

Article

# What Institutional Dynamics Guide Waste Electrical and Electronic Equipment Refurbishment and Reuse in Urban China?

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**Abstract:** For over two decades China has faced a veritable e-waste challenge due to the continuous increase in quantities of Waste Electrical and Electronic Equipment (WEEE) coming from foreign and domestic sources. Over more than a decade, the government's response has been focussed on developing large-scale recycling facilities so as to recover the valuable materials within WEEE. Simultaneously, China is home to a vast, informal segment, which engages in the collection, refurbishment, and processing (dismantling, extraction of components and materials) of obsolete electronics, thus directly competing with the formal system for devices and for the profits that they generate. The official discourse and most of the existing research concentrates primarily on WEEE recycling. However, project-based field research and interviews by the author in Beijing and Guangdong province have indicated that the repair, refurbishment, and reuse of discarded electronics are widespread and profitable practices of the informal domain. This paper aims to analyse the institutional, i.e., rule-based, mechanisms behind these activities and, via an institutional economics approach, to highlight how formal and informal rule-based practices structure WEEE refurbishment and reuse in China. The results show that informal activities are dominant due to the well-developed collection and transfer networks, the division of labour amongst informal actors, and the high responsiveness to market prices and consumer demand.

**Keywords:** China; waste electrical and electronic equipment; refurbishment; repair; reuse; informal sector; waste pickers; waste collectors; circular economy

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## 1. Introduction

For China, the challenge of managing Waste Electrical and Electronic Equipment (WEEE) first emerged in the 1980s with an influx of obsolete electronic devices from Western countries [1]. Initially, WEEE flows to China were driven by a demand for low-priced materials so as to alleviate shortages in manufacturing [2], which in turn induced a surge in WEEE imports. Crude estimates from 2004 went so far as to suggest that every year 70% of the WEEE generated in high-income countries (14–35 million tons p.a.) entered mainland China [3]. The subsequent regulatory response by the Chinese state helped to reduce these imports, but meanwhile domestic generation has risen continuously and eventually reached approximately 5.4 million tonnes in 2015 [4], with a peak rate of 18.8% during 2014–2015 [5].

Since the early 2000s the central and local governments of the People's Republic of China (PRC) have responded to this challenge in a variety of ways. Firstly, legislative frameworks have been developed, which in part imitated laws previously enacted in the European Union, e.g., the Chinese Restriction of Hazardous Substances (RoHS) (2008) and the Chinese WEEE directive (2011), and in

part used pilot experiments at a provincial level to further develop the regulatory body on WEEE management [3,6]. Secondly, the state refined private and public WEEE recycling infrastructure by gradually raising the standards for WEEE processing. Out of this process 109 large-scale recycling yards have emerged that constitute the physical pillars of China's official WEEE recycling system [7]. The recycling operations are sustained by a rigid national subsidy system, which entails strict monitoring by local environmental protection agencies before financial assistance is provided from a national WEEE fund. This fund is in essence an electronic producer's tax, a Chinese version of the EPR (Extended Producer Responsibility) concept, with additional financing granted by the state [6]. The system is state-dependent and operates in a top-down manner, but it neglects two crucial aspects of China's domestic situation. Firstly, collection from households, which generate the majority (approx. 70%–80%) of urban WEEE [8,9], has not been addressed by the current legislation. Nevertheless, approximately 80% of this waste is collected by private, unregistered actors [10,11]. Secondly, the concept of WEEE refurbishment and reuse is strongly marginalised in the official discourse and in legislation. This is especially noteworthy for two reasons. On the one hand, the PRC's formal Circular Economy (CE), which represents the main overarching law for all national recycling activities, promotes the notions of "reduce, reuse, and recycle". And yet, as highlighted by Schulz and others, the reuse of obsolete electronics is merely considered to be a marginal option when it is assessed according to the stipulations of formal legislation [6,7,12]. On the other hand, as we have already seen, WEEE refurbishment has a history in China that spans two decades. Field investigations by the author and previous research have indicated that urban and rural areas exhibit wide networks of refurbishment and reuse, comprising waste collectors, small repair shops, and also secondhand electronic markets with wholesale traders and buyers [12–15], most of which operate outside of the formal framework. The existence of informal actors in Chinese WEEE management and especially refurbishment can to a certain degree be explained through the socioeconomic context of the country: Firstly, the vast disparity between urban and rural income levels makes the refurbishment of obsolete devices a profitable concept, since these are relatively easily affordable to the rural population. The increasingly shorter lifetime of modern Electrical and Electronic Equipment (EEE) further accommodates the growing consumer demand in rural areas [4]. Secondly, low minimum wage levels in major cities and insecure employment relations induce parts of the labour force to search for jobs in the informal segment. This is of specific significance for rural-to-urban migrants as they had stated in interviews that working in waste management (WM) not only enables them to follow a path of personal fulfilment [11] but also offers a higher net income than the minimum wage level.

Given the strong competitive element, the central problem for WEEE management in China is founded in the misalignment of two realms: one is the official, formalised system comprising government bodies as well as public and private enterprises; the other is composed of the informal, non-registered collectors, traders, recyclers, and their respective networks. When it comes to processing (dismantling and extraction of components), both sides engage in fierce competition over end-of-life (EOL) devices and the valuable fractions such as gold, silver, copper, and aluminium that are contained within them [16]. Many of China's main informal recycling areas have, so far, resisted formalisation efforts. However, since 2015, informal activities in Guangdong have come under increasing pressure to enter the official system [4,17–20]. The field of WEEE repair, refurbishment, and reuse is similar in some ways but displays some notable differences. In China's urban areas informal collectors are only minimally obstructed, if at all, in their daily operations and selling repairable electronics for reuse to secondhand markets represents their preferred option. Not only are profits higher than from the sale of obsolete devices for final treatment [21], but repair and reuse of WEEE have, in the past, also been less prone to induce governmental curtailment and intervention.

In contrast to the processing of WEEE, the activities around refurbishment and reuse have received comparably little attention in literature (a notable exception are the articles by Y. Schulz [12] and Y. Schulz and J. Goldstein [15]). Therefore this paper takes up this task and inquires into the institutional (rule-related) dynamics that sustain WEEE refurbishment and reuse in urban China.

More precisely, the analysis will address the following questions: to what degree are formal and informal institutional structures promoting WEEE refurbishment, reuse, and resale activities? With regard to this, is there an interactive, constitutive, or competitive relationship between the codified, formal institutional system, and the non-codified, informal institutional system?

Tackling this set of questions, the subsequent sections of this paper are structured as follows: the next section will introduce a framework based on evolutionary institutional economics, so as to highlight the interplay between the formal and informal regulatory structures. Additionally, the data and materials will be introduced. In the results section, we will first review data on the quantity of WEEE in China and the channels through which discarded electronics are transferred. Following that, we present an analysis of how the formal institutional framework has addressed reuse and refurbishment of WEEE in the PRC. The third section deals with collection and refurbishment practices in the formal and informal sectors, as well as highlighting the respective dynamics of formalisation and counter-formalisation in this field.

## 2. Methods and Materials

### 2.1. Methodology

How can the institutional dynamics behind WEEE refurbishment and reuse practices in China be put into an analytical framework? As alluded to above, Chinese urban WEEE management can be framed as being contested by two institutionally divergent, sometimes even opposing, groups of actors: formal and informal. However, the distinction put forward between formal and informal in this paper is not one of class, legality, or socioeconomic background, but rather one that focuses on the nature of institutions, i.e., the systems of rules that structure behaviour, which are devised and practiced by the respective groups of actors.

The actors belonging to the informal sector in WEEE or in waste management (WM) more generally, such as itinerant waste pickers, waste collectors with tricycles, and recyclers, are in China often derogatorily described as “illegal” since they are either not registered, do not pay taxes, or are considered to be major polluters. This is common to the official perception in some other low-income countries, where public authorities see the pre-existing informal sector as an obstacle to a clean, modern WM system [22]. At the same time there are cases of countries, such as Brazil or the Philippines, where formal and informal actors in WM have established cooperative schemes [23,24]. What makes China exceptional in this regard is that the informal segment in WM has been continuously growing over three decades and it dominates the collection and recycling of WEEE [4,11,12,16,17].

