is suggested that in the aspect of fund policy management, we should appropriately improve the current fund collection standards, adjust the products and scope of the fund collection catalogue, and formulate differentiated collection standards for the products with different environmental protection performance, so as to realize the incentive and constraint of the fund collection on the production enterprises. In terms of the fund subsidy, we should further adjust the design of subsidy amount, establish a long-term subsidy performance evaluation system and a qualification examination mechanism for enterprises entering and exiting the subsidy list, ensure the effectiveness of fund subsidy distribution, narrow the gap in the fund pool, reduce the waste of fund subsidy, and achieve the unity of economic benefits, resources and environmental benefits and social benefits.

Keywords. WEEE; financial fund; efficiency; local equilibrium model; DEA model.
1. Introduction

China is the largest producer of waste electrical and electronic products; however, the annual recycling quantity is less than the scrap quantity. In 2013, the quantity of waste electrical and electronic products that was recycled was 11.43 million units, and the total weight of the solid waste was 2.638 million tons, with a recovery rate of 52.76%. In 2015, the cumulative quantity received by the processing enterprises reached 20.2824 million units, with a total weight of 3.974 million tons, while the absolute total amount from proper recycling exceeded that of Japan, and ranked second in the world behind the European Union. In 2017, more than 200 million units of waste electrical products were scrapped, and solid waste weighed over 5 million tons; the total annual processing capacity was 150 million units, and the actual disposal of electronic waste was 75 million units. Over the years, the average annual standard recovery rate was 37.5%, which is far behind the mid-and long-term planning goals for the construction of the renewable resource recovery system, whereby the average recovery rate of major urban renewable resources in 2020 should be over 75%. Since the launch of the processing fund and supporting policies for waste electrical and electronic products in 2012, China's regular dismantling and processing industry has developed rapidly and orderly, and the amount of recovered and dismantled electrical and electronic waste in compliance with regulations grew rapidly. At the beginning of the operation of the fund, the number of regular dismantling and processing enterprises increased from 39 in 2012 to 106 in 2013; moreover, the year-on-year growth rate of the volume of compliant dismantling and treatment of waste electrical and electronic products reached 200%, and the annual output value of the waste electrical and electronic industry exceeded 100 billion yuan. Since 2015, the fund has been in deficit, reaching 2.682 billion yuan, i.e., more than 90% of the total funds levied that year. In 2017, the subsidy was only 66 million yuan, and it was difficult to formally dismantle the enterprise in order to ensure a balance between fund revenue and expenditure.

This paper analyzes the current status of the processing fund of waste electrical and electronic products, conducts empirical research on the fund collection and utilization efficiency, identifies restrictive factors for the waste electrical and electronic products of the recycling industry, and forms a resource-based industry, thereby promoting the efficient operation of the fund and the harmless treatment of solid waste. The policy-oriented role of resource utilization and industrial development provides ideas for the recycling, dismantling, and disposing of other electrical and electronic wastes that are not listed in the Fund Catalog.

1.1. Waste Electrical and Electronic Products Processing Fund

Waste electrical and electronic products refer to the electrical and electronic products whose use-value cannot meet the requirements, or which are abandoned due to overage or termination of service life. The processing fund for the waste electrical and electronic products is levied on the producers of electrical and electronic products, the consignees of imported electrical and electronic products, or their agents. As shown in table 1, the levy standard is 7-13 yuan/unit (with different standards for different types of products), while the subsidy standard issued in 2011 was 35-85 yuan/unit, and the adjusted subsidy standard in 2016 was 30-130 yuan/unit. All revenues are collected by the central government, and are mainly used to subsidize the disposal expenses of waste electrical and electronic products.

According to the data published by the Solid Waste and Chemical Management Technology Center (hereinafter referred to as the Solid Waste Center) of the Ministry of Ecological Environment, in China Taiwan the first batch of enterprises under the subsidy list had a standardized dismantling capacity of 7.67 million units in 2012, and in 2013 the national “four machines” (in the early stage of the implementation of the fund, computers were neither included in the scope of subsidies, nor in the statistical scope of electronic waste dismantling capacity in 2013) had a standardized dismantling capacity of 17.59 million units. Due to the large accumulated number in the early stage, in 2014 the national standard disassembly capacity of the “four machines and one brain” exceeded 70 million units, and the volume of disassembly increased significantly. Due to the large demand gap in the dismantling and processing of electronic waste, 15 new enterprises were added in 2014, and the supply
of the dismantling industry increased. In relation to disassembly compliance, 39 enterprises had a total audit deduction of 1.4282 million units in 2012, with an audit pass rate of 84.16%. In 2013, the audit pass rate increased to 97.62%, and remained stable from 2014 to 2018, with an annual audit pass rate of 99% or higher.

**Table 1.** Types and standards of subsidies for processing funds of waste electrical and electronic products (yuan/unit).

| Types            | Subsidies Standard (yuan/unit) | Levy Standard (yuan/unit) |
|------------------|-------------------------------|---------------------------|
|                  | 2011 Version                  | 2016 Version              |
| Television       | 13                             | 85                        | 60-70                    |
| Refrigerator     | 12                             | 85                        | 80                      |
| Washing Machine  | 7                              | 35                        | 35-45                    |
| Air Conditioner  | 7                              | 35                        | 130                     |
| Computers        | 10                             | 85                        | 70                      |

In relation to the classification of disassembled electronic waste, the amount of disassembled TV units accounted for 86% of the total amount of disassembled products three years before the operation of the Fund (2012-2015). In addition to the discarded TV units, the amount of disassembled air conditioners, refrigerators, and computers in the other four categories of electronic waste products increased by about 20 times, 10 times and 6 times, respectively. The larger growth was guided by policies and the number of enterprises, and was caused by the increase in the average dismantling volume of the enterprises and the relatively small year-on-year base. In addition, since 2014 the fund subsidy enterprises have begun to implement the exit mechanism. For enterprises whose annual actual dismantling treatment capacity of all types of waste electrical and electronic products is less than 20% of the licensed treatment capacity, the regulations on granting fund subsidy qualification are cancelled, which also promotes the overall improvement of all kinds of dismantling treatment capacity. By 2015, all enterprises obtained a total of 1.669 million tons of various resource-based dismantling products, equivalent to saving 4.8 million tons of coal, 59 million tons of waste water, 33.14 million tons of solid waste, 11.52 million tons of carbon dioxide, and 11.52 million tons of sulfur dioxide, compared with the utilization of primary resources. In 2016-2018, the total number of waste TV units and computers disposed by dismantling enterprises was large and accounted for a high proportion. This was because the technical demand for dismantling and processing of these two types of products was relatively low, and the subsidy for the single dismantling of these two types of products was relatively high in the subsidy standard.

From 2013 to 2018, the annual disassembly processing volume of the “four machines and one brain” approved by the Ministry reached 70 million units per year, while the disassembly volume of “three machines and one brain”, excluding the increased number of waste TV units, and the disassembly product structure of electronic waste were adjusted synchronously. As of 2018, the total amount of “Four Machines and One Brain” waste that has been disassembled and standardized for environmental protection nationwide has exceeded 360 million units, while the weight of effectively recycled waste of the “four machines and one brain” was about 9.77 million tons, and the output of renewable resources was estimated to be about 70 billion yuan.

According to survey data, the number of China’s compliant companies included in the fund subsidy ranged from 43 in 2012 to a total of 39 companies that were put into production by the end of 2012. By the end of 2013, 91 companies were included in the fund subsidy range, of which 64 were in production. Apart from Tibet and Hainan, where no formal dismantling and processing enterprises were in place, in other provinces and cities, a total of 109 private and state-owned enterprises of different nature were included in the scope of fund subsidies; all of them were put into production,
with an annual processing capacity of 133 million units. In relation to the establishment time of the enterprise, more than half of the enterprises were established from 2009 to 2011, and about 70% of them were established from 2009 to 2013, indicating that, since the issue of the Regulations in 2008, related supporting policies have been continuously improved to promote the development of the industry. From the perspective of the distribution of enterprises, there are several compliance-qualified enterprises in wealthy provinces. The central and eastern regions have a high per capita living standard and a large quantity of electronic products, which has resulted in a large number of scraps and recycling of the “Four Machines and One Brain”. Qualified enterprises are distributed in the developed eastern and coastal provinces, while the number of household durable consumer goods such as the “Four Machines and One Brain” in the western region is low, and there are few qualified companies.

