



Varieties of business models for post-consumer recycling in China



Xin Tong^{a,*}, Dongyan Tao^a, Reid Lifset^b

^a College of Urban and Environmental Sciences, Peking University, Beijing 100871, China

^b School of Forestry & Environmental Studies, Yale University, New Haven, CT 06511, USA

ARTICLE INFO

Article history:

Received 29 September 2016

Received in revised form

22 August 2017

Accepted 3 September 2017

Available online 5 September 2017

Keywords:

Recycling

Extended producer responsibility (EPR)

Sustainable business model

Internet +

Waste electrical and electronic equipment

(WEEE)

E-waste

ABSTRACT

The effort to build an EPR system for waste electrical and electronic equipment (WEEE) in China has created unexpected niches for innovation in business models for post-consumer recycling of e-waste as well as other recyclables in recent years. This study used action research to evaluate the performance of emerging business models for post-consumer recycling in urban China in recent years. We identified three categories of emerging models: (1) community-based programs targeting the garbage sorting behavior of consumers for all household waste, (2) reverse logistic systems with automatic vending machines attached to traditional commercial chains, and (3) pure internet solutions to bridge the transactions between the consumers and recyclers. All these business models share the common characteristic that they use internet technology, which is aggressively promoted in China as “Internet +” by both government policies and venture capital investment. The various business models serve as the link between the firm and the system level and reflect the diverse possibilities for the future evolution of the recycling system in China. We developed a qualitative evaluation framework with five elements including convenience for consumers, traceability for producers, profitability for recyclers, hybridity for collection, and reliability of the information used by the public to address the various values pursued by different actors involved in the recycling chains. The results reveal the dilemmas facing each business model in balancing among all the elements and highlight the governance challenge of integrating the EPR scheme with the municipal waste management system.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

A business model describes how an organization may create, deliver, and capture value in various economic, social, and cultural contexts (Osterwalder and Pigneur, 2010). A growing body of research highlights the importance of understanding how sustainable development is operationalized in firm sustainability (Stubbs and Cocklin, 2008). This research identifies the business model as a key vehicle for corporate sustainability by creating, capturing, and sharing company's sustainable value proposition to its customers, and all other stakeholders, either within or beyond its organizational boundaries (Porter and Kramer, 2011). The typical studies in this field used case-based theory at the organizational level to form the “ideal type” of sustainability-oriented business model (Schaltegger et al., 2016). As Boons and Wagner (2009) have pointed out, an essential role of a sustainable business model is to link innovation niches at the micro level to the social-technical

landscape at the macro level to arrive at a balance between economic performance and ecological/social sustainability both at firm and system level in market competition. Given the uncertainty and diversity in innovation niches, it is important to understand how the changes in institutional settings can affect the evolution of business models in practice.

The development of extended producer responsibility (EPR) provides an opportunity for fostering green innovation and new business models by changing the institutional setting of urban waste regime (Rossem et al., 2006). As an environmental policy approach intended, among other things, to create incentives for product innovation with lower environmental impacts throughout the lifecycle, EPR extends a producer's responsibility, physical and/or financial, for a product to its post-consumer stage, and shifts the cost of waste management from local government to consumers and producers. This policy strategy addresses not only the physical properties of a product, but also the related modes of consumption and production. These include encouragement for the provision of the functions of the products in a more efficient way, a shift towards product-service systems, and an interest in re-manufacturing

* Corresponding author.

E-mail address: tongxin@urban.pku.edu.cn (X. Tong).

activities in the industries that manufacture and provide complex products (Lindhqvist, 2000). However, the practice of EPR in some sectors, for example, waste electrical and electronic equipment (WEEE), shows that the simplified causal relations between regulation and producer's behavior assumed by the policy makers have failed to address the complex interactions among various stakeholders (Lauridsen and Jørgensen, 2010).

Based on interviews with various stakeholders, Kunz and colleagues (2014) identified the factors that limit the effectiveness of EPR systems, including: commodity dynamics related to the volatile prices of materials, parts and used goods that affect the value recovered from waste; volume dynamics due to the uncertainty in waste collection; competition dynamics related to the variations in the level of competition in EPR markets; regulatory dynamics caused by unexpected changes in future legislation; and design dynamics resulted from potential product design changes (Kunz et al., 2014). In EPR system, these dynamics inevitably involved the government intervention for coordination (OECD, 2016).

This research presents our observation of an unexpected byproduct of EPR in China—the fostering of new business models for post-consumer recycling. Emerging in several countries in European Union (EU), EPR has been widely adopted in many countries including China. However, the local institutional settings for implementation in China differ from the original places where EPR developed. In the EU, a key factor in driving the adoption of EPR is that it shifts part of the cost of municipal waste management from local public expenditure to consumers and producers (Cahill et al., 2010). In developing countries such as China, however, post-consumer recycling is still thriving with an active informal recycling sector (Tong and Tao, 2016).

The introduction of an EPR approach in China's WEEE regulation disrupted the recycling market and produced unexpected outcomes. Since 2012, China's regulation has mandated that the producers of certain categories of electronic products contribute to government recycling funds based on their production volume (MOF, 2012). The funds are used to provide subsidies to certified e-waste recyclers by the government. Although this system has been criticized as providing little incentive for design change or take back actions by the producers (Tong and Yan, 2013), the subsidies have created market niches attracting investment and entrepreneurship devoting to recycling. Innovation in internet-based solutions for post-consumer recycling has exploded in last several years, most of which either benefited from the recycling funds or aims to do so. The aim of this paper is to describe and evaluate the effectiveness of these innovative business models and explore the possibility of sustaining the models through adjustment of the institutional settings.