In order to achieve their objectives, informal actors create and imitate non-codified institutional solutions to recurring business problems. In the case of urban WM in China, such solutions are manifested in collection strategies for recyclables from households or in the trading infrastructure of these valuable materials, such as second-hand markets or small, street-based trading points. In the formal sector, on the other hand, the actors are represented by government bodies or private and public enterprises that are active in the WEEE management sector. In the same way, these stakeholders find rule-based solutions to particular problems in WM. In most cases these institutional solutions are codified in, for example, regulations, decrees, and laws that are established by state legislative bodies or, in the case of companies, by internal management and organisational regulations derived from the codified state’s regulatory framework. The common denominator is that both sides strive to obtain WEEE so as to reap a profit from the devices or from the components contained within them. The distinguishing features are the regulatory systems that both sides employ to achieve their goals.

This systematic setup of two institutional realms that are at times oppositional and at times synergistic follows one of the conceptualisations of the old institutional and evolutionary institutional economics [25–28]. The evolutionary element that generates the interactive dynamic between formal and informal institutions is the linking feature of a mutually bound responsiveness between the formal and informal institutional realms. There is a challenge (socioeconomic, environmental, etc.) at

the root of this dynamic cycle that demands an institutional solution. For this paper the increasing quantities of WEEE could be framed as a problem of this kind. If increasing quantities of WEEE were left institutionally unchecked, obsolete devices would pile up in urban areas, as has already happened with municipal solid waste (MSW) in various Chinese cities, being dubbed “waste walls around the city” (*laji weicheng*) [29].

When groups of actors find themselves in circumstances where a specific challenge exists and no solution is in place, they come up with their own individually devised, institutional solutions that serve their own specific interests and values. These values can be environmental or health-related, e.g., “a green and clean environment”, or they can bear economic characteristics, e.g., by creating wealth through the extraction of the valuable components in WEEE and selling them. Applied to the case of MSW in China, the official side has in the past devised institutions that serve to reduce the environmental impact (government), creating value from extracting secondary resources out of the devices (enterprise) and thereby alleviating resource supply shortages for manufacturing (government and enterprise). Informal entrepreneurs, on the other hand, focus primarily on generating profit [30] through trading and treating obsolete devices according to the principle of cost minimisation [31]. As such, profit maximisation is an especially important driver that explains why informal actors establish particular rule-based routines. As will be shown in this paper, informal WEEE collectors prefer to sell WEEE for repair and refurbishment instead of for recycling, simply because they can reap higher revenues from doing so. Not only do higher revenues from device reuse increase the attractiveness of engaging in informal refurbishing activities; the practice per se represents a less polluting option compared to informal device dismantling and recycling and thus tends to attract less attention and intervention from state actors [4].

Overall, every institutional solution exhibits a varying degree of efficiency and inefficiency when it comes to resolving any particular problem. As soon as an institution cannot solve a newly emerged problem, it will be replaced by a new, updated institutional solution. What is equally important, however, is that any institution, once a solution is in place and being practised by one group of actors, will send out a signal (e.g., to other groups of actors), indicating that a solution to a challenge has been found and that it has been put into practise. The opposing group of actors will then respond to this solution, either by adhering to it if it corresponds to the values and serves the objectives of this group of actors, or by challenging it by devising and practicing their own institutional solutions. In the case of WEEE management in China, the two antagonistic groups are, on the one hand, the registered formal recyclers and bodies of the state, and, on the other hand, the informal, non-registered collectors and recyclers. Both sides have their respective institutions in place, which in some cases collide and in other cases synergise. A review of Chinese WEEE management shows that the informal side has been more active in devising their own institutions. Informal WEEE collection and recycling practices emerged in the 1980s and over time have established lasting network structures and relationships for managing the collection and trade of obsolete devices [4,11,32]. The formal regulatory system only began to challenge the informal management of WEEE in the early 2000s. Since then the major aim of these formal institutions has been to introduce import bans and technical policies to prevent pollution and ensure proper processing (dismantling and extraction of materials), and to enable the monitoring and supervision of registered recycling companies [33–35]. Therefore WEEE treatment is highly contested between the two institutional realms. Ever since the government began to intervene, informal regulatory practices have reacted to formal counter-regulations via the evasion and exploitation of formal institutional loopholes, best exemplified by the development of the informal recycling hubs in Guiyu and Taizhou [4,18,35] and in the outskirts of Beijing [17]. Collection, on the other hand, has barely been touched by formal legislation, with the exception of short-term pilot projects [6,11,16,34], and the fact that formal regulatory systems cannot cope with their informal counterpart may also attest to the institutional effectiveness of the informal segment’s regulatory arrangements. Moreover, the dominance in collection means that the informal sector has control over WEEE flows at the post-consumer stage. Because of this quasi-monopoly on collection from

households, formal and informal recycling activities alike depend on obtaining WEEE from informal channels [11,34,35]. The response of the formal institutional framework to this informal monopoly came in the form of the Chinese national WEEE fund in 2012, through which financial support was given to registered recyclers in exchange for state supervision. These companies in turn used the subsidies to purchase WEEE, which, in over 90% of cases, stemmed from informal channels [11]. This pattern of dynamic response between the formal and the informal institutional realms represents one variety of the many forms of institutional interaction. Currently this constellation, wherein informal collection dominates despite formal steps against it, has produced an institutional gridlock inducing a halt of the institutional dynamic. Possibly this institutional status quo benefits both sides: Although informal WEEE collection and recycling are still prevalent, registered recycling has slowly improved, and in 2014 it allegedly treated 61% of the WEEE from the five official categories destined for treatment for that particular year (ignoring the stocks from preceding years) [33].

This paper will shift its analysis to a different field of WEEE management, namely to refurbishment and reuse practices by formal and informal actors, focussing mainly on the investigation of the interaction between formal and informal rules. As stated above, we will attempt to identify which formal and informal institutional structures shape WEEE refurbishment and resale and why they prove to be effective. According to the methods used in the old institutional economics, the effectiveness of rule systems can be evaluated via (1) their relative dominance over other, competing institutions—this can be measured by responsiveness dynamics, e.g., when one side temporarily stops to create new rules and thereby concedes rule-dominance to the opposing institutional realm; (2) the utilisation frequency of a specific institution to solve a problem; and (3) the strength of respective sanctions to prevent others from circumventing the implemented institutions.

## 2.2. Data and Sources

The findings in the sections that follow are based on several sources; from 2012 onwards the author has been involved in several research projects on WEEE treatment and on the informal WM sector in the PRC (see Acknowledgments section). A number of interviews with informal collectors and traders and field investigations at secondhand markets for electronics have been conducted over the course of these projects. The interviews were primarily conducted in Beijing, Shanghai, Shenzhen, and Guangzhou, whereas the investigations of secondhand electronics markets took place in Beijing (Guang'an Zhonghai electronics market and Beijing Silicon Valley Computer City in 2013 and 2015), Guangzhou (Jinghong international digital city in 2015), and Guangdong province's, Guiyu (Circular Economy Industrial Park, Material exchange centre in 2015). Additionally, unpublished project reports have been used so as to provide information on the quantity of WEEE, on informal actor sizes, as well as on informal network structures. In order to complement this first-hand data, desk research has been conducted so as to obtain more information on the historical evolution of secondhand markets in China. Very useful sites in this regard are [www.solidwaste.com.cn](http://www.solidwaste.com.cn) and [www.crra.org.cn](http://www.crra.org.cn), which compile news on waste management developments in the PRC. Furthermore, a data repository for national and local legislation [7] has been used for the verification of regulatory measures on WEEE reuse and refurbishment.

## 3. Results

### 3.1. The Quantity of WEEE

#### 3.1.1. Domestic Generation of WEEE in China

As outlined above, the quantity of WEEE being imported from other countries has decreased, while the amount generated domestically has grown. However, there are some difficulties with assessing the actual quantity of domestic WEEE in China. The official range of WEEE categories was narrowed down to five major appliances (TVs, air conditioners, washing machines, refrigerators,

and PCs), which are considered to be the most popular products among Chinese consumers [35]. This means that a multitude of different types of WEEE, and the quantity of each type, are not included in official statistics. It was only in the first quarter of 2016 that the number of recycling categories was extended to 13 [6], which still only accounts for a much smaller range of categories than those set forth by EU legislation. Despite the smaller range of products that are destined for treatment in China, research and official bodies face considerable difficulties in ascertaining how much of each type of product is being generated. As shown in Table 1, there are widely varying estimates and calculations on WEEE generation in the country. The first row in the table shows results released by the China Household Electric Appliance Research Institute (CHEARI), which comprises stakeholders from academia, government, and industry and uses a survey- and questionnaire-based approach to estimate WEEE generation. The second row in the table gives figures from previous research, in which the numbers are mostly based on calculations and estimated projections. The figures in both rows for the year 2014 suggest that China’s domestic generation (for only five categories, as this was before 2016) had in all likelihood reached the same level as the highest estimated quantity of imported WEEE, which in turn required a realignment of formal domestic management (e.g., with regard to collection).