The source of fund collection end has been stable. In 2012, the fund was first collected for four machines, while the fund collection for computers was realized at the end of 2013. According to the final statement of the waste electrical and electronic products treatment fund, published by the Ministry of Finance over the years, in 2014, under the coordination and cooperation of the finance, tax, customs, and environmental protection departments, the total fund revenue and expenditure from 2012 to 2018 reached RMB 13.814 billion and RMB 14.224 billion, respectively. At present, the fund of the “Four Machines and One Brain” has an inflow of about 3 billion yuan, achieving a stable source of fund collection end and a low rate of missing collection.

1.2. Fund Operation and Problems

There are 109 manufacturers with a formal recycling qualification in China, with an annual processing capacity of 133 million units and an actual processing capacity of 75 million units. The standard recovery rate of electronic waste is only 37.5%, which is far behind from the medium- and long-term planning goals of the renewable resource recovery system construction. Table 2 shows the structure of the dismantling products. The dismantling enterprises have a low demand for processing technology. After dismantling, the high output of disused TV units and computers is subsidized at a high proportion of the total dismantling volume. In relation to refrigerators and air conditioners, it is difficult to deal with ozone depleting substances. The disassembly and recovery cost of recyclable raw materials is high, and the fund subsidy scale of the products is low.

|                | 2012    | 2013    | 2014    | 2015    | 2016    | 2017    | 2018    |
|----------------|---------|---------|---------|---------|---------|---------|---------|
| Television     | 94.53%  | 95.09%  | 83.20%  | 70.20%  | 41.76%  | 46.02%  | 52.39%  |
| Computer       | 9.63%   | 17.07%  | 2.91%   | 19.77%  | 13.68%  |         |         |
| Air Conditioner| 0.01%   | 0.02%   | 0.14%   | 0.21%   | 2.05%   | 8.24%   | 5.39%   |
| Refrigerator   | 1.78%   | 0.86%   | 2.27%   | 4.33%   | 5.76%   | 10.74%  | 11.03%  |
| Washing Machine| 3.68%   | 4.03%   | 4.77%   | 8.18%   | 47.52%  | 15.24%  | 17.52%  |

2. Research Review

Most of the domestic and foreign studies on the recycling of waste electrical and electronic products focus mainly on the establishment of a reverse recycling logistics system, based on the top-down policy-making, and there have been few quantitative analyses on the operation efficiency of waste electrical and electronic products processing fund [1-4]. Czajkowski [5] found that when establishing an electrical and electronic waste recycling system, household-based units, rather than individuals, can better promote waste recycling, and that preferences are clearly different, depending on the different role of individuals in the family. Generally speaking, household choice has a clearer preference than individual choice over waste recycling, from the point of view of the family interest. Most people believe that economic reasons are the dominant factor in choosing to participate in waste recycling,
followed by environmental factors. Tong and Tao [6] identified three emerging business models of IT solutions for consumers to recycle and use: community-based recycling plans; reverse recycling logistics systems, developed with the help of big data platforms; and third-party Internet platforms. These models provide an evaluation framework that includes the convenience of consumers in the recycling process, the traceability of producer products, the profitability of recyclers, the degree of mixing, and the reliability of the public, so as to resolve conflicts of interest between different recycling participants.

In terms of the impact of government incentives, Khan and Lodhi [7] analyzed the current status of global e-waste management, and put forward political suggestions for developing countries in Asia and Africa to design environmental strategies. Dubois [8] built a model to evaluate the efficiency of the extended producer responsibility system in Europe, and found that there was a big gap between the theory of static recovery goal and the actual effect. The static goal leads to a lack of incentives for producers to design green products. Dubois argued that, when uniting the minimum recovery goal, producers should be taxed to internalize the cost of waste disposal, make more effective use of price signals to motivate producers, and promote solid waste management. Atasu [9] analyzed the influence of government’s legislative choice on manufacturers’ preferences in product design, through an intellectual property model and a producer responsibility model, and compared the incentive mechanism and the cost-benefit of each recycling participant, concluding that the property incentive is more effective than the producer responsibility incentive. Based on the policies and the data of the China Taiwan Recovery Fund Management Committee for more than 10 years, Shih [10] generated four scenarios to evaluate the fund income from the two modes of annual balance and multi cycle. In the case of uncertain fund cash reserve, the incentive mechanism of the recovery fund is the main factor of fund management from the perspective of long-term accumulation of funds [11-17].

To summarize, scholars [18-24] have done little research on the operational effects and the financial efficiency of China’s waste electrical and electronic products processing fund. The selection of appropriate estimation methods for electrical and electronic waste generation can improve the quality of data and the efficiency of the fund for waste electrical and electronic products. At present, the production data of domestic and foreign waste electrical and electronic products are obtained by estimation. After combining the results of scholars’ estimation models over the years with actual annual data, this paper selects the Social Reserve Coefficient Method proposed by the China Household Electrical Appliances Research Institute to calculate the theoretical scrap of the “four machines and one brain”. In order to study the dismantling efficiency of various types of electronic waste by the grant of subsidies, this paper selects the input and output data of the subsidies issued by the “four machines and one brain” fund as a sample, and selects the product subsidies and dismantling and processing companies’ recovery costs and dismantling cost as an input index, and the economic benefits, resource environmental benefits, and social benefits after disassembling the product, as output indicators [25-31]. The data envelopment analysis method (DEA) is used to evaluate the “technical effectiveness” and the “scale effective” decision-making units. The CCR model [7] studies the efficiency of fund subsidies.

3. Efficiency of Treating Waste Electrical and Electronic Products is Affected by Financial Funds

3.1. Estimation of Amount of Taxes on Waste Electrical and Electronic Products to be Collected from “Four Appliances + Computer” Products

The number of taxable products equals the number of products produced by the manufacturing firms plus the number of imported products minus the number of exported products. The amount of collected funds each year shall be the number of taxable appliances multiplied by the corresponding tax rate. The production volume, import volume, and export volume of the “four appliances + computer” (“4A+C”) products obtained from the Wind database were used to estimate the number of taxable products from 2013 to 2018 and calculate the theoretical amount of collected tax. The four appliances are washing machines, refrigerators, televisions, and air conditioners. The results of the
estimation are shown in Table 3. From 2013 to 2018, the average theoretical amount of collectible tax each year was about 2.85 billion yuan, which deviates far from the actual average amount of collected tax (which is 2.76 billion yuan). As all the data had been obtained from the Wind database, the estimated amount of collected tax is larger than the amount of actually collected tax. This difference is attributable to two reasons: (a) All the produced, imported, and exported personal computers (PCs), which are in the category of microcomputer products, were incorporated into our calculations. However, the desktop PCs sold by the manufacturers of electrical and electronic products had not been taxed, indicating that the scope of the accounting in this study was larger than the actual taxing scope of PCs, which is bound to result in an overestimation of the amount of collected tax; (b) only the major manufacturers of “4A+C” products were subject to fund collection, thereby adding to the overestimation of the amount of tax collected on “4A+C” products.

Table 3. Amount of collectible tax from 2013 to 2018.

| Year | Television | Refrigerator | Washing Machine | Air Conditioner | Computer | Amount of applications (100 million yuan) |
|------|------------|--------------|-----------------|-----------------|----------|------------------------------------------|
| 2013 | 6284       | 6090         | 5086            | 9179            | 1321     | 27.3753                                  |
| 2014 | 5974       | 4288         | 3935            | 9448            | 8807     | 34.2698                                  |
| 2015 | 7824       | 4364         | 4502            | 10377           | 5195     | 27.4744                                  |
| 2016 | 7103       | 3637         | 4301            | 9581            | 9482     | 35.3059                                  |
| 2017 | 7109       | 3332         | 4289            | 11554           | 7001     | 30.3164                                  |
| 2018 | 8220       | 1778         | 3817            | 12094           | 4540     | 28.8694                                  |
estimate the theoretical discarded quantities of “4A+C” products. To implement this method, we first set the service life ranges of all types of electrical and electronic products, then calculated their annual discarded quantities. Using the data gathered over many years, we set the service lives of durable electrical appliances, such as the four appliances, to about 16 years. Generally, 60% of the electrical and electronic products owned by all households are discarded after 10–16 years of use, i.e., the last 7 years of the theoretical service life, which amounts to 8.57% per year. For home PCs, 60% of the products owned by all households are discarded after 4–6 years of use. The formula is:

Theoretical discarded quantity of electrical and electronic products = quantity owned by all households 16 years ago × 60% ÷ 7.

