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A dual channel, quality-based price competition model for the WEEE recycling market with government subsidy ☆

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ABSTRACT

It is quite common to find both formal and informal sectors for processing waste electrical and electronic equipment (WEEE) in many emerging countries. Typically, the formal channel consists of recyclers with official qualifications for disassembling WEEE while the informal channel is dominated by unregulated recyclers. We develop a quality-based price competition model for the WEEE recycling market in a dual channel environment comprising both formal and informal sectors. The equilibrium acquisition prices and effects of government subsidy in the two channels are examined under four competitive scenarios. While government subsidy can support the formal sector, our analysis shows that at a higher quality level of waste, the marginal effect of subsidy is not as promising. When the quality of waste is high but the government subsidy is not substantial, the informal sector always has a competitive advantage. To promote the healthy development of the recycling industry the government should adjust the subsidy appropriately to limit the quality of waste at a high level suitable only for refurbishing in the informal sector. Our study also shows that both the formal and informal channels prefer high quality products. However, the informal recycler always has a better acquisition price to capture a bigger market share of used products than the formal recycler at the quality level of refurbishing for both recyclers. In a quality-pricing environment, as quality increases the acquisition prices in the two channels may crossover. This indicates that neither of the two channels always have a clear price advantage at all quality levels. We will not be able to obtain this result in a uniform pricing model. As such product quality is an important factor to consider in a competitive recycling market.

1. Introduction

According to the European Commission Directive 2002/96/EC, WEEE (waste electrical and electronic equipment) means "electrical or electronic equipment, which is waste…including all components, subassemblies and consumables, which are part of the product at the time of discarding" [9]. With frequent updating and upgrading, the amount of WEEE has reached 4% growth [41] and about 40 million tons are generated each year [30]. For example, in UK around 4 million computers are discarded every year (UNEP 2010 year book [42]) and in Phnom Penh, Cambodia, the number of WEEE was forecasted to grow four times every ten years [22].

The issue of WEEE recycling continues to be a problem. The composition of WEEE differs greatly across product lines. Overall, e-products contain "ferrous and non-ferrous metals, plastics, glass, wood and plywood, printed circuit boards, concrete and ceramics, rubber and other items" [18]. Since valuable and scarce materials can be obtained, recycling WEEE can be very profitable. It is estimated that by 2014 global revenues from WEEE processing could be US$14.6 billion [49]. However, dealing with WEEE in an environmentally sound manner is quite complex and expensive, especially when handling hazardous materials. In reality, "environmental legislation continues to be poorly implemented by national governments in the European Union and often the legislation is not adequately enforced" [46]. In recent years,

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trans-boundary movement of WEEE, which refers to illegal exportation to developing countries, is quite common. Many crude recycling hotspots are reported in Asian countries, such as China, India, and Pakistan, and in some African countries, such as Ghana and Nigeria (Lundgren [18]). There are two reasons to explain this phenomenon. Firstly, it is cheaper to export to developing countries than to process WEEE in developed countries. For example, in Europe disposal of WEEE legally costs four times as much as the illegal exportation [27]. Secondly, these fast-growing economies also need large amounts of materials that could be reclaimed from recycling WEEE. Reports show that between 50% and 80% of WEEE collected is being exported from developed countries each year [18]. This aggravates the situation of WEEE recycling in developing countries.

In many developing countries there exists both informal and formal recycling sectors, with the informal one being more prevalent. Zhao et al. [52] note that Guiyu town in China may be the largest informal recycling site in the world with about 100,000 people engaged informally in recycling activities. Widmer et al. [47] report that in India, the "Cyber City" of Bangalore is threatened by a rapidly increasing amount of e-waste where the informal sector recyclers have caused serious harm to the health of the workers. According to Chi et al. [7] the informal unregulated recyclers often disassemble and dispose WEEE using crude and pollutive methods. If e-products collected are fit for reuse, collectors resell them to dealers in the secondary market. If unfit for reuse, WEEE goes to recyclers for disassembly to retrieve functional parts and valuable materials. Those recyclers, without disassembling qualification from the government, only use rudimentary processing techniques. Dangerous practices such as open burning and acid baths are common. In addition, the useless hazardous substances are directly thrown away. All of these actions greatly pollute the environment. Many governments have promulgated the recycling regulations and laws to forbid unlicensed recycling on WEEE. However, enforcement is very difficult due to the lack of detailed practical measures and standards, a gray zone the informal sector lies in, and consideration of local economic development and social welfare.