**Table 1.** Quantity of domestically generated WEEE in China (in millions of tonnes).

Source/Year	2000	2006	2009	2010	2011	2012	2013	2014	2015
Questionnaire survey [33]	0.3	0.9	1.5	1.7	1.9	2.2	3.1	3.3	-
Estimates and projections	-	1.7 [4]	-	4 [36] 3.3 [9] 1.6 [8]	3.7 [37]	1.9 [37]	2.6 [38] 2.3 [16]	3.1 [5]	5.4 [9]

At this point the question that arises is to what extent WEEE generation in China can be expected to grow in the coming years. From the first row in Table 1 a median growth rate of 19.8% p.a. can be calculated that is very similar to recent estimates by the Chinese Ministry of Commerce (MOC) that suggest a rate of 18.8% [5], and by the China Resource Recycling Association (CRRRA), a semi-official body that puts forward a yearly growth rate of 20% [39]. There are institutional implications to these high WEEE growth rates. For the official system, it will become necessary to increase financing and to further develop recycling facilities. For the informal system, increasing WEEE quantities will lead to changes in collection and transfer patterns.

### 3.1.2. WEEE Flows: From Households to Collection to Refurbishment

From the point of generation, which in the majority of cases in urban areas is the private household [8,9], WEEE flows are essentially collected and transferred via two channels, namely formal and informal channels. As can be discerned from Table 2, informal collection is dominant in China in general as well as in major Chinese cities, with collection rates ranging somewhere between 50% and 80%. Within this range, periodical fluctuations like those in Beijing might be coming about for a number of different reasons, but the most likely scenario is that the differences are due to the fact that each author defined the scope of their survey slightly differently.

When comparing these numbers to the proportion of WEEE obtained by formal channels (Table 3), the dominance of the informal collection segment becomes even more apparent. Formal recovery and take-back stations receive merely 10%–24% of the WEEE generated in households, and the return of WEEE to retail likewise displays low rates. In this respect it is noteworthy that the Old-for-New (OfN) pilot scheme, which aimed to increase EEE consumption and simultaneously to incentivise formal recovery, achieved relatively high take-back rates. Via the provision of state subsidies, consumers buying a new device at a retailer could receive discount vouchers offering up to 10% off if they handed over their old device [35]. Yet, even during the pilot period (2009–2011), formal WEEE recovery still lagged behind the proportions of WEEE being gathered informally.

**Table 2.** Informal collection of WEEE from urban households in China.

Informally Collected WEEE (% of Quantity Generated by Urban Households)	Area	Year of Measurement	Source
60.0	China	2011	[4]
88.0	China	2011	[16]
57.0	Peking	2005	[40]
50.0	Peking	2005	[40]
30.0	Peking	2008	[9]
60.0	Peking	2010	[41]
60.0	Peking	2011	[8]
30.0	Peking	2012	[42]
76.0	Shanghai	2013	[43]
55.0	Xi'an	2010	[44]
51.0	Baoding	2012	[45]
50.0	Hangzhou	2013	[46]
37.0	Taizhou	2009	[40]
43.0	Ningbo	2003	[40]

**Table 3.** WEEE from urban households via formal collection.

WEEE Received by	Proportion of WEEE (%) Generated	Area	Year of Measurement	Reference
Recovery and take back stations	10	Peking	2010	[41]
	10	Peking	2011	[8]
	24	Shanghai	2013	[43]
	13	Baoding	2012	[45]
	14	Taizhou	2009	[40]
Return to retailers before the OfN (2009–2011)	16	Ningbo	2003	[40]
	4	Peking	2005	[40]
	14	Peking	2005	[40]
Return to retailers during the OfN (2009–2011)	7.8	Xi'an	2010	[44]
	20	Peking	2009–2011	[8]
	20	Peking	2009–2010	[41]
	4	Taizhou	2009	[40]

The collection channels exert a significant influence on the availability of WEEE for subsequent treatment stages, i.e., product refurbishment for reuse or recycling for material extraction. From the perspective of the formal system, the main goal in WEEE treatment is product recycling for material extraction. Therefore, formally collected EOL devices are destined to enter formal recycling yards and only seldom find their way into reuse [6]. The main aim of informal collection, on the other hand, is to generate a high turnover and thus selling WEEE for reuse is seen as more profitable than transferring it to formal or informal recyclers for material extraction [47]. The different preferences of the formal and informal collection channels also manifest in the sources of WEEE supply for secondhand electronics markets (see Table 4). Informal collectors originally delivered around 60%–80% of the EOL devices sold at these markets. Formal retail and repair services provide around 10%–20%, which in many cases constitutes a grey area practice due to imprecise regulatory coverage. Thirdly, residents may also sell directly to secondhand market dealers (5%–15%) so as to cut out the middlemen and receive more money for their old devices. In summary, Tables 2–4 exemplify the fact that repair and reuse practices centred in secondhand markets are highly dependent on the informal collection of WEEE from households, as this channel provides the majority of what is sold at these markets.

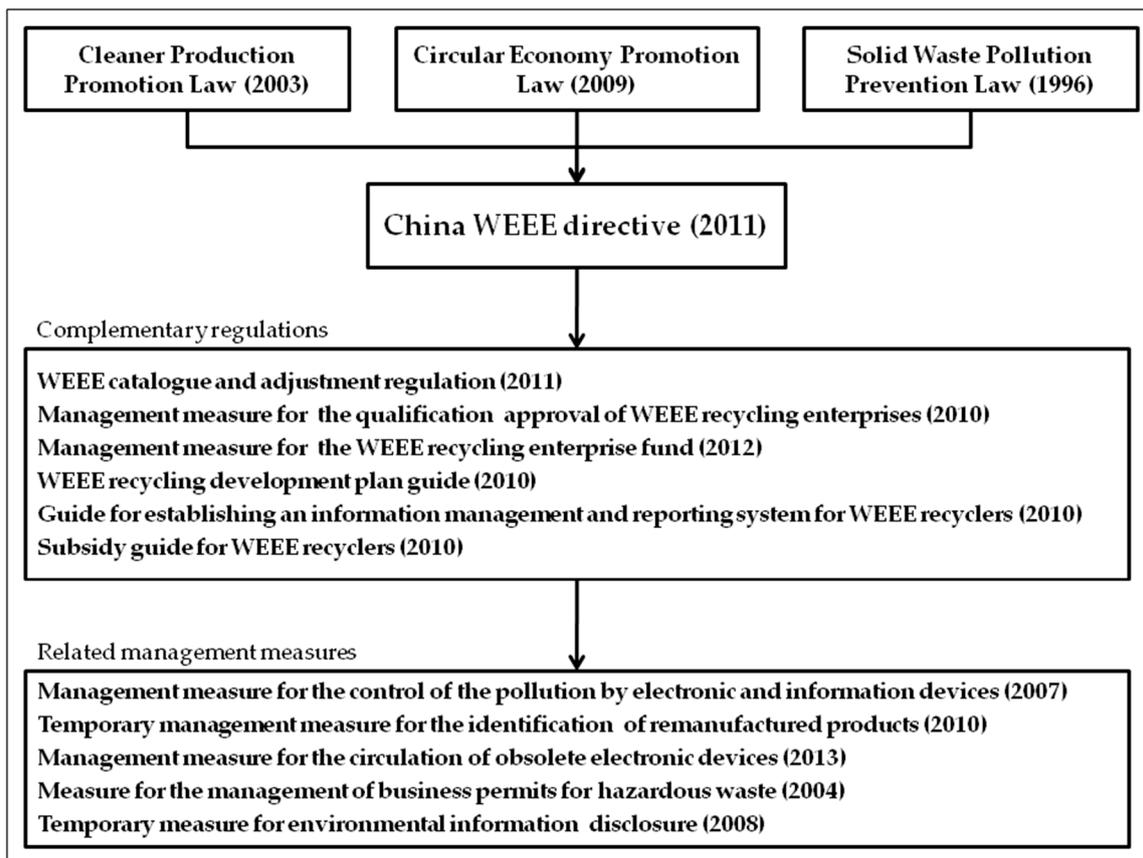
**Table 4.** The sources of WEEE sold to secondhand electronic markets.