Theoretical discarded quantity of PCs = quantity owned by all households 16 years ago × 60% ÷ 3.

With the data provided by the statistical yearbook, the quantities of durable consumer goods owned by urban and rural households can be predicted. By 2020, the total number of discarded “4A+C” products in China will reach 1.269 billion units, amounting to a weight of 37.17 million tons. Specifically, the quantities of newly discarded TVs, PCs, refrigerators, washing machines, and air conditioners will be approximately 438.62 million, 202.39 million, 239.18 million, 260.83 million, and 12.77 million, respectively (table 5). If the standardized treatment rate of discarded waste electrical and electronic products in 2020 reaches 75% as planned, then the output of renewable resources will reach 136.1 billion yuan. By 2025, the quantity of newly discarded TVs will grow slightly to reach 492.61 million units at an annual growth rate of approximately 2.35%. The quantity of newly discarded refrigerators will be about 361.66 million units, amounting to an increase of about 51.2% relative to 2020 and an annual growth rate of about 8.62%. The quantity of newly discarded washing machines will be about 332.61 million units, amounting to an increase of about 27.52% relative to 2020 and an annual growth rate of about 4.98%. The quantity of newly discarded air conditioners will be about 207.43 million units, amounting to an increase of about 62.35% relative to 2020 and an annual growth rate of about 10.18%. The quantity of newly discarded PCs will be about 25.345 million units, amounting to an increase of about 25.22% relative to 2020 and an annual growth rate of about 4.6%. If the standardized treatment rate of discarded waste electrical and electronic products in 2025 reaches 90% (which is on a par with the developed countries) as planned, then the output of the “4A+C” dismantling and processing industry will reach 200 billion yuan.

### Table 5. Average recycled weight and the recycled resource output value of “4A+C” products.

| Types         | Average product weight (kg) | Steel | Copper | Aluminium | Plastics | Glass | Others | Recovery value (yuan) |
|---------------|-----------------------------|-------|--------|-----------|----------|-------|--------|----------------------|
| Television    | 25                          | 13%   | 1%     | 1%        | 25%      | 55%   | 5%     | 180                  |
| Refrigerator  | 45                          | 55%   | 3%     | 2%        | 35%      | 5%    | 217    |
| Wash Machine  | 30                          | 30%   | 5%     | 5%        | 50%      | 25%   | 196    |
| Air Conditioner | 28                         | 50%   | 18%    | 10%       | 16%      | 6%    | 320    |
| Computer      | 25                          | 22%   | 8%     | 12%       | 25%      | 25%   | 8%     | 187                  |

The number of recycled PCs in China will grow steadily. If the standard treatment rate could reach a level (about 90%) similar to those of developed countries in 2025, the problems of resource shortages and environmental pollution would be alleviated significantly while the output of the “4A+C” dismantling and processing industry will exceed 200 billion yuan. With the year 2020 as an example, a comparison of the theoretical discarded quantities of “4A+C” products and the existing dismantling capacity is shown in table 6. According to the calculations, the theoretical discarded quantities of “4A+C” products are 11 times the existing dismantling capacity in 2020 even if the 109 certified dismantling and processing firms across China were to operate at their full capacities.

Quantity – capacity ratio = theoretical discarded quantity / existing dismantling capacity.
This indicator can be used to measure the ability of a region to dismantle and process waste electrical and electronic products. A value of 1 is ideal for the quantity-capacity ratio. The higher the ratio, the weaker is the region’s ability to dismantle and process waste electrical and electronic products.

The southwestern and central regions of China have relatively low quantity-capacity ratios of 7.29 and 8.15, respectively. The northwestern, northeastern, and southern regions have achieved relatively high quantity-capacity ratios of 21.86, 16.22, and 16.13, respectively. The quantity-capacity ratios of the eastern and northern regions are close to the national average. The number of firms dismantling waste electrical and electronic products and their capacities in each region are largely proportional to the quantities of waste electrical and electronic products produced in the region. The dismantling and processing industry is still in the initial expansion stage with much room for growth.

Table 6. Comparison of dismantling capacity and theoretical discarded quantity of “4A+C” products in 2020.

| Region (Province)                                      | Theoretical number of scrap (10,000) | Existing dismantling capacity (10,000) | Multiple Dismantling capacity |
|-------------------------------------------------------|--------------------------------------|----------------------------------------|-------------------------------|
| East China (Shandong, Jiangsu, Anhui, Zhejiang, Jiangxi, Fujian, Shanghai) | 49801                                | 4408                                   | 11.30                         |
| North China (Beijing, Tianjin, Hebei, Shangxi, Inner Mongolia) | 17039                                | 1584                                   | 10.76                         |
| Middle China (Hubei, Hunan, Henan)                    | 20003                                | 2455                                   | 8.15                          |
| South China (Guangdong, Guangxi, Hainan)              | 14500                                | 899                                    | 16.13                         |
| Southwest China (Sichuan, Yunnan, Guizhou, Xizang, Chongqing) | 12944                                | 1776                                   | 7.29                          |
| Northeast China (Liaoning, Jilin, Heilongjiang)       | 9017                                 | 556                                    | 16.22                         |
| Northwest (Ningxia, Xinjiang, Qinghai, Shannxi, Gansu) | 6711                                 | 307                                    | 21.86                         |
| Total                                                 | 126879                               | 11985                                  | 10.59                         |

3.3. Model of Effects of Funds for Waste Electrical and Electronic Products on Local Equilibrium of Household Appliance Manufacturing Industry

Drawing upon existing research [7, 10], we used a partial equilibrium model to study the impacts of the funds for waste electrical and electronic products on manufacturing firms. Under the assumptions that all market participants are fully rational and the manufacturers of “4A+C” products make production decisions to maximize their utility, equations (1)-(3) can be derived under the condition of full market clearing:

$$\ln \frac{p_1'}{p_1} = \frac{-e^d_1 \ln(1 - t_1)}{e^d_1 - e^e_1}$$

$$\ln \frac{p_2'}{p_1} = \frac{(e^d_1 - 2e^e_1) \ln(1 - t_1)}{e^d_1 - e^e_1}$$

$$\ln \frac{Q_1'}{Q_1} = \frac{e^d_1 e^e_1 \ln(1 - t_1)}{e^d_1 - e^e_1}$$

$P_1$ is the equilibrium price before fund collection; $P_1'$ is the consumer price after fund collection; $P_2'$ is the producer price after fund collection; $Q_1$ is the output quantity (i.e., consumption quantity) before
fund collection; \(Q_1\) is the output quantity (i.e. consumption quantity) after fund collection; \(e_{1d}\) and \(e_{1s}\) are the demand elasticity and supply elasticity, respectively, of the product; \(t_i\) is the fund collection rate reflecting the fund collection level.

As revealed by the local equilibrium analysis with the equations, the collection of funds would cause the ex-factory prices of the “4A+C” products to fall, whereas the consumer prices of the same products will rise. The difference between the two prices is the fund collection level. After taxes have been levied on waste electrical and electronic products, the manufacturers will slash the ex-factory prices of their products and reduce the outputs (i.e., supply) of these products accordingly. Then, consumer demand will fall as a result of the rise in consumer prices, and ultimately, the market will reach a new equilibrium. We performed a local equilibrium model calculation on the market’s state in two complete years after the levying of the tax. The year 2013 was selected at first because it was the first complete year after the funds for waste electrical and electronic products had been implemented, as well as the first complete year after the tax was levied on “four appliances” products. Then, the year 2014 was also selected for a comparison of the market equilibrium states before and after the levying of the tax. A partial equilibrium model was established at first. After inputting parameters such as fund collection level, product supply elasticity, product demand elasticity, product output, and sales volumes, we calculated the impacts of the fund collection on market prices, producer prices, outputs, and net profit margins for 2013 and 2014.