In the next section, we present our research methods and data sources. In Section 3, we present an evaluation framework to assess the effectiveness of each model in capturing and sharing values of recycling among different stakeholders. In Section 4, we conclude the paper with implications for EPR as a financial mechanism to make new business models sustainable.

2. Research methods

We take an action research approach in data generation (Greenwood and Levin, 1998; Flood, 2010; Reason and Bradbury-Huang, 2013). The information comes from our participant observation during an ongoing project to build EPR systems for e-waste management in China since 2005. During this process, we witnessed the change of the structure of the e-waste recycling sector in China, and extensively participated in policy dialogues between the industry and related government agencies (Tong and Yan, 2013).

These dialogues led to the launch of the experimental demonstrations of new business models in EPR for e-waste recycling in China in 2016 (MIIT et al., 2016).

Several business models emerged during our observation including community-based recycling programs, automatic reverse vending machine chains, and pure Internet platforms. All these business models share a common characteristic: they use Internet technology as a vehicle for innovation and entrepreneurship, an approach which is aggressively promoted in China as “Internet +” by both government policies and venture capital investors. However, the models are quite different in their strategy with respect to the linkage between online and offline activities. This difference has significant impacts on their performance and replicability. In order to assess the performance of these business models, we conducted action research with constant reflections and adjustment from 2013 to 2016. The observations can be divided into three parts:

First, we conducted experiments to test the feasibility of internet-based solution in two residential communities in Beijing from 2013 to 2016. Our partners included E-waste Comprehensive Utilization Work Committee, a nongovernmental organization (NGO) focusing on e-waste recycling with support from the Ministry of Industry and Information Technology (MIIT) (www.e-waste.org.cn), the China Home Electronic Appliance Research Institute (CHEARI) which has supported national WEEE policy making in China since 2002 (www.cheari.org), and Huaxin Environmental (www.hxepd.com), one of the three certified e-waste recycling companies in Beijing. All these organizations are based in Beijing and deeply involved in the development of the EPR system for WEEE in China.

We chose to use the Internet solution provided by Green Earth in Chengdu, one of the pioneers in developing IT solutions for community-based recycling programs in China. They have operated their system in many communities in Chengdu since 2011. They provide specific bar codes to the participant households for identification of recyclable goods. When a household sends back the recyclable goods with its bar code attached, the community collector scans the bar code and inputs the information into the system through an application on a mobile phone. Then, a coupon based on the value of recyclable goods is deposited in a green account of the household. The household can use the coupon to buy new products. By using this system in our recycling program in Beijing, we have been able to see the true responses towards new business model by various stakeholders along the recycling chain.

Second, from 2013 to 2016, we organized a series of conferences on WEEE & EPR annually in Beijing and Shanghai, inviting the major electronics producers, the certified e-waste recyclers, and the related government/nongovernment organizations throughout the country to discuss the progress of EPR in WEEE management in China. Each conference had more than 100 attendees. In these conferences, we had sessions on reverse logistics and community-based tools for WEEE recycling. We shared the results of our experiment and compared different models employed in various cities. The presentations and discussions were recorded as documentation of the conference.

Third, from 2015 to 2016, we were involved in the experimental demonstrations of new business models in EPR for WEEE recycling in China jointly launched by Ministry of Industry and Information Technology (MIIT) and other 3 ministries (MIIT et al., 2016). The producers applied to participate in this program as volunteers by submitting a proposal on their plan to conduct a demonstration project. MIIT established a committee to evaluate the proposals, and finalized the list of participating producers as shown in the announcement (MIIT et al., 2016). After a series of meetings with producers and recyclers to identify new business models with

potential for upscaling, we conducted a field investigation on four models in Wuhan, Anhui, and Shenzhen in the summer of 2016.

With the grounded experiences in social experiments, field investigations, and dialogues with industry (summarized in Table 1), we built a framework to evaluate the performance and effectiveness of the various business models and analyze the governance structure supporting them.

3. Performance of business models

3.1. New business models facilitated by information technology

We identified three major business models emerging in different cities in China: community-based recycling programs, automatic reverse vending machine chains, and pure Internet platforms. All these business models use Internet technology to track the flows of recyclables from the generation sources and provide incentives to users accordingly with various strategy in the relationship between online and offline activities.

3.1.1. Community-based recycling program

This business model targets the garbage sorting behavior of consumers in residential communities. Examples include Ala in Shanghai (www.alahb.com), Xiangjiaopi in Beijing, Huishouge in Wuhan and Green Earth in Chengdu. Ala in Shanghai, the pioneer of this model, is a subsidiary company of Xinjinqiao, a state-owned certified e-waste recycler in Shanghai. Initially, Ala was established in order to find an efficient way to collect used household electronics from the residents in order to directly supply the recycling plant of Xinjinqiao. However, the company soon expanded its collections to include many types of recyclable goods in the communities. This model was followed by certified e-waste recyclers in other regions, such as Huaxin in Beijing (Xiangjiaopi) and GEM in Wuhan (Huishouge). In contrast, Green Earth (www.lvseidiqu.com) was established with funds from the Vantone Foundation, a charity fund established by a real estate company devoted to sustainable community programs in China. Green Earth intended to promote general garbage sorting in residential communities. They are also interested in whether e-waste collection could be a revenue source in future.

3.1.2. Automatic reverse vending machine chains

In this business model, a reverse logistic system with automatic vending machines is attached to traditional commercial chains.