Area	Source of WEEE	Proportion by Source (%)	Reference
Peking	Informal collectors & traders	80–85	[8,40]
	Residents	5–6, 17	
	Formal retailer or repair service	10–15	
Baoding	Informal collectors & traders	60–70	[45]
	Residents	10	
	Formal retail or repair service	10–20	
Xi'an	Informal collectors & traders	70	[44]
	Residents	15	
	other	15	
Taizhou	Residents	6	[40]
Ningbo	Residents	12	[40]

### 3.2. Formal Regulations on WEEE Refurbishment and Reuse

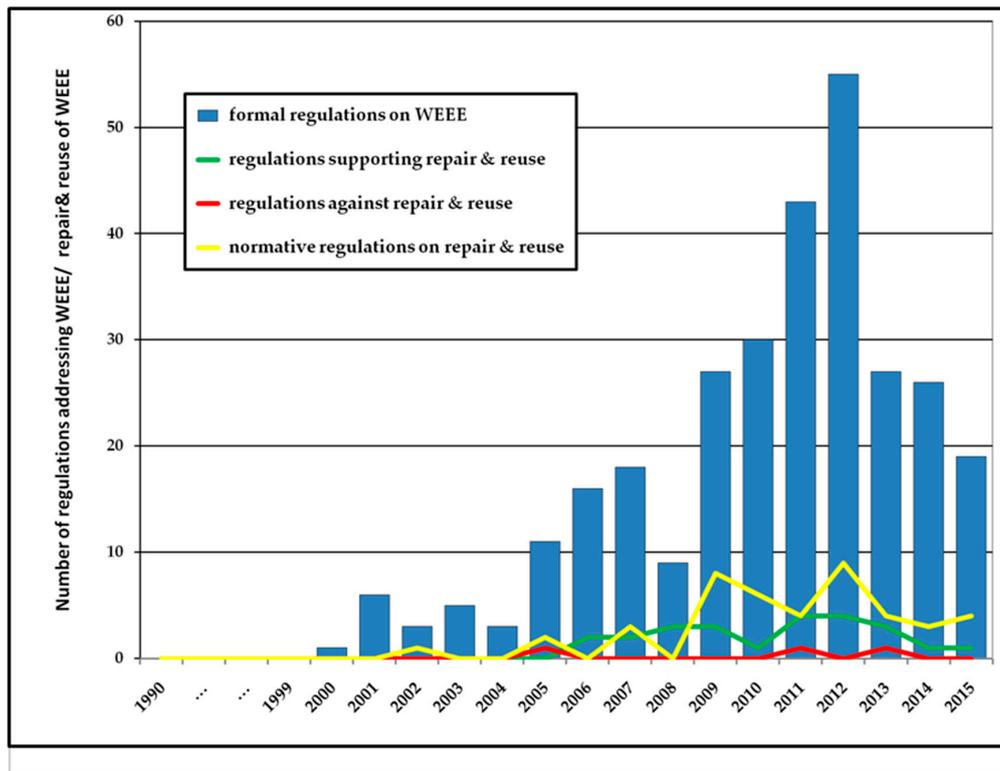
The Chinese formal regulatory framework for WEEE management is relatively young, as it originated in the import ban for obsolete electronic devices issued in 2000 [2,6]. Over time, the institutional structures at local and central levels experienced a rapid expansion, which broadly evolved along two lines. Firstly, foreign regulations such as the EU RoHS and WEEE directives were transferred and adapted to China's local requirements [6]. Secondly, extensive use was made of pilot projects so as to test different institutional approaches for WEEE management. The results that were generated subsequently were, in a second phase, integrated into national regulatory structures and thereby increased the effectiveness of the country's WEEE management system [3]. A typical example of a domestic institution-building approach was the OfN scheme (2009–2011), which began as an experimental trial and culminated in the WEEE Recycling Fund system that has been in place since 2012 [11].

The PRC has now set up a multi-tiered institutional system for WEEE management at a national level (see Figure 1). At the top, three fundamental laws define the ideological basis for WEEE management, i.e., the Cleaner Production Promotion Law (2003, the revised version has been in place since 2012 (if not otherwise indicated, dates for legal texts are the dates when they were implemented, rather than the dates when they were issued)), the Circular Economy Promotion Law (2009), and the Solid Waste Pollution Prevention Law (1996; revised versions have been in place since 2005, 2013, and 2015, respectively). The WEEE directive (2011), at the next level down, can be seen as a refined result serving two purposes. Firstly, it conveys the institutional value concepts of the previous first tier laws, i.e., the Cleaner Production Law's aspect of dealing with hazardous substances [48] (art. 28), the concepts of "reduce, reuse, and recycle" promoted by the Circular Economy Law [49], and the WM concepts of the Solid Waste Management Law [50]. Secondly, the directive also merges measures and regulations from lower down in the hierarchy into one piece of legislation. This institutional formation, directed from the bottom up, primarily serves the purpose of consolidating otherwise isolated management practices as well as integrating management approaches that have proven to be effective in the form of trial regulations. Examples of this kind of function in the China WEEE directive are the combinatory mechanism of enterprise licensing via control over information relating to material input and output [51] (art. 12–17), and the adoption of the funding mechanism for WEEE recyclers that was trialled during the OfN [51] (art. 7).



**Figure 1.** Overview of China’s regulatory body for WEEE management ([33], adapted by the author).

In terms of content, the WEEE regulatory framework prioritises the promotion of product recycling, that is, the stage of final processing (dismantling and material extraction), and puts relatively little emphasis on collection [6,11] or on repair and refurbishment of WEEE for reuse. As can be discerned from Figure 2, the institutional system behind WEEE management has exhibited a very quick expansion from virtually zero in 1999 to an average of 18 new regulations per year (2000–2015). This quantitative growth trend itself does not give any specific indication of its institutional nature or of its effectiveness, except for the fact that the government has dedicated more attention to the subject. However, an analysis of the content shows that the number of regulations touching upon the aspect of WEEE repair and reuse is relatively small within the overall regulatory context (see Figure 2). Moreover, these regulations predominantly carry the normative tone of formalisation, which indicates the state’s endeavour to reorganise this segment under formal institutional control.



**Figure 2.** Quantification of Chinese WEEE regulations with regulations addressing repair and reuse indicated separately (source: the author, based on [7]).

As for WEEE repair and reuse, the government has only in recent years begun to integrate these management approaches into the formal institutional framework. The earliest notion of WEEE reuse in a key piece of regulation occurred in the Circular Economy Promotion Law, which has been in place since 2009. In this piece of legislation the guiding idea regarding WEEE management is to promote recycling activities (dismantling and material extraction for re-manufacturing purposes), whereas reuse remains largely untouched except for the requirement that repaired EEE destined for resale needs to be clearly labelled as a “reuse product” and has to meet corresponding recyclable product standards [49] (art. 39). During the implementation period of the OfN pilot regulations (2009–2011), there was a sole focus on transferring WEEE and recycling, with refurbishment and reuse being neglected entirely until they were finally taken up in the China WEEE Directive (2011). The specifications in this directive are that repaired electronic products destined for reuse need to be properly labelled as “old goods” (*jiu huo*) and that they have to meet user safety standards [51] (art. 12). The Management Measure offers a more detailed guideline on reuse for the Circulation of Obsolete Electronic Devices (2013). There the intention to further formalise the reuse segment is not only exemplified by acknowledging individual entrepreneurs (often identified as belonging to the informal sector) as traders of refurbished WEEE [52] (art. 2), but this is also expressed in the attempts to further clarify the processes and standards related to device repair, the respective documentation of the quantity of WEEE transacted, and proper product labelling [52] (art. 3, 7, 8, 13, 15, 17). A very recent incentive to buttress the formalisation of secondhand product exchanges came with the issuing of the 2014 Notice on the VAT Collection Policy, in which it was specified that the VAT for selling secondhand goods such as refurbished WEEE would be reduced from 4% to 2% [53]. Finally, the latest amendment on WEEE repair and reuse to the formal institutional system was the 2015–2020 Mid- to Long-Term Plan for the Establishment of a Renewable Resource Take Back System. It aims to upgrade the physical take-back and distribution network for secondhand goods including WEEE. Basically the idea is to develop a three-tiered recovery structure consisting of take back points, sorting and separation centres, and distribution markets, which would help to

increase the scope of recovery activities e.g., by reducing the distance between reuse processing entities and take-back structures. Regarding the conflict between formal and informal structures, the MOC as principal author of the plan sets forth the fact that pre-existing, informal structures are to be formalised so as to fit into the proposed official structure [5]. As a conclusion to this section, it should be noted that no single regulation prohibits or bans informal secondhand markets for EOL devices. The current status of the regulatory body therefore makes it possible for unregistered operations to continue within the formal framework.