For the “4A+C” sector as a whole, there was no significant difference in performance between the period of 2013–2014 and the years before 2012. So, it is appropriate to perform local equilibrium simulations and calculations. The theoretical amount of tax to be levied on the “4A+C” products was calculated by using the data (including output, export volume, import volume, and inventory) recorded in the Wind database and released by the Ministry of Industry and Information Technology. The calculations showed that the theoretical amounts of tax leviable on waste electrical and electronic products in 2013 and 2014 were 2.738 billion yuan and 3.427 billion yuan, respectively, which deviate considerably from the actual collected amounts of 2.81 billion yuan and 2.878 billion yuan in 2013 and 2014, respectively. Considering the relatively large error in the data of the tax leviable on PCs, we obtained a more accurate amount of the tax by subtracting the combined amounts of tax leviable on the “four appliances” from the amount of tax that had actually been collected. The theoretical fund collection rates of the “4A+C” products were calculated by using the previously calculated amounts of tax leviable on these products and the retail sales data of 2013 and 2014. The ratio of the lowest retail price to the highest retail price of a certain product with a relatively high fund collection level and sales volume was calculated to reflect the tax burdens of different types of firms in the market. The supply elasticity and demand elasticity of the products were calculated by using the export prices and import prices. We obtained the fund collection rates of the “4A+C” products and the estimated parameter values of the partial equilibrium model (as shown in tables 7-9).

The results of the simulations and calculations using the partial equilibrium model are shown in table 8. In 2013, the ex-factory prices and production volume of the ‘four appliances’ decreased year-on-year, whereas the market prices increased year-on-year. The theoretical fund collection rate of refrigerators reached 0.73%, indicating a fluctuation larger than those of the other three appliances. The market price of refrigerators increased by 0.6%, the ex-factory price fell by 0.13%, the profit fell by 0.46%, and the profit margin fell by 0.13%. The theoretical fund collection rate of air conditioners was the second highest (reaching 0.57%), the market price increased by 0.4%, the profit decreased by 0.3%, and the profit margin decreased by 0.08%. For TVs, the theoretical fund collection rate reached 0.51%, the market price increased by 0.38%, the profit decreased by 0.37%, and the profit margin decreased by 0.13%. For washing machines, the fund collection rate reached 0.48%, the market price increased by 0.45%, the profit fell by 0.39%, and the profit margin decreased by 0.13%. The theoretical fund collection rate of PCs was the lowest at only 0.05%. As the tax for waste electrical and electronic products had not been fully levied on PCs in 2013, the fluctuations of the market prices, ex-factory prices, production volume, and profit were all smaller than 0.05%, indicating that the PC industry had been barely affected by fund collection. As revealed by a comparison of the theoretical.
fund collection rates of 2014 and 2013, those of air conditioners had increased significantly and the theoretical fund collection rate had decreased because of the drop in the export volume (hence, the decline in the proportion). In contrast, the export volume and the proportion of washing machines had increased.

**Table 7. Parameters of local equilibrium model.**

| Types            | Theoretical Rates, 2013/% | Theoretical Rates, 2014/% | Upper Limit of Tax Burden/% | Lower Limit of Tax Burden/% | Supply Elasticity | Demand Elasticity |
|------------------|---------------------------|---------------------------|----------------------------|----------------------------|------------------|------------------|
| Television       | 0.51                      | 0.6                       | 1.63                       | 0.2                       | 1.6              | 0.6              |
| Refrigerator     | 0.73                      | 0.39                      | 2.1                        | 0.19                      | 2.3              | 0.51             |
| Wash Machine     | 0.48                      | 0.45                      | 0.5                        | 0.13                      | 2.5              | 0.53             |
| Air Conditioner  | 0.57                      | 0.79                      | 2.33                       | 0.17                      | 1.8              | 0.57             |
| Computer         | 0.05                      | 0.02                      | 0.5                        | 0.12                      | 2                | 0.56             |

**Table 8. Simulation and calculation results of local equilibrium model (2013) (%).**

| Types            | Market Change | Price Producer Change | Outputs Change | Profit Change | Rate Profit Amount Change |
|------------------|---------------|-----------------------|----------------|---------------|--------------------------|
| Television       | 0.38          | -0.13                 | -0.24          | -0.13         | -0.37                    |
| Refrigerator     | 0.6           | -0.13                 | -0.23          | -0.13         | -0.46                    |
| Air Conditioner  | 0.4           | -0.08                 | -0.22          | -0.08         | -0.3                     |
| Washing Machine  | 0.45          | -0.13                 | -0.26          | -0.13         | -0.39                    |
| Computer         | 0.04          | -0.01                 | -0.02          | -0.01         | -0.03                    |

| Upper Limit of Tax Burden (%) | Television | Refrigerator | Air Conditioner | Washing Machine | Computer |
|-------------------------------|------------|--------------|-----------------|-----------------|----------|
| 1.22                          | -0.43      | -0.76        | -0.43           | -0.19           | -1.19    |
| 1.75                          | -0.38      | -0.95        | -0.38           | -0.12           | -1.33    |
| 0.42                          | -0.08      | -0.23        | -0.08           | -0.06           | -0.31    |
| 1.84                          | -0.53      | -1.05        | -0.53           | -0.32           | -1.58    |
| 0.4                           | -0.1       | -0.22        | -0.1            | -0.1            | -0.32    |

| Lower Limit of Tax Burden (%) | Television | Refrigerator | Air Conditioner | Washing Machine | Computer |
|-------------------------------|------------|--------------|-----------------|-----------------|----------|
| 0.15                          | -0.05      | -0.09        | -0.05           | -0.15           |         |
| 0.16                          | -0.03      | -0.09        | -0.03           | -0.12           |         |
| 0.11                          | -0.02      | -0.06        | -0.02           | -0.08           |         |
| 0.13                          | -0.04      | -0.08        | -0.04           | -0.11           |         |
| 0.1                           | -0.02      | -0.05        | -0.02           | -0.08           |         |
As can be seen from the calculations of the partial equilibrium model, the supply and demand elasticities of the ‘4A+C’ products in 2014 deviated from those in 2013 because of the difference in the theoretical tax rates of ‘4A+C’ products between 2014 and 2013. This difference explains why the calculations for 2014 and the variation in the growth rate in 2013 deviated from the calculations of fund collection.

As revealed by a comparison of the calculations of the partial equilibrium model in 2013 and 2014 (tables 8 and 9), the theoretical tax rate for waste electrical and electronic products decreased because the proportion of refrigerators and other exported products had increased to a high level. Meanwhile, the calculated supply and demand elasticities also changed as a result of the increased proportion of exported refrigerators and other products. Under the condition that all relevant products were taxed, the full implementation of fund collection did not have a significant impact on the costs and profits of the “4A+C” products. As can be seen from the calculations, the impacts of the fund collection on TVs and washing machines were relatively large in 2013, whereas those on the profits from the sales of refrigerators were relatively small. In 2014, the profits from refrigerators were the most affected as the collection of funds dropped by 0.53% year-on-year and the profit margin fell by only 0.19%. The indicators of air conditioners and PCs had remained stable throughout the two years. All of these indicate that even after all the produced and imported “4A+C” products had been taxed, the impacts of fund collection on the profits and profit margins of the manufacturers would be limited. According to the calculations, the theoretical tax rate for waste electrical and electronic products levied on some firms manufacturing low-end products was found to be relatively high during the period 2013–2014 and may have reduced the profit margins by more than 0.5%. For firms manufacturing high-end products, the impacts of the fund collection were small.