Examples include Aihuishou (www.aihuishou.com) in Shanghai and INCOM in Beijing. Aihuishou was established in 2011 with only an online trading platform for used information and communication technology (ICT) products. With three rounds of investment from venture capital since 2012, Aihuishou quickly developed a network of fashionable reverse vending machines in shopping malls and subway stations in big cities in China to collect used mobile phones (Fig. 1). With support from the municipal government in Beijing, INCOM (incom.cc) initially copied a model from overseas to collect used drinking bottles with automatic reverse vending machines. Recently, they modified their machines to take back more items, such as used clothes, mobile phones and batteries.

3.1.3. Pure internet platform

This business model focuses on providing ICT solutions to bridge the transactions between the consumers and recyclers. Examples include Huishoubao (www.huishoubao.com) and Taolv365 (www.taolv365.com), both located in Shenzhen. Huishoubao cooperates with mobile phone producers to combine takeback of used products with sales of new ones. Taolv365 provides a trading platform for used mobile phones whose customers are mainly informal recyclers. Some large portal websites, such as Baidu, also provide their own takeback platform for trading of used products, but these systems are not so influential in the industry.

3.2. The elements of new business model

Extended producer responsibility is a market-based, life-cycle-oriented policy strategy to address the product-related environmental impacts. However, the static recycling targets at the end of life stage generally lead to inefficient market outcomes and weak incentives for prevention and green product design (Dubois, 2012). How to create and capture the value of waste reduction and recycling and share it among all the involved actors is a critical challenge in the design of EPR schemes (Massarutto, 2014). The national Home Appliances Replacement Scheme (HARS) (家电以旧换新计划) from 2009 to 2011 in China created an attractive market niche for the “old-for-new” model of producers to take back old products when selling new ones. In order to be qualified to receive the subsidy, the old products collected through this program had to be sent to the certified recyclers. After the termination of HARS, the government funds obtained from fees paid by producers according to EPR regulations were established as the long term solution for WEEE recycling in China, which continue to support the market

Table 1
Fieldwork investigations.

Research Periods	Individuals or Organizations contacted and studied	Details
Pre-experiment investigation (2005–2013)	Interviews with various actors related to e-waste recycling in Beijing, including Informal e-waste recyclers, government agencies, association of resources recycling, NGOs, certified recycling companies, and recycling markets	64 interviews with recording and transcripts.
Social experiment (2013–2016)	Community-based recycling program in Hongfuyuan and Wanguocheng, two residential communities in Beijing	Action research conducted in cooperation with external institutes and local authorities. In Hongfuyuan, more than 500 households participated in the program In Wanguocheng, 108 households participated in the program. All data were automatically recorded by the Internet-based system provided by Chengdu Green Earth. Telephone interviews were conducted with participant households in Hongfuyuan every half year, inquiring about their attitudes towards the experiment.
Investigation for up scaling (2016)	Electronics producers Internet solution providers Certified recycling companies with community-based collection program	Personal contacts with personnel in charge of the experimental demonstration affairs in each company Personal contacts with entrepreneurs Personal contacts with personnel in charge of the community recycling program



Fig. 1. The automatic reverse vending machine of Aihuishou in a shopping mall. Note: The consumers select several descriptions about their used products, then the machine offers a price accordingly. If the user accepts the price and submits his product, he can get a coupon for discount when buying new product.

niche for new business model (Tong and Yan, 2013).

However, not all of the involved actors have been satisfied with the allocation along the recycling chain of the funds raised through the producer fees. On the one hand, the newly built recycling plants complain that the competition among certified recyclers in purchasing recyclable goods from the informal recyclers has squeezed their profits (Gu et al., 2016). On the other hand, the formal channels established by the certified plants have difficulty competing with the informal collectors in efficiency and flexibility. The producers have little interest in being involved in the take-back activities after paying the recycling fees to the government funds. Knowledge gaps and value conflicts exist between various actors in forming an efficient collaboration.

Fig. 2 shows a flow chart of information and material exchange among key actors under the EPR system. In order to create a closed-loop supply chain, an IT solution is used to provide a platform for information sharing along various actors. The information sharing has multiple effects: (1) It helps the consumers and the public authority to differentiate among recyclers according to their environmental protection standards. Currently, the newly-built formal recycling plants are equipped with the best available technologies and monitored according to very strict environmental protection standards. However, it is important to convey the information to the consumers for their decisions in waste disposal. (2) Theoretically, it can help producers to follow the status of their end-of-life products, and inspire eco-design for new product according to the 3R principle (reduce, reuse and recycling). In 2017, the policy makers in China were discussing the possibility to remit a portion of the recycling fees if the producers can prove that they have taken responsibility for collecting used products on the market in the upcoming recasting of China WEEE regulation. Thus, the tracking information in reverse logistics could be valuable for producers. (3) It can help the recycler to easily obtain information on the generation of recyclable goods and improve the value of collected goods on a wider and more transparent recycling market.

Various IT solutions have been developed respectively by different companies since 2011. And the focus of each system evolved towards different models as addressed in section 3.1. During the implementation, several elements were identified through the research presented here as key for success according to the value to various involved actors along the recycling chain.