### 3.3. Informal Refurbishment and Reuse

#### 3.3.1. The Development of Informal Refurbishment and Reuse Practices

The initial emergence of informal WM structures in urban China can be traced back to the 1980s [12,17]. This development was triggered by the dismantling of public urban WM systems, when public budgets were reallocated towards the building of industry and commerce so as to boost GDP growth that needed urban space. Apart from the demise of official structures from the planned economic period and the lack of formal regulations, surplus labour from the countryside poured into the cities for work. Some of these actors started to replace the former formal system by setting up their own structures in the collection, trade, repair, and recycling of reusable goods, including WEEE [10,12,17,54]. As for obsolete electronics, two different types of refurbishment and exchange structures emerged in urban areas, “waste villages” and secondhand markets. The so-called “waste villages” are mostly situated in the outskirts of cities such as Beijing and Guangzhou, where recyclables are pre-processed (cleaning, sorting, separation, extraction of components) and stored ready for transfer to recycling or remanufacture facilities [17,54,55]. The secondhand markets within city centres, on the other hand, take back discarded products and, after repairing them, sell them on to consumers. During the 1990s and early 2000s these markets flourished due to the variety of devices on offer, to strong consumer demand for refurbished devices, and to their internal organisational structures, e.g., different storeys specialising in different product categories. Prices were very cheap, as compared to those offered by the retail sector, and due to the influx of foreign secondhand devices refurbished for reuse on Chinese markets, consumers were quickly attracted by the low prices of these secondhand devices. As shown by preceding research, one of the crucial factors that facilitated these informal systems was the lack of regulations or the bending of formal rules: Vendors in these markets, for the most part, largely ignored formal regulations (labelling, guarantees, and safety standards) [56]. Moreover, informal refurbishment began to thrive after respective formal regulations had been loosened. At the beginning of the 2000s, secondhand markets and “waste villages” in Beijing went through a period of extension after regulations that had previously curtailed their activities were abolished or reduced [17,56]. Similar observations were made in the city of Guangzhou during the mid-2000s, when regulations on this sector were weak, and informal collectors, traders, and vendors often bent the rules to meet their needs. In many instances these actors did not possess licenses for the sale of refurbished WEEE [57], while in other cases regulatory loopholes were exploited, for example via modifying land use rights to establish secondhand markets [55]. Despite the consequential increase in formal regulations during the mid-2000s, this has not successfully reduced informal control over WEEE flows. Formal recyclers are highly dependent on informal collectors as these deliver about 90% to the yards [11,58]. These 90% only constituted an estimated 12% of overall generated WEEE quantities in 2011 [8]. The remaining 88%, however, stayed in the possession of informal channels. As shown above, herein, a major proportion goes to informal refurbishing and repair (see Section 3.1.2).

#### 3.3.2. Systems of Informal Refurbishment and Reuse

Given this strong control of the informal sector over WEEE collection and repair segments, the question is how informal institutional structures operate and why they perform better than the formal sector. Firstly, informal collection is driven by high revenues, which the actors involved initially

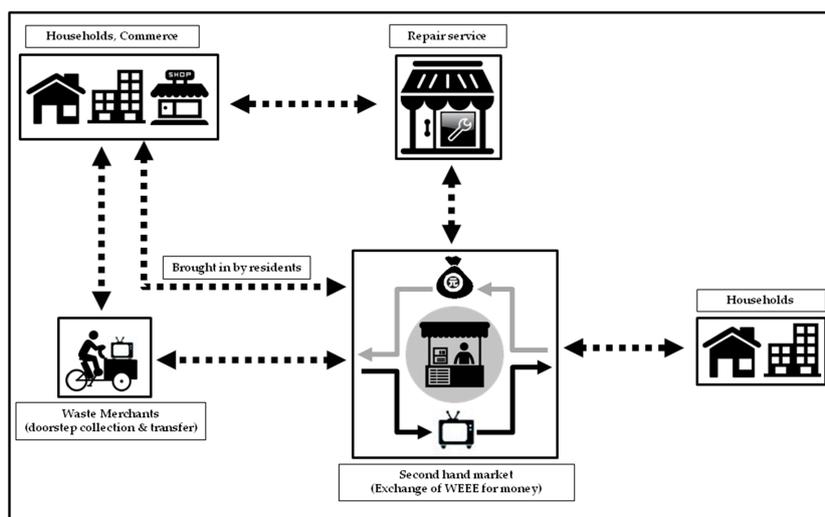
provide so as to pay the relatively high compensation to households for their WEEE (see Section 3.1.2). Formal collection is incapable of competing with these reimbursements and, as such, formal systems operate on a high-cost basis due to the comparatively high expenditures for labour and transport mandated by state regulations [59]. Once informal actors have gathered a sufficient amount of WEEE, they either transfer it to recycling or to secondhand markets for reuse. Previous research has shown that informal collectors and even informal recyclers transfer EOL devices or components into reuse as long as these products possess a certain degree of functionality or are in a repairable condition—the decisive reason being that the functional value of old devices is much higher than the value that can be reaped from material recovery [12,15,60].

For such turnovers to be made and thus for the maintenance of informal dominance in this segment, secondhand markets are pivotal. These nodes not only offer a wide variety of products to consumers, they are also connected to or provide space to repair services (see Figure 3). The legal position of these markets is in between the formal and the informal realm. On the one hand, the sellers within them have, in most cases, obtained licenses for their operations. On the other hand, legally prescribed warranty claims or proper labelling of the refurbished devices is often missing.



**Figure 3.** Guangzhou's Dashatou secondhand market with (a) trading area and (b) integrated repair service structures (© Yvan Schulz).

Over the course of several research projects between 2013 and 2015 the author visited secondhand markets in Beijing and Guangzhou, where informal WEEE collectors selling to these markets and local vendors were interviewed. On this basis the operative system structure behind informal WEEE transfers to and from secondhand markets was outlined (see Figure 4). Private households and businesses are the generators of obsolete devices, which they either transfer directly to markets for monetary compensation or sell to informal collectors who act as intermediaries and transfer them to the markets. Another transfer channel comes in the form of repair services. These are generally small shops that sell devices obtained from consumers to markets; in some cases they provide repair services directly to secondhand markets. A symbiotic system like this has been adopted by the Weixun digital city secondhand market in Guangzhou; in the back alley behind the trading hall for used electronics, a row of small repair shops has been set up according to the principle of division of labour. Repairs on LCD screens were conducted in sequential steps for traders within the market, as well as for others [61]. Finally, markets serve as suppliers of refurbished devices to households/consumers, who are attracted by comparatively cheap secondhand electronics.



**Figure 4.** WEEE transfers for reuse via secondhand markets (grey arrows indicate monetary flows, black ones represent WEEE flows, and two-directional arrows indicate diametrical flows of money and WEEE) (© the author).

The decisive function of secondhand markets is the generation of high revenues that accrue to informal actors. Although no comprehensive research has been conducted on the revenue generated within secondhand markets, reports and documentation on Chinese online recycling portals indicate that high profit margins are generated through the repair and reuse network. For example, in 2015, a 25-inch TV was bought at a secondhand market for 150 RMB and then resold for 300 RMB after some simple repairs, thus generating a profit of 100% [62]. For profit generation, some factors are crucial. Firstly, the location of the markets plays a significant role. The more centrally located these markets are within an urban area, the higher the cost for refurbished devices. Taking Dongxiaokou's "waste village" in Beijing's urban-rural fringe district of Changping as an example, profits were only 50% of the buying price for refurbished refrigerators [63]. However at markets that are more within a city's centre as in Guangzhou, informally repaired LCD screens may be sold with a profit margin of 200%–300% of the buying price [61]. Secondly, the price of refurbished devices is also determined by product age, generation, and brand. Such features are highly relevant, especially for mobile phones. Devices stemming from the "pre-smartphone" era would be bought for 10–20 RMB, then sent to repair and finally sold for 50 RMB at secondhand markets. Similarly, less popular smartphones, such as HTC devices, would be bought for 50 RMB and sold for reuse to markets for a multiple of the buying price [21]. On the other hand, a relatively modern Samsung Galaxy 4, which would cost 2600 new, would reap around 1500 RMB when sold for informal refurbishing in 2014 [64]. So it is, in fact, the very flexible profit margins, the steady flow of goods from informal collectors, and the continuing demand for refurbished electronics that turn secondhand markets into an effective mechanism for redistributing repaired electronic devices to consumers and away from formal recycling [65].