Table 9. Simulation and calculation results of local equilibrium model (2014) (%).

| Types                  | Market Price Change | Producer Price Change | Outputs Change | Profit Rate Change | Profit Amount Change |
|------------------------|---------------------|-----------------------|----------------|-------------------|---------------------|
| Television             | 0.44                | -0.16                 | -0.26          | -0.16             | -0.42               |
| Refrigerator           | 0.32                | -0.07                 | -0.16          | -0.07             | -0.23               |
| Air Conditioner        | 0.37                | -0.08                 | -0.2           | -0.08             | -0.27               |
| Washing Machine        | 0.6                 | 0.19                  | -0.34          | -0.19             | -0.53               |
| Computer               | 0.02                | -0.01                 | 0              | -0.01             |                     |
| Television             | 1.2                 | -0.43                 | -0.71          | -0.43             | -1.14               |
| Refrigerator           | 1.75                | -0.35                 | -0.88          | -0.35             | -1.23               |
| Air Conditioner        | 0.41                | -0.09                 | -0.22          | -0.09             | -0.3                |
| Washing Machine        | 1.81                | -0.52                 | -1.02          | -0.52             | -1.53               |
| Computer               | 0.39                | -0.11                 | -0.11          | -0.11             | -0.33               |
| Television             | 0.15                | -0.05                 | -0.09          | -0.05             | -0.14               |
| Refrigerator           | 0.16                | -0.03                 | -0.08          | -0.03             | -0.11               |
| Air Conditioner        | 0.11                | -0.02                 | -0.06          | -0.02             | -0.08               |
| Washing Machine        | 0.13                | -0.04                 | -0.05          | -0.04             | -0.11               |
| Computer               | 0.09                | -0.03                 | -0.03          | -0.03             | -0.08               |
Since the beginning of the fund collection until now, the production volumes of the ‘four appliances’ have varied with different patterns. As seen from the data obtained from the Wind database shown in figure 1, the growth rate in TV production volume had fallen in Q1 2012, rebounded slowly in Q3 2013, reached a high level in the first half of 2014 before falling again, experienced negative growth by the end of 2014, fell in 2015, and gently rebounded after passing an inflection point in 2016. The production volume of air conditioners hit a low level in 4Q 2011 before the beginning of the fund collection but started to pick up after 2Q 2013, then returned to a low level in 2014, and rebounded sharply in 2018. The production volumes of washing machines and refrigerators (freezers) remained rather stable in the past decade, but their year-on-year growth rates have been low since 2014. On the basis of this trend analysis, we used the Chow test method to test the correlation between the production volumes of the “four appliances” and the fund collection. The test results showed that, for all the “four appliances”, the second quarter of 2012 (the starting time of the fund collection) was not the breakpoint of the time series, indicating no proof that the production volumes had been affected by the fund collection. It is worth noting that, in 2013, which was the first complete year for taxing the “four appliances”, the overall production volumes were relatively higher than in the several previous years when no tax had been levied on waste electrical and electronic products. In 2014, the second complete year of taxing, the marginal impacts of fund collection on the costs of the manufacturers of the “four appliances” were very small, or even, negligible as compared with the situation in 2013. Therefore, it can be speculated that the significant reduction in the production volumes of the ‘four appliances’ after 4Q 2014 had little to do with the collection of funds. The more influencing factors may have been China’s overall economic trend, consumer demand for durable consumer goods, and the overcapacity of the ‘4A+C’ industries. Since PC manufacturers were not taxed in 2013, the first complete year of fund collection for PCs was 2014. So, the correlation between the decline in PC production volume and fund collection in the second half of 2014 requires further research.

![Figure 1. Quarterly production volumes of “4A+C” products from 2010 to 2018.](image)

The variations in the financial indicators of the industries to which the “4A+C” products belong before and after the levying of the tax on waste electrical and electronic products during the period of 2011-2015 can be established by using the data obtained from the Wind database. Both the main business incomes and profits of the TV manufacturing industry increased to varying degrees during the studied period. In 2013, in particular, the main business incomes of the TV manufacturing industry increased by 16.45% year-on-year (an increase of 8.82% in the growth rate), the total profit increased by 6.76% year-on-year, and the main business profit margin dropped by 0.62%. For the household cleaning and sanitary electric appliance manufacturing industry (to which washing machines belong), the year-on-year growth rate of the main business income declined continuously, but the main business profit margin increased continuously in 2014 and 2015 after falling by 0.14% in 2013. For the
domestic refrigeration appliance manufacturing industry (to which refrigerators belong), the growth rate of the main business incomes increased by 3.56% in 2013 and the main business profit margins increased by 0.5%. In 2014 and 2015, the growth rates of the main business incomes declined, but the profit margins increased. For the household air conditioning appliance manufacturing industry (to which air conditioners belong), the year-on-year growth rates of the main business incomes declined continuously, but the profit margins increased continuously. When analyzing the financial reports of the ‘4A+C’ manufacturers, we found that most manufacturers do not consider taxes on waste electrical and electronic products as factors affecting their profits and profit margins, even though such taxes could put pressure on their operating costs. According to the industry reports released by research institutions, the level of fund collection did not change as much in 2014 and 2015 as it had in 2013, so firms had sufficient time to cope with the impacts of fund collection. In 2014, the impacts on the profit margins were smaller than in 2013. In summary, fund collection has not affected the profit margins of the firms. The proportions of the tax payments for waste electrical and electronic products out of the main business costs of some typical ‘4A+C’ industries were calculated. The results are shown in table 10. The tax payments account for only a small portion of the cost of each product, indicating that fund collection is not likely to become a major factor affecting production decisions.

Table 10. Proportion of waste electrical and electronic products tax payment in the cost of main business of each “4A+C” industry.

| Industry                          | Tax Payment Proportion |
|-----------------------------------|------------------------|
| Television industry               | 0.24%                  |
| Refrigeration Appliances Industry | 0.13%                  |
| Household Appliances Industry     | 0.18%                  |
| Cleaning Manufacturing Industry   | 0.41%                  |
| Air Conditioner Industry         | 0.02%                  |

3.4. DEA Model Describing the Impact of Fund Subsidy on Waste Electrical and Electronic Products Recycling Industry

The CCR model is used to evaluate the relative effectiveness of each unit. The five major types of waste electrical and electronic products receiving the bulk of the fund subsidy are decision-making units (DMUs) for DEA analysis. Suppose there are n DMUs, and each DMU has m input indicators and s output indicators.

1) Sample selection

The fund subsidy serves to guide the early development of the waste electrical and electronic products dismantling & processing industry and promote the specialization of the industry that turns waste electrical and electronic products into useful resources. In order to comprehensively evaluate the impact of the fund subsidies on the recycling & dismantling industry, we used the five major types of waste electrical and electronic products (TV, refrigerator, air conditioner, washing machine, and computer) that receive the bulk of the fund subsidy as the DMUs for DEA analysis. We established the DEA model and performed a test on the waste electrical and electronic products dismantling activities before and after the adjustment of fund subsidies. Specifically, the period of 2013-2015 was chosen as the initial stage of the fund subsidies (the 2011 version of subsidy standard was implemented in this period), and period of 2016-2018 was chosen as the initial adjustment phase of the fund subsidies (the 2016 version of subsidy standard was implemented in this period). The impacts of the fund subsidy on the overall dismantling efficiencies of various types of waste electrical and electronic products and the recycling industry were measured by comparing a host of indicators before and after the adjustment of fund subsidies.

2) Indicator selection and calculation

The purpose of setting up a waste electrical and electronic products processing fund is to reduce the environmental pollution caused by waste electrical and electronic products and correct the imbalance between the economic development and environmental protection. We established an effective
evaluation indicator system at first, and then used the DEA analysis method to perform efficiency evaluation on a group of DMUs. The selected indicators are shown in table 11.