Compared with the informal sector, the formal sector is at a distinct disadvantage in disposing cost. The formal recyclers have disassembling qualification granted by the government and use approved techniques in handling WEEE appropriately. For the formal sector, the environmentally sound processing usually costs a lot more. For example, in 2005 Haier's spending on disposal measures accounts for one half of recycling costs and millions of dollars will be lost if Haier pays to compete with informal recyclers [8]. For the informal sector, environmentally sound processing is lacking and as such the disposal cost is cheaper. The non-government organization Basel Action Network (BAN) made an investigation of Guiyu town and found that local unlicensed processing is done manually and with little protection for workers or the environment. For example, the acid used by workers to retrieve gold from electronic chips is disposed off directly into the river [38]. A consequence of unprotected low-cost processing is a severe damage to the environment.

Because of high disposal cost, the formal recyclers find it difficult to provide a competitive acquisition price. In addition, the informal recyclers have strong operations flexibility and convenience. With a lack of public environmental awareness, most of the products flow to the informal sector. In general, the formal sector plays a minor role in the recycling industry. For example, in Brazil a formal recycling structure for treatment of WEEE is still in its infancy; with the WEEE recycling rate estimated by the Brazilian Electrical and Electronic Producers Association to be only 2% [3].

Although there is a cost disadvantage, the formal recycling sector still has other exclusive advantages. For one, as an industry that has an impact on public welfare, WEEE recycling cannot be done without support from the government. The government is committed to providing some incentives for the formal sector to increase recycling volume. To some degree, the subsidy will enable formal recyclers to offer a more competitive acquisition price and thus change the weak position they have been in. The question then becomes: what is the appropriate level of government incentive? The role of government subsidy is worth studying to provide managerial insights in regulating the recycling industry. For the other, due to disposing regulations, especially with respect to product security and quality assurance, remanufacturers are more willing to cooperate with the formal sector rather than informal sector. As such the formal sector has a distinct advantage over the informal recyclers by being able to sell recycled useful parts to remanufacturers.

WEEE quality is an important factor in the study of pricing structure in the recycling industry. Quality refers to the WEEE recyclable condition, which is usually measured by product integrity, usage age, and maintenance state. According to the difference in quality level of e-waste products, recyclers can utilize different disposal methods, which in turn can affect the profit margin. When collecting WEEE, the formal and informal sectors decide acquisition prices according to the WEEE quality level. In the existing literature, there are few studies focusing on price competition between the two sectors. However, an in-depth research on price competition is an invaluable foundation for setting government recycling policy on incentives. Only when the competitive dynamics of the recycling industry is clearly understood will the government be able to promote the development of the formal sector using a subsidy policy.

Overall, our motivation for studying quality-based price competition between formal and informal recycling channels which have different disposing methods, is to explore the impact of government incentives on the recycling industry. What is the effect of price competition? How does subsidy change the industry competitive environment? What level of subsidy is reasonable? Our research will attempt to answer these questions.

Earlier studies focus mainly on the recycling channel choice of a manufacturer, optimizing reverse logistics network and remanufacturing management in a single enterprise or a supply chain. However, the problem of uncoordinated competition between the two recycling channels is quite common in many developing countries and there is a lack of quantitative research on this. The objective of our study is to develop an analytical model that will provide insights to assist the government in developing regulating policy for the recycling industry. Here the policy studied is government subsidy, which is a financial incentive.

This paper is organized as follows. In the next section we provide a summary of the literature related to recycling and remanufacturing. This is followed by the development of the price competition model in two channels and four competitive scenarios. Then the results for the different scenarios are presented. Next, we carry out numerical simulations that describe the competition in a graphic way. Finally, we provide managerial insights and concluding remarks.

2. Literature review

Recently, there are an increasing number of research papers focusing on reverse logistics management. Fleischmann et al. [11] present a review of mathematical models for reverse logistics. Krumwiede and Sheu [14] provide a conceptual model of reverse logistics by introducing a third party in addition to OEMs (original