### 3.4. Formal Refurbishment and Reuse

Given the effective informal mechanisms maintained by consumer demand, the question that arises is how and to what degree formal private and public stakeholders have reacted to or become engaged in this field of WEEE management. Previous research by Schulz [15] confirms that neither academics nor major industrial actors are active in WEEE repair and reuse. For the former, public funding is hardly, if at all, available, and in industry it is primarily small-scale enterprises (such as repair service shops) that are involved in the refurbishment of electronic products. According to internal figures of the semi-governmental body the Chinese National Household Electronic Appliances Service & Maintenance Association (CHEASA), up until 2012 only 1217 formally registered enterprises were

engaged in repair and refurbishment of EEE in China. Most of these companies (42%) are small-scale with less than seven employees, and yet the segment exhibits moderate growth rates of 8.3% p.a. [66].

Apart from small-scale repair shops, there are two major players in WEEE refurbishment and reuse that are worth mentioning, although their operational focus is exclusively set on the relatively valuable category of obsolete mobile phones. One of them, the second largest of these two companies, is Ai Huishou (Love Recycling), which was established in 2011 and which currently covers the areas in and around Beijing, Shanghai, Guangzhou, and Shenzhen. Up until 2014 the company obtained 100,000 mobile phones, with current collection rates of 500 devices per day through their own individual collection system. So far Ai Huishou has generated a turnover of 5 million RMB. About 90% of the collected phones have a high reuse value and after repairs the company adds 10% of a phone's current market value before selling it directly to consumers or wholesale to secondhand traders via the company's own online trading platform. This in fact constitutes a much smaller profit margin than what is generated by informal stakeholders. The majority of the phones sold go to China's central and western regions, where the demand for refurbished phones is relatively high. Given the strong consumer demand, the company prefers to sell refurbished phones for reuse rather than to sell them for recycling [67,68].

A similar system is adopted by the largest provider of refurbished mobile phones, Taolü Huanbao (Clean Green Environmental Protection), which has also used the Internet to develop its business. Established in 2009, the company relies on online structures to buy mobile phones from individual users and collecting parties at prices determined by the company based on the age and type of the device. In addition to working with individual users, the company has contracted over 1000 mobile phone take-back operators in over 80 cities in China, some of whom offer doorstep collection services [67]. This approach shows some similarities to the effective schemes of informal actors. As a matter of fact, Taolü Huanbao indirectly makes use of informal collection systems, as it does not discriminate between formal and informal supply channels. In interviews with the author it was indicated that anyone who sets up an online account with the company may supply Taolü with discarded mobile phones. The online exchange starts with suppliers transferring the devices first; upon receiving the products Taolü verifies the brand, age, and category before making an offer. In order to explain how they convince wholesale suppliers to transfer devices before receiving payment, Taolü's CEO Manson Loo refers to the company's transparent online information service, which has been designed so as to foster reliability between the sellers, the company, and the buyers. This trust-generating mechanism does, in turn, provide an alternative to informal, less transparent collection systems. A look inside the company's headquarters shows a refined organisation of device pre-processing (cleaning, sorting, and separation) for reuse (see Figure 5). Every batch of mobile phones entering the company is first scanned, photographed, and then documented regarding the quality, size, weight, and number of devices. This information is then stored in the company's database and the seller is supplied with documentation that attests to it. In the second step, every device is manually scanned and categorised according to product generation, screen size, functionality, battery type, and product age. Based on this categorisation, Taolü Huanbao makes an offer to the seller, and if the offer is accepted, they either conduct refurbishments within the company or transfer the mobile phones via wholesale markets to buying parties, e.g., secondhand markets. These internal measures for estimating the device value resemble a refined, more detailed method of what is practiced by the informal sector. A look at the figures shows that this "fundamentally market-oriented" and information-intensive model reaps economic success. Up until 2013, 8.7 million phones were transacted from sellers over Taolü Huanbao to buyers, and in 2014 this number grew to 14 million, equating to a 61% increase in transacted mobile phones. Echoing the core concept of Ai Huishou, Taolü Huanbao calculates the reuse and refurbishment of mobile phones to be significantly more profitable than selling the devices to formal recyclers [69]. This again follows the same logic that informal actors in WEEE management employ: The gain from reuse is higher than the gain from material extraction.

Beyond the field of obsolete mobile phones, there are also other formal systems of refurbishment and reuse practiced in China. In most cases, these relate to company specific systems that have

established product life extending or product leasing schemes that have employed take-back, repair/upgrade, and resale services. For example, Alcatel has established a take-back scheme for telecommunication equipment in private and public offices, which it regularly updates so as to serve the needs of their customers [70]. Another example is Fuji Xerox in Suzhou, which offers a take-back, repair, and upgrade service for office printers and copy machines in China. By means of this practice the company has managed to extend its products' lifetime, to recycle broken components, and to upgrade customer-used products via component exchange. Such practices may be seen, in the broadest sense, as reuse, and have mainly been implemented due to the fact that the company easily achieves increases in their profits given the specific nature of the device [71]. Although this latter example of repair and reuse is also driven by profit maximisation, such product specific practices are limited to a few industrial frontrunners in China and cannot, in terms of size and impact range, compare with the relatively broad mobile phone repair and trade services of Ai Huishou and Taolü Huanbao, let alone with the even more encompassing repair and reuse practices demonstrated by informal secondhand markets and "waste villages".



**Figure 5.** (a) Storage and (b) subsequent code-scanning based sorting of mobile phones at Taolü Huanbao (© Benjamin Steuer).

### 3.5. Pushing Formalisation against Persistent Informal Practices

As indicated above, WEEE repair, refurbishment, and reuse take place simultaneously and thus formally registered and informal, non-registered actors compete for them. The question raised by this is how the state, as the guiding formal institutional coordinator, reacts to the segment-specific competition. Based on documentation in previous studies as well as interviews and observational evidence by the author, there are three processes that exhibit the competing dynamics between formal and informal rule systems:

#### (1) Expulsion without formal substitution

One of the earliest documented approaches was the attempt by the state to abolish markets that had emerged informally where old goods including WEEE were traded. In Beijing, such measures had already begun in the 1980s, when the city was experiencing vast spatial expansion, during which informal waste trading areas were abolished by the government so as to create space for commercial activities. The reaction from informal actors was, and currently still is, to relocate to fringe areas until the city's expansion and government planning would again drive them out of these areas. Beijing's Dongxiaokou "waste village" is a telling example of this phenomenon, where informal WM operations active since the 1990s are now shifting to the new edge of the growing city [11,17,54]. This procedural pattern of the official expulsion of informal activities from one area, followed by the automatic resettlement of the same activities in a nearby area, is primarily a consequence of the lack of effective replacement through formal institutional solutions.

Another attempted expulsion that aimed to suspend informal management of WEEE without substitution was the OfN scheme. The attempt to divert WEEE from households to formal channels was based on the provision of reimbursements to consumers when handing over EOL devices to formal

take-back services [35]. However while the scheme was running, business at informal secondhand markets continued to thrive and profits made by trading refurbished devices even increased by 100%–200% [72]. This development in part resulted from consumers' increasing awareness of value, sparked by the pilot's reimbursement system. But, rather than transferring their old devices to a retailer for at most a 10% discount, consumers would go to informal secondhand markets and reap a much higher return on their appliance [73]. In fact, the OfN insufficiently substituted the profit creation mechanism of secondhand markets by implementing a reimbursement system. This adversely created a negative incentive for consumers: Not only were they left with a smaller pecuniary return, they moreover had to buy a new electronic device so as to enjoy the remuneration.

## (2) Integration of informal activities via licensing and infrastructure provision

The second pattern of formalisation can be seen as an alternative to or a result of a learning process due to the preceding expulsion approach. For example, in Beijing, the government initiated a pilot scheme to upgrade the waste collection and exchange infrastructure in 2000. Apart from setting up community-based recycling systems in some inner city districts, it also attempted to standardise the logos, vehicles, uniforms, prices, and categories of recyclables collected and traded within the remit of the pilot scheme. Furthermore, plans were established to build recycling markets with large automatic sorting and dismantling equipment, accompanied by attempts to keep non-registered informal actors out of business [14,17]. Follow-up attempts to establish formal markets were undertaken again in 2004, with a focus on high spatial density, the standardisation of transaction processes, and the mechanisation and automation of pre-processing [54]. However, these proactive integration measures were met with suspicion and rejected by the majority of informal actors. Those willing to be integrated into formal structures began to work in new uniforms for formal companies, but they still had their ties to the informal segment and preferred to sell their devices and recyclables to the informal sector at market prices instead of selling at fixed prices to the companies that hired them [14,17]. A similar approach was taken by the municipal government in Guangzhou, formulated over a period of 10 years and culminating in the 2014–2020 Development Plan for the recycling industry. Again the concept was to standardise the management of informal actors in the business by providing them with training, standardised vehicles, clothing, and tools, and even standardised ways of communicating with and providing services to customers [29,74]. However, like the reactions of informal collectors in Beijing, the actors that entered the formal structures became increasingly alienated by the government's approach [75]. Those who first entered and subsequently left this formalised system stated that their decision was not influenced by the formalisation per se, but by the fact that they would have had to pay around 660 RMB—nearly a month's salary in 2007—in management and other fees per year to be allowed to remain within the system [76].