3.2.1. Convenience for consumers

It has been argued that the take-back scheme should be convenient for consumers to return their products (Wang et al., 2011). Generally, there are two ways for consumers to dispose of their old products. Before HARS, most of the consumers would sell their old products to the urban informal junk buyers who collected all categories of recyclable goods routinely in residential communities. But after HARS, more people prefer the “old for new” model. In this model the retail stores organize the collection of discarded products and consumers received discounts in purchasing new products. (In fact, they generally outsource the collection business to the informal junk buyers specializing in e-waste collection). The IT solution must employ one of the two channels as the main function. But none of the solutions can be integrated with both, for the on-line and off-line strategies are totally different. The biggest challenge to the community-based model is to build an image that

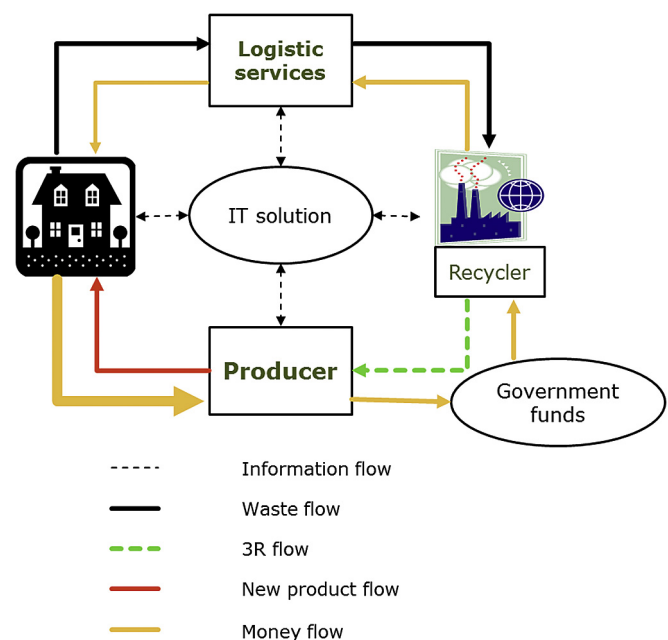


Fig. 2. IT solution as the center of the new business model.

can distinguish themselves from the informal junk-buyers. Thus, they need continuing presence in the community with routinized offline activities such as on-site promotion and door-to-door collection. The challenge to the old-for-new channels is finding a way to get the discounts for new product sales from the producers, either in traditional retail chains or on-line marketplaces.

3.2.2. Traceability for producers

Producers need to be able to trace the flow of used products if they are to be able to benefit from EPR. As the response to the legal requirement for extended producer responsibility, producers increasingly accept that it is necessary to include reverse logistics in an integrated approach of closed-loop supply chain for their products (Govindan and Soleimani, 2017). The potential business value of returned products has been well-recognized (Guide Jr and Van Wassenhove, 2009). The HARS established a standard process of “old for new” promotion for the electronics products in China. This process enables producers to trace the old products they take back when selling new ones to verify the consumers eligible for discounts. When the returned products have high values on the second hand market, the producers have great incentives to cooperate with the recyclers to explore this market niche. If the new product market and the second hand one are not separated clearly, however, the producers’ new product sales may be reduced. Thus, for example, Aihuishou provides the mobile phone producers a total solution of “old-for-new” promotion with traceability of all products being taken back so as to receive authorization from the producers to sell the secondhand products they collected from the end users.

3.2.3. Profitability for recyclers

The recyclers see the potential to increase their profits through the new business models. In China, the government is trying to formalize the informal recycling sector. The formal sector receives subsidies from the government funds, while the informal recyclers can only rely on the market sales of the secondary materials recovered. The justification for such discrimination comes from the potential of the formal sector regarding their performance through the increase in the stringency of environmental and social standards applied to recyclers. Thus, the recyclers have to accept very strict monitoring from local environmental agencies, which also increases the operational cost and decreases flexibility in recycling process (Zeng et al., 2017). In order to enjoy the subsidy or authorization to conduct business, many formal recyclers are trying to build their own collection system. They expect that an information technology solution can provide an auditable record of their collection and recycling activities to differentiate themselves from the informal sector and thus justify the subsidy from the public funds for waste reduction and recycling with environmental sound technologies.

3.2.4. Hybridity for collection

The existence of an extensive informal sector has been identified as one of the key challenges to develop a financially and environmentally sound recycling and disposal system for e-waste management in China (Chi et al., 2011; Gu et al., 2016). Although the formal recyclers would like to exclude the informal collectors so as to control the collection channels, most of the formal recyclers found that it is much cheaper to rely on the supply from the informal collectors than to build their own collection channels. The hybridity—the mix of formal and informal enterprises—leaves space for various business models to fit in different channels, especially those for the second hand markets for reuse and refurbishment (Liu et al., 2016). However, in any business model we observed, it is a challenge to balance the allocation of the value

from collected goods between the formal and informal sectors. Some business models choose to exclude the informal sector and try to build a totally new image for the formal sector, while others are tempted to include the informal sector into the collection network. However, the rigid standards of the subsidy from the government funds generally reduce the profitability of recycling activities in the informal sector, which relies on flexible approaches to both waste conversions from material recovery and refurbishment/reuse according to the condition of products and market demands.

3.2.5. Transparency for public

The expenditure of public funds on recycling requires transparency and reliability of information provided to the public (Kissling et al., 2013). The government needs to make sure that the certified recycling plants that receive subsidies recycle the e-waste in a proper way. The monitoring and traceability of the subsidy system was designed for the formal recycling system. However, wherever the formal system has to interact with the informal system, there are conflicts on the definition of the proper way to recycle. The complexity of transaction and material flows makes it inevitable that the formal system will have many open loops competing with or complemented by the informal sector. The open access to information is critical to public oversight of recycling activities.

3.3. Evaluation of the business models

According to the five elements described above, we evaluated the performance of various business model for post-consumer recycling in China. It is a qualitative evaluation based on our interviews and field observation and summarized in Table 2.