### Table 11. Selected input/output indicators and description.

| Indicator class | Specific indicator | Description |
|-----------------|-------------------|-------------|
| Input indicator 1 | Fund subsidy | Government investment in turning waste electrical and electronic products into resources |
| Input indicator 2 | Recycling cost | Firms’ investment in waste electrical and electronic products recycling |
| Input indicator 3 | Dismantling cost | Firms’ investment in waste electrical and electronic products dismantling and processing |
| Output indicator 1 | Economic benefit | Value directly created by turning waste electrical and electronic products into resources |
| Output indicator 2 | Resources and environmental benefits | Value directly generated by reducing energy consumption and emission |
| Output indicator 3 | Social benefit | Value created by promoting employment and technological innovation |

The government implements subsidy standards for various products as shown in table 1. The purchase cost is the cost that occurs when the recycling firm buys the waste electrical and electronic products from the consumers. According to calculation, the total investment needed for constructing a waste electrical and electronic products dismantling & treating plant with an annual processing capacity of 1 million units is about 80 million yuan. The costs directly linked to waste electrical and electronic products processing include: salary and welfare of the staff: 140 persons, 50,000 yuan/person/year, totaling 7 million yuan/year; cost of water: 4.1 yuan/ton, 260 workdays/year, 150 tons/day, totaling 159,900 yuan/year; cost of electricity: 0.8 yuan/kWh, 720 kWh/day, totaling 150,000 yuan/year; cost of processing unusable residue: 2,000 tons/year, 2,000 yuan/ton, totaling 400,000 yuan/year; cost of processing Freon: 40 tons/year, 2,000 yuan/ton, totaling 80,000 yuan/year.

The fixed assets will depreciate every year. A certified waste electrical and electronic products processing plant needs an investment of about 80 million yuan, among which 75 million yuan is to be invested on fixed assets according to the characteristics of the industry. Assume that the service life of the facility is 15 years, an annual depreciation of 5 million yuan for fixed assets can be obtained through a calculation using the straight-line depreciation method. However, few firms can use more than 80% of their annual processing capacity. Generally, most waste electrical and electronic products processing firms only use 30%-40% or their annual processing capacities. The depreciation cost apportioned to each unit of waste electrical and electronic products is about 17-25 yuan.

In practice, dismantling waste refrigerators requires more expensive facility than dismantling other waste products, and the refrigerator dismantling line cannot be adopted easily for dismantling other waste products. Therefore, the refrigerator dismantling line is usually treated separately when calculating the fix asset depreciation cost. In this case study, the fixed asset needed for building the refrigerator dismantling line with a processing capacity of 200,000 units/year is worth 30 million yuan, and the depreciation cost apportioned to each refrigerator is 10 yuan/unit. Considering the idle time of the refrigerator dismantling line and lower recycling rate of refrigerators, the actual depreciation cost each refrigerator is 33.3 yuan/unit. The depreciation of the remaining 45-million-yuan worth of fixed assets is equally apportioned to the dismantling lines of other products, translating to a unit depreciation cost of 12.5 yuan/unit. Around 40% of the total investment is spent on purchase equipment. If 5% of the equipment cost is needed for maintenance each year, the maintenance cost will be 1.6 million yuan/year. The management cost is 800,000 yuan/year. The financial costs and other costs will be 1.3 million yuan/year. The average purchase prices of the waste electrical and electronic products can be calculated according to the survey data (see table 12).
Table 12. Purchase prices of waste electrical and electronic products on the market (yuan/unit).

| Product types          | Purchase price range | Purchase price calculation |
|------------------------|----------------------|----------------------------|
| Television             |                      |                            |
| 40 inch below          | 10-50                | 25                         |
| 40 inch above          | 50-100               | 80                         |
| Refrigerator           |                      |                            |
| 150 litre below        | 30-50                | 50                         |
| 150 litre above        | 50-100               | 100                        |
| Washing machine        |                      |                            |
| Wave wheel washing machine | 60-80              | 60                         |
| Roller washing machine | 60-100               | 100                        |
| Air conditioner        |                      |                            |
| Split wall mounted     | 50-100               | 100                        |
| Split cabinet          | 100-150              | 150                        |
| Computer               |                      |                            |
| Main engine            | 20-50                | 35                         |
| Indicator              | 20-40                | 20                         |

With regard to economic benefit, the profit of a firm is its income minus costs. The income of a waste electrical and electronic products processing firm contains two main parts: one is the income obtained by selling the useful materials recycled from the dismantled appliance parts, and the other is the subsidy for dismantling waste electrical and electronic products. On the basis of the existing research results, we made a survey and calculated the profit that the waste electrical and electronic products processing firms can get from dismantling and processing each waste electric/electronic appliance during the period of 2012-2015. The calculation results are shown in Table 13. For example, the theoretical value of the materials recycled from a single 40-inch TV set is 180 yuan. At present, the existing dismantling & processing technology achieves a recycling rate of 80%, which means the materials recycled from a single 40-inch TV are worth about 126 yuan. When the cost of selling the recycled materials is not considered, the profit that the waste electrical and electronic products processing firm can get upon completion of dismantling is -67 yuan. After adding the amount of subsidy according to the 2011 version of the fund subsidy standard, the profit becomes 18 yuan. It is also the case for other electric/electronic products, that is, the profit is negative upon the completion of dismantling and turns positive only after adding the fund subsidy. For most waste electric/electronic products, no profit can be made by merely dismantling them and recycling useful materials.

Table 13. Profit gained by waste electrical and electronic products processing firms from processing a single waste electric/electronic appliance during 2012-2015 (yuan/set).

| Product types                          | Profit before fund subsidy | Profit after fund subsidy |
|----------------------------------------|----------------------------|--------------------------|
| Television (40 inch below)             | -69.45                     | 15.55                    |
| Television (40 inch above)             | -66.68                     | 18.32                    |
| Refrigerator (150 litre below)         | -142.45                    | -57.45                   |
| Refrigerator (150 litre above)         | -116.86                    | -31.86                   |
| Wave wheel washing machine             | -48.75                     | -13.75                   |
| Roller washing machine                 | -75.93                     | -40.93                   |
| Air conditioner (Split wall mounted)    | -159.55                    | -124.55                  |
| Air conditioner (Split cabinet)        | -66.05                     | -31.05                   |
| Computer main engine                   | -14.26                     | 28.24                    |
| Computer indicator                     | 0.74                       | 43.24                    |
(4) Data processing
Before using the basic CCR model of DEA for analysis, it is necessary to nondimensionalize the raw data of input and output indicators obtained from the aforementioned survey. The processing function is equation (2), in which $x_i$ represents the maximum value of the i-th indicator of all DMUs,

$$\min_{1\leq j \leq J} z_{ij} = y_i$$ (4)

$y_i$ represents the minimum value of the i-th indicator of all DMUs, j represents the j-th DUM, and the result of nondimensionizing $z_{ij}$ is $z'_{ij}$

$$z'_{ij} = 0.1 + 0.9 \times \frac{z_{ij} - y_i}{x_i - y_i}$$ (5)

(5) Output data of DEA model
The five major types of waste electrical and electronic products receiving the bulk of the fund subsidies are used as DMUs for DEA analysis. Assume that there are n DMUs, each DMU has m input indicators and s output indicators. The linear programming of the CCR model of DEA is shown in equation (4).

$$\min \theta$$

$$s.t., \sum_{j=1}^{n} \lambda_j x_j + s^- = \theta x_o$$

$$\sum_{j=1}^{n} \lambda_j y_j + s^+ = y_o$$

$$\lambda_j, s^+, s^- \geq 0, j = 1, 2, \ldots, n$$

$\theta$ is the efficiency value of $n$. If $\theta=1$, then $DMU_n$ is valid; if $\theta<1$, then $DMU_n$ is invalid.

We used MATLAB to calculate the dismantling & processing efficiency of 5 types of waste electrical and electronic products, obtaining the CCR technical efficiency and scale efficiency values of these five types of waste electrical and electronic products during the aforementioned two stages. The results are shown in table 14.