The examples that we have looked at are examples of formalisation within the broad informal segment in urban waste management, but there are also specific cases of the “formalisation via integration” pattern applied to secondhand markets for electronic devices and components. Because of various inconsistencies regarding information on the sources of electronic devices that are sold at secondhand markets, local governments have set forth regulations in order to better verify transaction processes and throughput. Examples of these regulations include formal licenses for traders, documentation of incoming and outgoing product quantities, and specific service guidelines. It is hoped that these regulations can help secondhand markets become better regulated and thus integrated into the formal system [21]. A relatively gradual pattern of integrative formalisation was put in place in Beijing's Gold Bridge Profit and Health Electronics Market between 2006 and 2012. The first step was to transform the market into a company, so as to endow it with its own legal status—almost that of a legal person—as well as management and operating rights. With this step, all of the traders in the market and their operations were pushed onto a path of formalisation that would increase control over refurbishment activities. In 2008, a service guideline was implemented that guaranteed consumers that, for all products sold at the market, repair and additional parts would be free of charge.

Additionally, any product sold that stopped working within the guarantee period would be replaced by another product of equal standard. In 2011, the billing systems for all traders and booths were streamlined, whereupon all invoices had to include the date, price, name, and place of the seller. In the same year the market became the only fully formalised one in Beijing's Haidian district and even installed a security service, surveillance, and documentation system [77]. Clearly these measures are indications of the gradual integration of less controllable, informal activities within a formal, tightly monitored framework. Similar measures were implemented in the biggest secondhand market in Haidian district, the Zhongguancun China Sea Electronics Market, which was visited by the author in 2013 and 2015. Interviews with traders confirmed the increasing influence of formalisation on the operations. Nevertheless, some traders refused to adhere to these new regulations. Many were not labelling their products correctly; indeed, some were not labelling them at all, and some were not giving discounts to consumers to compensate for the fact that they were not offering the required product guarantee. Despite these informal counter-strategies, traders perceived that the increasing formalisation has had an adverse effect on their profits, which had caused some shop owners to leave the market for better options [77]. Therefore it can be seen that a gradual formalisation, which ignores profit generation, induces a rejection by informal actors.

The negative correlation between opportunities for profit generation and increasing regulation through formalisation has been especially visible in a secondhand market for electronic components that was recently set up in Guiyu. In the 1990s the township was one of the two centres for informal WEEE recycling, but since the 2010s the government has geared up the formalisation process. As local, informal recycling activities not only aimed to carry out material extraction but also to salvage components, the local government reacted on both fronts. Following the construction of an Eco Industrial Park (EIP) in the area in 2010, local officials pushed forward the formalisation of WEEE processing by forcing informal dismantlers into the park. Via the establishment of an electronics component trade building, local officials intended to provide infrastructural means to integrate informal traders. A visit in May 2015 by the author, however, revealed that several buildings and storeys stood idle, that the local administration was represented only by one official, and that there were hardly any sellers or buyers present (see Figure 6). In interviews with the few traders that were present, the author was told that business has not flourished since the establishment of the trade hall, due to the comparatively high prices for secondary components, e.g. processors (see Figure 7). When asked for the reasons, the interviewees stated that this was due to various fees being imposed by the market administration on the traders, who in turn had to adjust their selling prices. In response to the question as to why the traders had entered the market, they said that the local government had confronted them with the choice to either integrate and resettle within the industrial park's market, or close down their operations [78]. This indicates that profit margins in this segment are too small to cover the burden of formalisation costs and that there are still informally traded refurbished components available outside of the EIP.



**Figure 6.** Idle trading stalls (a) in the second and (b) the first floor of Guiyu's secondhand electronic component market (© Yvan Schulz).



**Figure 7.** Salvaged processors sold in Guiyu’s electronics component market (© Yvan Schulz).

### (3) Circumventing formalisation via (pre-emptive) evasion

Official measures pushing forward formalisation have not gone unnoticed by informal actors. For example, in Dongxiaokou, where the government had recently started to initiate rigid actions against improper land use including informal recycling and reuse activities [79], some informal actors in the local waste business took the initiative and left the area to resettle in a nearby location called Nanqijiazhuang so as to pre-emptively avoid formalisation. The operations in that new area are, however, relatively similar and resemble a copy of Dongxiaokou’s organisational and transaction model [11,54]. Beyond that, the organisational leadership among the informal actors also tried to conduct endogenous organisational improvements so as to obtain the approval of the local government for their operations [13,54]. This practice can be considered a movement towards alignment with formal institutional requirements. In essence, however, the institutional framework for these organisational structures remains informal and thus the process may be best described as formalisation on informal terms. Similar patterns have occurred in markets for secondhand electronics. Beijing’s Zhongguancun China Sea Electronics Market, which has been subject to continuous formalisation by the authorities, has experienced a gradual abandonment by traders, who felt that diminishing profits had become unbearable. According to interviews by the author and online reports, these traders have relocated to another area instead of abandoning their businesses [80–82]. Likewise, developments in Guiyu have displayed a similar pattern; the actors have met attempts at formalisation and integration by the government not with resistance, but with evasion. In 2015, when official formalisation aimed to close down all informal activities in the area, interviews with local informal actors in WEEE management indicated that there were strong tendencies among the sector towards simply relocating operations to another nearby area [83]. Given the fact that there are obvious signs of a strong demand for refurbished electronic components in nearby Shenzhen’s Huaqiangbei area [83–85], informal repair and component recycling activities may avoid formalisation and may be given leeway to remain in the area.

## 4. Discussion

In this final section we will revisit the paper’s central and secondary questions, namely what formal and informal institutional structures shape WEEE refurbishment and resale in China, and which of these have proven to be effective. Therefore the focus here will be on institutional practices that demonstrate dominance over competing, alternative rules, on how frequently certain rules are put into practice, and on the impact of sanctions imposed by formal institutions.

The first case of unilateral institutional dominance and usage frequency is reflected in the question of the quantity of WEEE. As indicated by the figures on collection, informal rule patterns and routines are clearly dominant; not only is the majority of WEEE collected by informal actors, but most of it is also channelled to secondhand markets for reuse. The key institutional variables responsible for this outcome are consumer-friendly collection services, flexible market pricing routines, as well as information exchange and transaction systems established between informal collectors and sellers [11,30].

The relative effectiveness of these rule systems is reflected in the sheer superiority of informal WEEE collection and transaction ratios.

Given these circumstances and the Chinese state's preference for top-down solutions, the obvious expectation would be a strong formal institutional response to these activities. However there are relatively few regulations that manage the refurbishment and reuse of obsolete devices, as compared to the overall size of the legislative WEEE framework. Nor are there any sanctions in place that would effectively prohibit such activities, which in turn allows the (often unregistered) operations in secondhand markets to continue to run. The general legislative response is predominately normative and top-down oriented. Given the lack of detailed institutional arrangements and the small margin for the integration of bottom-up developments, this type of regulatory response inadvertently shapes WEEE refurbishment and reuse. It does so less because of its effectiveness in dominating the segment institutionally, but rather because it leaves many loopholes open and unregulated, which in turn allows informal actors to employ their specific, informal routines and habits to handle WEEE. In fact, informal rule systems have flourished in these instances, when formal rule systems contract. Beijing's "waste village", for example, only emerged because of a deregulation process that affected the formal WM framework in the early 2000s [17,56]. Similar patterns were observed in Guangzhou during the mid-2000s, where traders of refurbished WEEE employed their own rules given that the formal ones were not effectively formulated so as to structure the segment [55,57].