All business models improve the traceability and reliability due to the tracking function of the waste flows. The exception is Taolv which provides a transaction platform for the informal recyclers and thus cannot trace to the generation source of the collected product.

Conflicts exist between the convenience to consumers and the profitability for recycling for both formal and informal sectors. The provision of off-line services, such as on-call service to pick up the waste products at home and recycling stations close to the users, is positive for the convenience to consumers in the community-based cycling program, but detracts from the profitability of recyclers. Especially for the formal recycling plants, economies of scale are significant for efficiency in operation. However, the automatic reverse vending machine chains could achieve both convenience to the consumers and the profitability for recyclers, but are only feasible for standardized products, such as drink containers or mobile phones.

Different strategies exist among these business models as to whether the informal sector is included in their collection system. We have addressed the dilemma in dealing with the informal recycling in developing countries in section 3.2.4. The inclusion of the informal sector can raise the efficiency and flexibility of collection, but increase the complexity in monitoring the material flows and transactions.

In general, the evaluation highlights the tension between different elements in the business models in balancing the efficiency of recycling with the social/environmental objects pursued at the system level. The compromises reflect the governance challenge between the EPR schemes and municipal waste management systems noted in the research literature (Hickle, 2014).

4. The impacts of governance structure on business models

EPR presumes a simple producer-driven commodity chain in the lifecycle of a complex product. However, complex interactions among all stakeholders along product chains have challenged such a static view (Hafkesbrink, 2007). In practice, EPR provides an approach to waste issues that leads to a shift of authority from a local public service to activities entailing cross scale governance structures. Such a structure can match the scope of production networks of complex products making emergence of new governance structure possible (Hickle, 2014). The differences in online/offline strategies in the various business models reflect the variety of governance structures among the key stakeholders in post-consumer recycling in China. This, in turn, reflects the key conflicts between the logic of efficient closed-loop supply chains anticipated by the EPR scheme and the traditional municipal waste management system operated by local public authorities (Hickle, 2014). In this section, we discuss the impact of governance structure on the emerging business models along two dimensions: (1) how the business models vertically integrate the production and consumption chain, including the upstream producers and downstream recyclers (either formal or informal); and (2) how the business models horizontally coordinate with the broader urban waste management system, such as garbage sorting in communities and reverse logistic systems that divert the recyclables from the municipal waste stream.

4.1. Vertical integrations with the product chains

To benefit from the government funds for WEEE recycling, companies using the new business models seek to forge a niche by bridging production and consumption/recycling which were generally separate before the introduction of EPR. As mentioned above, the consumer, producer, and recycler have various roles and objectives in participating in recycling activities. The governmental recycling fund created a value for recycling by collecting a small fee on each new product from producers and injecting the value back into the commodity chains by providing subsidy to the certified recycling plants. Several proposals have been widely discussed among policy makers and the industry to extend the role of producers by including them in take-back and recycling programs, so as to materialize the incentive for eco-design from the beginning of new product development as the EPR scheme had expected. However, the complexity and conflicts in definition of eco-design prevent a universally accepted evaluation framework that can be used as a basis for differential fee system according to the quality of the producer's eco-design.

The practical motivation for producers to be involved in the

takeback activities comes from sales of new products in an increasingly saturated market. Thus, the largest opportunity for value capture in the new business model comes from the discounts by producers in “old for new” sales promotion because it increases sales of new products to participating households. As more and more producers have included these “old for new” discounts as a necessary part of their new product marketing cost, the fee for the government recycling funds has become trivial in the total marketing cost. For example, one of the refrigerator producers we interviewed provided a discount of about 10% for consumers in old-for-new transactions which amounted to Chinese currency RMB 150–300 (USD 22–44) for each unit, much higher than the recycling fund rate at RMB 12 (USD 1.76).

Compared to large consumer electronics which have thin margins for refurbishment or recycling, used mobile phone recycling has attracted the most attention. Even though mobile phones had not been included in the catalogue of China WEEE regulation until 2015, business in the collection of used mobile phones has been booming in recent years due to both the expectation of the expansion of the catalogue and the obvious profitability in selling the second hand mobile phones. Three companies investigated in our field study, Huishoubao, Aihuishou and Taolv365 exhibit the different strategies being adopted.

4.1.1. Huishoubao

Based in Shenzhen, the largest mobile phone manufacturing region in the world, Huishoubao designed its business model to closely fit the “old for new” promotions of producers, and has been actively involved in their partners' marketing promotions both online and offline. And Huishoubao chose to sell the used mobile phones collected from the consumers into secondhand markets by themselves, and send the rest of collected phones that were not of sufficient quality for reuse to the certified recycling plants. This model was welcomed by the major producers, because it provides very good traceability of the flows of used products. Counterfeit products have been embarrassing the brand producers in Shenzhen for years. Huishoubao promised not to refurbish the products they collected or remove any components, so as to prevent the outflow of components into the market for counterfeit production. This model provides a possible closed loop within the formal sector, from production, to consumption, then back to Huishoubao for reuse, and finally into the certified recycling plants for material recovery. It is a complement to “fast fashion” consumption in consumer electronics, which encourages consumers to easily move to the next generation product.

Table 2
Evaluation of performance of various business models for post-consumer recycling in China.

Business	Business Model Element				
	Convenience to consumers	Traceability for producers	Profitability for recyclers	Transparency for the public	Hybridity in collection
(1) Community-based recycling program					
Ala	+	+	–	+	–
Huishouge	+	+	–	+	+
Xiangjiaopi	–	+	–	+	–
Green Earth	+	+	+	+	–
(2) Automatic reverse vending machine chains					
Aihuishou	+	+	+	–	–
INCOM	+	+	+	+	+
(3) Pure Internet platform					
Huishoubao	–	+	+	+	–
Taolv	–	–	+	–	+

Note: “+” indicates good performance, and “–” indicates poor performance.