Different types of waste electrical and electronic products differ significantly with each other in the overall dismantling & processing efficiency, so do various products with different specifications within the same product category. i. The overall efficiency of dismantling and processing desktop PCs is the highest, achieving EDA weak efficiency. ii. The overall efficiency of dismantling and processing air conditioners is low. In particular, the overall efficiency of dismantling and processing split cabinet air conditioners is the lowest (which is 0.4570), and the overall efficiency of dismantling and processing split wall air conditioners is 0.4587. iii. The lowering of fund subsidy standard for TVs had positive impact on the dismantling efficiency of TV sets larger than 40 inches and negative impact on that of TV set smaller than 40 inches. Before the adjustment of fund subsidy standard, the overall efficiency of dismantling TV sets larger than 40 inches and that of TV sets smaller than 40 inches were 0.8229 and 0.5288, respectively. After the adjustment of subsidy standard, the overall efficiency of dismantling TV sets larger than 40 inches improved and that of TV sets smaller than 40 inches declined. iv. There is a big difference in the overall efficiency of dismantling and processing between refrigerators of different specifications. The overall efficiency of dismantling and processing refrigerators above 150 liters is higher than that of refrigerators below 150 liters. After lowering of fund subsidy standard, the overall efficiencies of dismantling and processing refrigerators with different capacities dropped to different extents. v. After the adjustment of fund subsidy, the overall efficiency of disassembly and processing drum washing machines increased from 0.6191 to 0.6675. This indicates the imbalance in the waste electrical and electronic products dismantling & processing industry, and the overall dismantling efficiencies of most waste electrical and electronic products are at
It is imperative to make full use of the existing resources to improve the sophistication levels of management and technology in dismantling and processing waste electrical and electronic products, especially for those products with low overall dismantling efficiency like air conditioners.

Table 14. Result of running CCR.

| Product types                      | Overall efficiency | Scale efficiency | Scale benefit |
|------------------------------------|--------------------|------------------|---------------|
| **Before adjustments of subsidy standards** |
| Television (40 inch below)         | 0.5288             | 1                | Increase      |
| Television (40 inch above)         | 0.8229             | 1                | Increase      |
| Refrigerator (150 litre below)     | 0.7702             | -1               | Decrease      |
| Refrigerator (150 litre above)     | 0.9322             | -1               | Decrease      |
| Wave washing machine               | 0.6191             | 1                | Increase      |
| Roller washing machine             | 0.7172             | 1                | Increase      |
| Split wall mounted air conditioner | 0.4587             | 1                | Increase      |
| Split cabinet air conditioner      | 0.4570             | 1                | Increase      |
| **Computer main engine**           | 1.0000             | 0                | Invariant     |
| **Computer indicator**             | 1.0000             | 0                | Invariant     |
| Television (40 inch below)         | 0.4230             | 1                | Increase      |
| Television (40 inch above)         | 0.9052             | 1                | Increase      |
| Refrigerator (150 litre below)     | 0.7095             | -1               | Decrease      |
| Refrigerator (150 litre above)     | 0.9381             | -1               | Decrease      |
| Wave washing machine               | 0.6675             | 1                | Increase      |
| Roller washing machine             | 0.7172             | 1                | Increase      |
| Split wall mounted air conditioner | 0.5353             | 1                | Increase      |
| Split cabinet air conditioner      | 0.5847             | 1                | Increase      |
| **Computer main engine**           | 1.0000             | 0                | Invariant     |
| **Computer indicator**             | 1.0000             | 0                | Invariant     |

**After adjustments of subsidy standards**

| Product types                      | Overall efficiency | Scale efficiency | Scale benefit |
|------------------------------------|--------------------|------------------|---------------|
| Television (40 inch below)         | 0.4230             | 1                | Increase      |
| Television (40 inch above)         | 0.9052             | 1                | Increase      |
| Refrigerator (150 litre below)     | 0.7095             | -1               | Decrease      |
| Refrigerator (150 litre above)     | 0.9381             | -1               | Decrease      |
| Wave washing machine               | 0.6675             | 1                | Increase      |
| Roller washing machine             | 0.7172             | 1                | Increase      |
| Split wall mounted air conditioner | 0.5353             | 1                | Increase      |
| Split cabinet air conditioner      | 0.5847             | 1                | Increase      |
| Computer main engine               | 1.0000             | 0                | Invariant     |
| Computer indicator                 | 1.0000             | 0                | Invariant     |
With regard to scale efficiency, the scale efficiency of dismantling and processing desktop PCs is 0. This indicates that its current dismantling efficiency is in the stage of constant scale benefit, i.e., the stage of optimal scale return, which means it is efficient to invest resources in the dismantling of desktop PCs. In addition, except that the scale efficiency of dismantling and processing refrigerators is -1, the scale efficiencies of dismantling and processing other waste electrical and electronic products are 1, indicating that there is room for improvement in the resource allocation for dismantling waste electrical and electronic products other than waste PCs. So, it is necessary to increase the scale of fund investment and allocate the resources scientifically so as to push the operation of waste electrical and electronic products dismantling & processing into the optimal stage of constant scale benefit.

(6) Sensitivity analysis

We deleted input and output indicators in turn, i.e., only 5 indicators were used, and obtained 6 groups of overall efficiency figures in the MATLAB for comparison. See table 15.

As can be seen from the figures in table 15, after the input indicator 1 was omitted, the overall dismantling efficiencies of waste washing machines and waste air conditioners experienced relatively large change; after the input indicator 3 was omitted, the overall dismantling efficiencies of TVs larger than 40 inches experienced relatively large changes; after the output indicator 1 or output indicator 2 was omitted, the overall dismantling efficiencies of most waste electrical and electronic products experienced great changes; after the input indicator 2 and output indicator 3 were omitted, no salient changes can be seen in the overall dismantling efficiencies of all waste electrical and electronic products.

Figure 2. Comparison of analysis results of overall efficiency sensitivity.

We converted the data in the table into a graph using MATLAB. The overall efficiency values obtained using the original model are shown on the left part of figure 2, and the overall efficiency values obtained after indicator modification are shown on the right part of figure 2. As can be seen from the graph, the input indicators 1 and 3, namely fund subsidy and dismantling & processing cost have great impact on the overall efficiency; and the output indicators 1 and 2, namely economic benefit and environmental protection benefit of resource have great impact on overall efficiency. As the result is undependable when one indicator is omitted, we used the Mann-Whitney rank sum test method to test the statistical figures in the process of hypothetical testing. We first assumed that the hypothesis was true, and discovered that the difference was symmetrically distributed, which means the difference between the positive and negative ranks was very small. One set of data was obtained using MATLAB. The calculation results are shown in table 16.
### Table 15. Sensitivity analysis of overall efficiency.

| Subsidy standard | Television (40 inch below) | Television (40 inch above) | Refrigerator (150 litre below) | Refrigerator (150 litre above) | Wave wheel washing machine | Roller washing machine | Split wall mounted air conditioner | Split cabinet air conditioner | Computer main engine | Computer indicator |
|------------------|---------------------------|-----------------------------|-------------------------------|--------------------------------|---------------------------|------------------------|-------------------------------|-------------------------------|------------------|-----------------|
| CCR value        |                           |                             |                               |                                |                           |                        |                               |                               |                  |                  |
| 2011 Version     | 0.53                      | 0.82                        | 0.77                          | 0.93                           | 0.62                      | 0.72                   | 0.46                          | 0.46                          | 1                | 1               |
| 2016 Version     | 0.42                      | 0.91                        | 0.71                          | 0.94                           | 0.67                      | 0.72                   | 0.54                          | 0.58                          | 1                | 1               |
| Delete input indicator 1 | 0.53                      | 0.82                        | 0.61                          | 0.93                           | 0.44                      | 0.72                   | 0.28                          | 0.31                          | 1                | 1               |
| Delete input indicator 2 | 0.44                      | 0.82                        | 0.71                          | 0.93                           | 0.44                      | 0.72                   | 0.54                          | 0.58                          | 1                | 1               |
| Delete input indicator 3 | 0.35                      | 0.91                        | 0.71                          | 0.94                           | 0.44                      | 0.72                   | 0.54                          | 0.58                          | 1                | 1               |
| Delete output indicator 1 | 0.53                      | 0.52                        | 0.57                          | 0.61                           | 0.44                      | 0.72                   | 0.46                          | 0.46                          | 1                | 1               |
| Delete output indicator 2 | 0.42                      | 0.57                        | 0.57                          | 0.65                           | 0.38                      | 0.63                   | 0.25                          | 0.24                          | 1                | 1               |
| Delete output indicator 3 | 0.53                      | 0.82                        | 0.71                          | 0.94                           | 0.44                      | 0.72                   | 0.46                          | 0.46                          | 1                | 1               |
| 2016 Version     | 0.41                      | 0.46                        | 0.13                          | 0.17                           | 0.08                      | 0.04                   | 0.41                          | 0.21                          | 1                | 1               |
| Delete output indicator 1 | 0.41                      | 0.46                        | 0.13                          | 0.17                           | 0.08                      | 0.04                   | 0.41                          | 0.21                          | 1                | 1               |
| Delete output indicator 2 | 0.20                      | 0.12                        | 0.04                          | 0.02                           | 0.10                      | 0.22                   | 0.34                          | 0.14                          | 1                | 1               |
| Delete output indicator 3 | 0.53                      | 0.82                        | 0.71                          | 0.94                           | 0.44                      | 0.72                   | 0.40                          | 0.46                          | 1                | 1               |
| 2016 Version     | 0.42                      | 0.91                        | 0.71                          | 0.94                           | 0.44                      | 0.72                   | 0.54                          | 0.58                          | 1                | 1               |