So what are the informal rule systems that enable the informal segment to perform effectively? Broadly speaking, for the field of WEEE refurbishment and reuse, we can distinguish three key institutional mechanisms of the informal segment. The first is the practice of cooperative, mutually beneficial exchange patterns between households and informal actors as well as between the informal actors themselves. This basic yet crucial set of rules centres on the exchange of old devices for relatively high monetary rewards. Beyond the obvious value transformation that comes from turning waste into a commodity, the interacting actors also transfer valuable information with every transaction they conduct. This information is significant, not only because it tells the parties involved more about prices and respective changes, but also because it conveys the realities of market demand for specific product (device) types. In interviews, collectors and traders have often stated the fact that their preferences for certain devices change over time, and that they instruct their suppliers so they can supply them according to their changing needs [20,47,81,82]. Households, on the other hand, indicated on a number of occasions that they adapt their bargaining behaviour for devices or recyclables depending on the information they acquire by observing the collectors' routines [11,30]. The same is true for secondhand markets [13,14]. This institution of cooperative exchange is sustained through a high degree of personal contact and interaction and through the high density of actors involved in the operations. The second notable institutional element is the organisation and operation of infrastructural nodes. Secondhand markets, small street markets, and other physical sites where devices are exchanged play a pivotal role for several reasons. Firstly, they span a dense network over entire cities and facilitate collection and transfer activities [30]. Secondly, they generate synergies between actors, e.g., secondhand markets are not only operated by traders, as adjunct refurbishment and transport service providers also play a role. Thirdly, these hubs are significant junctions for information exchange, i.e., sites where demand and supply come together. Finally, these sites are also profit-making centres as they are attractive to consumers due to the variety of devices available, and also to traders, who can compete for the highest offers. As is the case for the institution of cooperative exchange, infrastructural nodes like these seem to have emerged because of legal loopholes or due to a lack of formal alternatives. The third and final institution benefitting informal actors is embedded in the routines of pricing obsolete devices. This is not only done through the capacity of informal actors to master the changes in device price and consumer preferences, but it also requires skilled handling of information asymmetries [12,13,47,81,82]. Despite relatively cooperative patterns within the informal segment, actors in each part of the transaction chain tactically withhold some information so as to gain advantage over cooperating actors and thereby generate a certain amount of profit. The specific

routines behind the use and dissemination of information are a crucial component for profit generation within the informal sector and therefore they support its effectiveness.

The well-evolved informal institutional system is, however, not the only effective mechanism that refurbishes WEEE in China. As exemplified by the case of Taolü Huanbao, formal-private activities can also generate organisational and operational mechanisms that work well. In contrast to the informal systems, Taolü Huanbao emphasises transparency in its refurbishment and sale of obsolete devices. This in turn could explain the high level of consumer trust and thus economic profit that the company has been able to generate. In fact, it seems as if an effective answer to informal refurbishment systems would, on the one hand, need to make use of the vast growing online market to sell repaired devices, and, on the other hand, need to emphasise transparency and thereby generate trust among consumers. That said, private, formal systems such as those operated by Taolü Huanbao also depend on informal channels when it comes to the supply of obsolete devices.

The discussion above on the effectiveness of formal and informal institutions was carried out for the purpose of understanding the formal–informal institutional dynamic behind WEEE refurbishment and reuse in China. The analysis indicates that the realm of formal regulations is incomplete insofar as it leaves many aspects of management open or covers them imprecisely. This, in turn, creates vast leeway for informal actors to implement and practice their respective informal rule systems. By implication it means that formal regulations, overall, are not efficient. They do not dominate with regard to structuring WEEE refurbishment and reuse, nor do they exhibit a high frequency in actual usage or a capability to sanction those deviating from formal regulations. For the overall institutional dynamic, this means that the main impetus is created through the practice of informal rules. It is thus primarily informal actors and their respective rule systems that guide the dynamic in WEEE refurbishment, while formal actors are locked in a position in which they, for the most part, must respond to previous informal institutional activities. This has been exemplified in particular in the three processes of formalisation and counter-formalisation. The first dynamic process of formal expulsion without substitution resembles a cat-and-mouse game, where working informal solutions have primarily been expelled by means of top-down policies. The ineffectiveness of the formal approach is revealed by the fact that expulsion is not followed by any effective institutional replacements. The second dynamic pattern centring on integration appears to bear some elements of a learning process within the formal framework, as it attempts to maintain and imitate some of the informal institutional elements. However, this approach ignores the vital market pricing mechanism adopted by informal actors, and tries to replace it with a less profitable attempt to implement a fixed price system. Furthermore, elements of top-down control are dominant in this context, and they run counter to the decentralised decision-making routines of the informal sector. The third dynamic pattern (evasion) clearly represents the outcome of a learning process by informal actors. Accustomed to being subject to curtailing top-down measures, informal refurbishers have learned when and how it is best to converge to formal injunctions somewhat, or to relocate their operations spatially so as to avoid falling under the formal framework. In these instances, the obvious informal strategy is not resistance to formal rules, but the evasion or reduction of its spheres of influence.

## 5. Conclusions

This paper has shown that WEEE refurbishment and reuse is driven by a dynamic between formal and informal institutional systems. The major impetus promoting this dynamic, however, stems from the informal rule systems. Their relative effectiveness manifests in the dominance and frequency of informal rule practice in the field of WEEE refurbishment, and, moreover, is strengthened by the inability of the formal framework to effectively curtail or sanction these activities. The fact that state actors primarily resort to a top-down enforcement of formal rules, and yet fail to curtail informal practices, could lead to the hypothesis that the state will be forced to change its strategy from prohibition to increased cooperation with the informal sector in WEEE refurbishment and reuse. This constellation of two groups of actors does in fact constitute a major singularity of the

PRC: whereas the informal WM sector in high-income countries in the West has gradually vanished over time [31], it has gradually grown in size in China [30]. Moreover, China exhibits very strong antagonistic competition between formal and informal actors in WM, which stands in stark contrast to other countries at similar stages of development such as Brazil or the Philippines, where informal actors are much more integrated into the formal WM system [23,24].

With regards to the future of WEEE refurbishment in China, any assessment has to take a number of elements into account. The first element concerns the future demand of secondhand devices in China. In contrast to the high demand for cheap, repaired electronics in the 1990s and 2000s, current urban consumer demand is increasingly focussed on new products. However, there are at least three exceptions to this rule. The rural population with lower disposable income, for the most part, cannot not afford new devices, and will continue to resort to refurbished ones; the same is true for the approximately 200 million migrant workers in the cities, who equally tend to buy repaired devices, especially mobile phones; and, finally, a significant quantity of refurbished devices are bought by African traders, who export and sell these products to consumers in their home countries [19,47,79,81,82]. Therefore, it is relatively safe to state that this segment will continue to operate in China [86]. The second element relates to the legality of WEEE refurbishing. As there are indications that state pressure on informal WEEE recycling is increasing [83], the question is whether refurbishment activities will also be affected. Analysing the intrinsic perspective of China's WEEE policy framework can help to illuminate this issue. Therein refurbishment is considered to be different to recycling [12], in so far as it is not framed as a polluting practice. Indeed, most of the discernible sanctions that are applied under the formal framework on WEEE repair and reuse focus on economic and product safety concerns, but do not explicitly prohibit refurbishing activities. Even in China's Circular Economy Promotion Law, device refurbishment and device recycling are treated as two entirely different practices. Up until now, regulations on the former have merely set forth sanctions on informal, unregistered profit making, but have not taken into account any environmental considerations of device repair and reuse [49]. Informal refurbishing of WEEE is thus seen by the state to be an economic rather than an environmental issue. The third and last decisive factor, for the future of informal WEEE refurbishing and repair, centres on the question of changing income within the informal WM segment. For over three decades rural-to-urban migrants have dominated the informal sector in WM and they still do so today. The primary reason for this is that net income in this segment has been much higher than what they would have earned in the formal economy [11,30], where economic migrants in most cases only have access to low-paid jobs. In recent years the formal minimum wage has risen significantly in urban China, yet it has been found to be lower than the net income generated by urban informal recycling [30]. Given the current economic downturn in the PRC, jobs in the formal economy might be even more difficult to obtain, and therefore informal employment may maintain its attractiveness to migrant workers. Moreover, jobs in the informal recycling economy, including refurbishment, offer an additional attraction that was frequently emphasised by the informal actors interviewed by the author, namely independence and individual decision-making, which are seen as crucial motivations for this particular choice of profession [11,13,14,19]. In fact, this perception of entrepreneurial independence and the motivation to improve individual living conditions may be some of the key variables that help to explain the flexibility of informal institutions and the respective institutional dynamics in urban Chinese WM.

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## Abbreviations

The following abbreviations are used in this manuscript:

CHEARI	China Household Electronic Appliance Research Institute
CRRA	China Renewable Resource Association
EEE	Electrical and Electronic Equipment
EIP	Eco Industrial Park
EPR	Extended Producer Responsibility
MSW	Municipal solid waste
MOC	Ministry of Commerce
OfN	Old-for-New scheme for household electronics
PRC	People's Republic of China
RoHS	Restriction of Hazardous Substances
VAT	Value-added tax
WEEE	Waste electrical electronic equipment;
WM	Waste management

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