4.1.2. Aihuishou

In contrast, Aihuishou, as a strategic partner with Xinjinqiao in Shanghai, focused its business on a transaction platform between the consumer and recyclers. It also provides the consumers with coupons for discounts in buying new products. The discounts, however, come from payments arising from a bidding process among recyclers based on the value on the secondhand market. This model is open to the informal recyclers, and cannot be used to trace the material flows after sale to the recyclers. With the support from venture capital, Aihuishou has invested in building extensive chains of automatic reverse vending machines in traditional retail centers in big cities, so as to compete with Huishoubao in attracting higher income consumers to bring back the most valuable used products.

4.1.3. Taolv365

Taolv365 is another transaction platform for sale of used mobile phones, established in 2009. As a pure internet platform, Taolv365 provides information on supply of and demand for different modules of used products. The users of Taolv365 are mainly informal recyclers. Recyclers from Shenzhen collect the discarded mobile phones through varied channels. They mail the goods in bulk to Taolv 365 in Shenzhen. Workers in Taolv365 check the products one by one, then classify them according to the components and quality required by the buyers. The buyers are also informal recyclers doing refurbishment or disassembly. There is a vast network of informal recycling around Shenzhen highly specialized in the division of labor along the recycling chains. The functional components taken apart from the used products are classified and sold on the informal market for repair, refurbishment, or other usage such as toy production. Taolv365 provides a bidding platform for sellers and buyers. The price index generated from the transactions on Taolv365 has been used in other IT solutions for pricing used products.

Since mobile phones became eligible for government recycling funds in 2015, significant change in business environment has been widely expected within the industry. Generally, the new business environment will probably favor the model of Huishoubao and Aihuishou, leaving decreasing margins for the informal refurbishment and disassembly activities prevalent in Shenzhen, which threatens the profitability of Taolv365.

4.2. Horizontal relations with the urban waste management system

The new business models for used mobile phone recycling represent possible solutions for post-consumer recycling of the “fast fashion” consumption products in which the cost of “old for new” is included in producer's new product promotion. The comparatively high value for second hand mobile phones and easy transportation of the products make this business model economically feasible. However, the business model is quite different from taking back the large used consumer electronic products, such as televisions, washing machines, refrigerators, air conditioners, and personal computers, which have been included the catalogue of China WEEE regulations for years. Although “old for new” has been a prevalent strategy for new product promotion of these products, it is the retail chains selling electronic products that dominate the sales process. They generally outsource the take-back business to the informal recyclers. Since the end of the HARS, the certified recycling companies largely rely on informal channels to collect the waste products. The subsidy either from the HARS or from government recycling funds sets a floor price for the waste products. If the informal recyclers can find better price than that given by the certified recyclers, the used products will not flow into the certified recycling plant, which creates environmental risk

related to inappropriate recycling.

In order to improve the traceability of the take-back flows as well as increase the profitability of the certified recycling plants, some certified recyclers have been tempted to establish their collection system directly from the waste generation sources – the households in residential community. In contrast to the vertical specialization focusing on specific waste products such as mobile phones, this community-based model is horizontally integrated to encompass all sorts of recyclable goods, and closely interacts with the urban waste management system.

By establishing partnerships with local government, these companies actively engage in promotion of garbage sorting in communities. The growth of municipal solid waste has become a pressing environmental challenge in many cities in China with increasing burden on local public expenditure and NIMBY-ism related to the construction of waste disposal facilities (Zhang et al., 2010). Since 2000, various programs to promote garbage sorting and an urban circular economy have been initiated in different cities, either as national demonstration projects, or as bottom-up grassroots experimental actions (Wang et al., 2008). However, most of these efforts have been difficult to maintain. On the other hand, the informal recycling sector has been booming, and resulted in the prevalence of waste villages around many big cities (Tong and Tao, 2016). The government expected that the new business model could help the transform urban waste management systems.

With support from both the certified recycling plant and municipal government in Shanghai, Ala created a business model using IT technology to trace the garbage sorting behavior of households and provide incentives accordingly. They designed various activities on-site in the communities and broadcasts on public media to spread knowledge about recycling to the public. Economic incentives were used as complement to the education. With continuous efforts lasting for several years, Ala has become widely known among Shanghai residents. However, their contribution of collections to the certified recycling plant was still very low, less than 10% of the recycling capacity of Xinjinqiao. The conflicts between the pursuit of economies of scale by the certified recycling company and the expectation on an all-inclusive solution to community recycling by the local government, prevented the certified recycling company from continued use of this business model.

A similar business model was adopted by other companies, such as Green Earth in Chengdu which is focusing on community recycling promotion, and Sound, the leading company in solid waste treatment in China. They are trying to integrate resource recycling and solid waste disposal into an all-inclusive solution for the local government with reduced burden on public expenditure and enhanced environmental performance.

The existence of the informal recycling sector, however, complicates the situation. All the three companies mentioned above have excluded informal recyclers from their collection system. They compete with the informal sector directly in the community by distinguishing themselves from the traditional urban junk-buyers. One exception is Huishouge in Wuhan. With door-to-door collection service in the community, Huishouge tried to open their IT platform to the urban junk buyers. They signed contracts with the junk buyers and provided information about the demands for collection of recyclable goods by household, then a nearby junk buyer would go to collect the goods door to door. With the support from GEM, another leading solid waste treatment company headquartered in Shenzhen with many certified e-waste recycling plants in different cities, Huishouge operated for more than one year. However, just as with Ala, it contributed limited amounts of recyclable goods to the certified recycling plants of GEM.