### Table 16. Results of Mann-Whitney rank sum testing.

| Protest | 0.0350 | 0.0797 | 0.0466 | 0.0140 | 0.0172 | 0.9069 |

As can be seen from the test results, at a significance level of 5%, the null hypotheses of 1, 3, 4, and 5 are rejected, which indicates that the waste electrical and electronic products dismantling &
processing efficiency is sensitive to the indicators of fund subsidy (input), dismantling & processing cost (input), economic benefit (output) and environmental benefit of resources (output). The null hypotheses of 2 and 6 are accepted at the significance level of 5%, indicating that the waste electrical and electronic products dismantling & processing efficiency is not sensitive to the remaining 2 indicators. This shows that the waste resource recycling industry should pay attention to policy subsidy, dismantling & processing cost, economic benefits, and environmental benefits of resources. As these factors have the greatest impact on the overall efficiency, the overall efficiency is also highly sensitive to their changes.

Through the construction of the DEA model, we verified that the fund subsidy was effective in promoting the dismantling and processing of five types of waste electrical and electronic products. The fund subsidies serve to compensate for the losses of the firms on the one hand, and to improve the dismantling efficiency thus promote energy conservation and emission reduction on the other hand. Because waste electrical and electronic products are a quasi-public good, the support of government in the form of fund subsidy is needed to encourage more firms to enter the waste electrical and electronic products processing industry characterized by high cost and low profit. Except for high value waste electrical and electronic products such as waste PCs, fund subsidy is needed to provide incentive for dismantling most waste household appliances. Some defects in the design of fund subsidy standards incentivize some waste electrical and electronic products dismantling firms to make improper decisions on what waste electrical and electronic products to dismantle and process. Before the adjustment of fund subsidy standards, many dismantling & processing lines for products other than TV laid idle. After the adjustment of fund subsidies, the overall efficiency of waste electrical and electronic products dismantling and processing was improved. The design of the fund lacks the incentive to encourage waste electrical and electronic products dismantling firms to engage in technological innovation. As the biggest incentive for the waste electrical and electronic products dismantling firms is the subsidy for dismantling waste electrical and electronic products, these firms are not enthusiastic about improving the waste electrical and electronic products dismantling technology, and the high cost becomes a drag for the dismantling & processing efficiency.

In addition, the high cost of waste electrical and electronic products dismantling hinders the improvement of the overall efficiency of dismantling, the improvement of corporate economic benefits and the long-term development of the industry. The waste electrical and electronic products processing industry is facing many adverse factors: the initial investment of a waste electrical and electronic products processing plant is large; the waste electrical and electronic products processing facilities often lay idle because of the problems with public awareness and recycling channels; and the average cost of dismantling and processing waste electrical and electronic products is high due to the backwardness of the existing dismantling technology. Different types of waste electrical and electronic products require different levels of subsidy. The dismantling and processing of PCs does not require sophisticated technology, so the efficiency is at a high level, which means that less subsidy is needed. The dismantling and processing of some waste products like TV relies heavily on subsidy and is sensitive to changes of subsidy standard. The loss of social welfare resulted from cutting the subsidy could be greater than the saving in government and corporate investments, so it is not a good idea to cut subsidies for dismantling these products before the overall efficiency reaches the stage of constant scale benefit.

All things considered, the development of the waste electrical and electronic products dismantling industry is unbalanced. The overall dismantling efficiencies of most waste electrical and electronic products are at a low level. In particular, the dismantling and processing of products like air conditioner is characterized by enormous technological challenge, low overall efficiency and low scale efficiency. More attention must be paid on improving the sophistication levels of fund subsidy management and waste electrical and electronic products dismantling technology, maximizing the return of investment. In the resource recycling industry, measures must be taken to improve the management of the fund subsidies, ensure proper allocation of public resources, and improve the waste
electrical and electronic products dismantling efficiency, thereby increasing the economic benefit of the firms, environmental benefits and social benefits in a balanced way.

4. Conclusions and Policy Recommendations

4.1. Conclusions
This paper covered the management of funds for the treatment of electrical and electronic waste products, as well as summarized the progress in the design of fund systems and the management of actual revenues and expenditures [32-38]. By using the partial equilibrium model, the empirical analysis of the impacts of fund collections on the manufacturing industry found that fund collections led to declines in the prices and outputs of products, such as televisions, refrigerators, air conditioners, washing machines, and computers. The actual model’s results and tests showed that the funds had no significant impacts on the manufacturers. The DEA model was used to analyze the impacts of fund collections on the dismantling industry. It was found that fund subsidies brought economic benefits to enterprises after the dismantling of electronic waste products and had significant impacts on resources and environmental benefits, which were greater than the economic benefits.

The empirical study showed that the main reason for enterprises to adopt waste electrical and electronic products recycling is the environmental standards and energy-saving subsidies issued by the government. The fund collections for electrical and electronic waste treatment strengthens, to a certain extent, the awareness of enterprises for environmental protection and urges them to manufacture products with good environmental protection. Also, the model’s results showed that the efficiency of the disassembly and treatment of electrical and electronic waste products listed in the catalog was sensitive to the fund subsidies. The reuse of waste resources requires more attention to policy subsidies, dismantling costs, and economic benefits, which have the greatest impact on the comprehensive efficiency. Such efficiency is the most sensitive to its changes. To improve the efficiency of the use of fund subsidies, the government should further adjust the amounts of fund subsidies, grant the appropriate preferential policies to enterprises, focus on the allocation of resources, improve the efficiency of electronic waste dismantling, and guide enterprises to increase their investments in R&D, as well as in human and material resources, of dismantling technology because electronic waste products are difficult to dismantle and cause much environmental harm [39-45].

4.2. Policy Recommendations
According to the results of the empirical analysis, the current fund collection standards have a very limited impact on manufacturing enterprises and the fund deficit has a trend of expansion. If the fund deficit can be effectively remedied, then the current fund collection standards should be appropriately raised, the products listed in the catalog and scope of fund collection should be adjusted, and differentiated collection standards for products with different environmental performance should be developed. Specifically, products with ecological designs, environmental friendliness, and the potential for easy dismantling and disposal, as well as high levels of recycling of waste products, are subject to fewer or no collection funds. The implementation of high collection standards for high-energy-consuming and high-polluting products in the processes of production, use, recycling, and dismantling, assisting intellectual property incentives, strengthening producers’ sense of responsibility, and promoting production companies to do ecological design at the source to motivate and constrain production enterprises by implementing fund collection.

We should adjust the amounts of subsidies, establish a long-term evaluation system for the performances of the subsidy, establish a mechanism for determining the qualifications of enterprises to grant or deny them subsidies, ensure the effectiveness of the distribution of subsidies, narrow the gap in the fund pool, and reduce any waste of subsidies. In addition, consideration should be given to introducing motivational mechanisms for formal processing enterprises, which can establish special R&D subsidies, improve and increase equipment required for harmless dismantling and treatment,
increase investments in dismantling and treatment technology, and break through the bottleneck of the weak R&D capacity for renewable resource recovery technology in China.

After the adjustment of the refrigerator subsidy standard, the overall efficiency improved but remained at a low level, so it is necessary to simplify the audit process of fund subsidies properly, improve the efficiency of fund issuances, achieve the expected recycling effects, and minimize environmental pollution [46-52].

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