In our own experimental program in Beijing, we find that the inclusion of informal recyclers into the collection system challenged the local governance structure in waste management. Traditionally, the urban-rural segregation resulted in the division between the capital-intensive waste disposal system (the formal sector) and labor-intensive resources recovery (the informal sector). In order to include the informal recyclers in the community recycling program, the urban-rural segregation has to be ended. What is more, the junk buyers have quite a different role from the companies with new business model. Every junk buyer in the city is an individual entrepreneur, making every effort to improve the value of his goods. For example, one junk buyer we interviewed would be willing to bike for 3 h for the extra 10% for each kilogram of his goods. The most important value to them is the market price of the recyclable goods they collect. However, to the companies using new business models, their value arises from their image to the consumers. They devote considerable effort to creatively attract the consumers' attention and to maintain the consumers' participation in their programs. With the financial support either from the subsidy via recycling funds, or from the local public funds for waste reduction projects, the value of the recovery materials only contributes a fraction of their revenue.

From the perspective of the public interest, waste reduction and resource conservation has increasing value. The IT solution used in the new business models make it feasible to track the volume and quality of the sorting process as a reliable measurement of waste reduction and resource recovery. However, the business models require the governance structure to be flexible enough to bridge the formal and informal sector, so the value captured from the waste reduction and recycling can be shared among the stakeholders.

5. Conclusion

The EPR studies have revealed the governance challenge in urban waste management to capture the value from waste reduction and recycling, and sharing it among all stakeholders in a complex and dynamic product system. Most of the research in this field has addressed the induced change in product design or business model at firm level, but few studies have examined the systematic change that the new business models could trigger in the recycling sector, especially in developing countries.

The change of institutional settings based on EPR principle in China provides an excellent empirical case to study how new business models can emerge as response to the government interventions. The introduction of EPR for WEEE in China created an innovation niches for new business models in recycling sector and has triggered extensive change in the business relations in waste/recycling sector. It took an unexpected form in practice: not the producer doing the take-back themselves, but creating opportunities for the use of various new business models to build links between the recycling and production/consumption regimes.

The most important technological change enabling the new business models is the use of ICT technology to bridge the knowledge gap among stakeholders including producers, recyclers, consumers, and the governments. This contributed to the improvement of the transparency of EPR systems in the complex and fragmented product chains, and allowed effective response to the market dynamics. Currently, most of the new business models heavily rely on the subsidy from the government. However, the using of ICT technology in new business models shows the possibility of incorporating the informal sector in developing countries into the organized provision of recycling, which has been highlighted in literature on WEEE in recent years.

Furthermore, this research reveals the diverse ways that the new business models connect the EPR system to the production

network and the urban waste management system. On the one hand, the “old for new” business model, targeting secondhand products with high value and taking full advantage of on-line transactions, is favored by venture capital investors. This is complementary to the “fast fashion” consumption of current consumer electronics industry. On the other hand, the community-based recycling program is closer to the local government's expectation of an “all-inclusive” solution to the waste management from bottom up. However, gaps exist between the economy of scale pursued by the certified recycling plants and the variety of waste reduction strategies in local community. This is one of the key problems in EPR strategies – balancing the innovation-oriented policy for industry and the efficiency oriented operation in waste management.

The case studies on various business models in China demonstrate the diversity of market niches and the responses in strategies of the entrepreneurs. The differences arise from the conflicts and compromises in the values of different stakeholders reflected in the five elements we identified in the field investigation. In the evaluation of the performance of the major business models for post-consumer recycling emerging in China cities, we find that each business model has its own approach to the balance between the efficiency of recycling and the broader social/environmental targets that the EPR scheme is intended to achieve. Therefore, there is not just one business model, but a variety of models to fit different institutional settings either within the vertical production chains at the macro level, or across the horizontal relations with the waste management at the local level. This suggests that EPR could open a gate to new business opportunities, beyond closing the loop of material flows within the product chains.

Acknowledgement

This research was supported by grants from the China National Natural Science Foundation (‘Technological Transition through Extended Producer Responsibility in Electronics Industry’ [41271548]). We thank China Household Electronic Appliances Research Institute for all the cooperation in the research and all of the interviewees for sharing their ideas with us during our field studies.

References

- Boons, F., Wagner, M., 2009. Assessing the relationship between economic and ecological performance: distinguishing system levels and the role of innovation. *Ecol. Econ.* 68 (7), 1908–1914.
- Cahill, R., Grimes, S., Wilson, D., 2010. Extended producer responsibility for packaging wastes and WEEE – a comparison of implementation and the role of local authorities across Europe. *Waste Manag. Res.* 29 (5), 455–479.
- Chi, X., Streicher-Porte, M., Wang, M.Y.L., Reuter, M.A., 2011. Informal electronic waste recycling: a sector review with special focus on China. *Waste Manag.* 31 (4), 731–742.
- Dubois, M., 2012. Extended producer responsibility for consumer waste: the gap between economic theory and implementation. *Waste Manag. Res.* 30 (9 Suppl. 1), 36–42.
- Flood, R.L., 2010. The relationship of ‘systems thinking’ to action research. *Syst. Pract. Action Res.* 23 (4), 269–284.
- Govindan, K., Soleimani, H., 2017. A review of reverse logistics and closed-loop supply chains: a Journal of Cleaner Production focus. *J. Clean. Prod.* 142 (Part 1), 371–384.
- Greenwood, D., Levin, M., 1998. *Introduction to Action Research*. Sage, Thousand Oaks, California.
- Gu, Y., Wu, Y., Xu, M., Wang, H., Zuo, T., 2016. The stability and profitability of the informal WEEE collector in developing countries: a case study of China. *Resour. Conserv. Recycl.* 107, 18–26.
- Guide Jr., V.D.R., Van Wassenhove, L.N., 2009. The evolution of closed-loop supply chain research. *Oper. Res.* 57 (1), 10–18.
- Hafkesbrink, J., 2007. Transition management in the electronics industry innovation system: systems innovation towards sustainability needs a new governance portfolio. In: Lehmann-Waffenschmidt, M. (Ed.), *Innovations Towards Sustainability: Conditions and Consequences*. Physica, Heidelberg, pp. 55–86.
- Hickie, G.T., 2014. An examination of governance within extended producer responsibility policy regimes in North America. *Resour. Conserv. Recycl.* 92,

- 55–65.
- Kissling, R., Coughlan, D., Fitzpatrick, C., Boeni, H., Luepschen, C., Andrew, S., Dickenson, J., 2013. Success factors and barriers in re-use of electrical and electronic equipment. *Resour. Conserv. Recycl.* 80, 21–31.
- Kunz, N., Atasu, A., Mayers, K., Wassenhove, L.V., 2014. Extended Producer Responsibility: Stakeholder Concerns and Future Developments. INSEAD Social Innovation Centre. www.erp-recycling.org/wp-content/uploads/sites/13/2014/02/ERP_140211_INSEAD_White_Paper_FINAL.pdf. Fontainebleau. (Accessed on 21 August 2017).
- Lauridsen, E.H., Jørgensen, H., 2010. Sustainable transition of electronic products through waste policy. *Res. Policy* 39 (4), 486–494.
- Lindhqvist, T., 2000. Extended Producer Responsibility in Cleaner Production. IIIIEE Dissertations: 2. IIIIEE, Lund University, Lund.
- Liu, H., Lei, M., Deng, H., Keong Leong, G., Huang, T., 2016. A dual channel, quality-based price competition model for the WEEE recycling market with government subsidy. *Omega* 59 (Part B), 290–302.
- Massarutto, A., 2014. The long and winding road to resource efficiency – an interdisciplinary perspective on extended producer responsibility. *Resour. Conserv. Recycl.* 85, 11–21.
- Ministry of Industry and Information Technology, Ministry of Finance, Ministry of Commerce, Ministry of Science and Technology, 2016. The Announcement of the First Batch of Experimental Demonstrations in EPR for WEEE. www.s.gov.cn/n1146285/n1146352/n3054355/n3057542/n3057544/c5153020/content.html. Accessed (21 August 2017) (In Chinese).
- Ministry of Finance, 2012. No. 34: Measures for the Collection and Administration of the Funds for the Recovery and Disposal of Waste Electronic and Electrical Products. www.gov.cn/gzdt/2012-05/30/content_2149195.htm. last access (17 September 2016) (in Chinese).
- OECD, 2016. Extended Producer Responsibility: Updated Guidance for Efficient Waste Management. OECD Publishing, Paris.
- Osterwalder, A., Pigneur, Y., 2010. Business Model Generation: a Handbook for Visionaries, Game Changers, and Challengers. John Wiley and Sons, New Jersey.
- Porter, M., Kramer, M., 2011. Creating shared value. *Harv. Bus. Rev.* 89 (1/2), 62–77.
- Reason, P., Bradbury-Huang, H., 2013. The SAGE Handbook of Action Research: Participative Inquiry and Practice, second ed. SAGE Publications, London.
- Rossem, C.v., Tojo, N., Lindhqvist, T., 2006. Extended Producer Responsibility: an Examination of Its Impact on Innovation and Greening Products Greenpeace International. Friends of the Earth and the European Environmental Bureau (EEB). www.greenpeace.org/international/PageFiles/24472/epr.pdf. Accessed (21 August 2017).
- Schaltegger, S., Hansen, E.G., Lüdeke-Freund, F., 2016. Business models for sustainability: origins, present research, and future avenues. *Organ. Environ.* 29 (1), 3–10.
- Stubbs, W., Cocklin, C., 2008. Conceptualizing a “sustainability business model”. *Organ. Environ.* 21 (2), 103–127.
- Tong, X., Tao, D., 2016. The rise and fall of a “waste city” in the construction of an “urban circular economic system”: the changing landscape of waste in Beijing. *Resour. Conserv. Recycl.* 107, 10–17.
- Tong, X., Yan, L., 2013. From legal transplants to sustainable transition. *J. Ind. Ecol.* 17 (2), 199–212.
- Wang, J., Han, L., Li, S., 2008. The collection system for residential recyclables in communities in Haidian District, Beijing: a possible approach for China recycling. *Waste Manag.* 28 (9), 1672–1680.
- Wang, Z., Zhang, B., Yin, J., Zhang, X., 2011. Willingness and behavior towards e-waste recycling for residents in Beijing city, China. *J. Clean. Prod.* 19 (9–10), 977–984.
- Zeng, X., Duan, H., Wang, F., Li, J., 2017. Examining environmental management of e-waste: China's experience and lessons. *Renew. Sustain. Energy Rev.* 72, 1076–1082. <http://dx.doi.org/10.1016/j.rser.2016.1010.1015>.
- Zhang, D.Q., Tan, S.K., Gersberg, R.M., 2010. Municipal solid waste management in China: status, problems and challenges. *J. Environ. Manag.* 91 (8), 1623–1633.