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Study the complexity and control of the recycling-supply chain of China's color TVs market based on the government subsidy

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ABSTRACT

In these days, as the recycling of household appliances becomes increasingly popular, the recycling network tends to be perfect in television industry. This paper focuses on the game among two recyclers and a processor in a Duopoly market of color TV recycling. We find that if the adjustment coefficients of the decision variables are changed abruptly, the system will fall into chaotic state. In order to avoid hazard of falling into a chaotic state, we adopt the method of delay control, providing the manufacturers with effective measures about chaos control. This paper analyzes the system's reactions to government decision, finding that when the parameters become beneficial for manufacturers, consumers and the environment, the system will fall into chaos and system's regional stability will reduce. Resulting from our analysis, this paper gives advice on the improvement of the environment and enhance in social welfare. Tested through the data we collected, this study is practical in both its theory and its applicability.

1. Introduction

Mankind has created not only a highly developed material civilization, but also a great drain on resources and energy, generates a lot of waste. These wastes are mainly waste electrical and electronic products. According to statistics, at the end of the 1990 s, Europe ECOWAS countries created 540 to 600 million tons household electrical and electronic waste every year, accounting for 4% of municipal solid waste. Swedish solid waste more than 20 tons waste household electrical appliances every year, an average of more than 20 kg. In the rapid economic development of China, home appliance was upgrading fast, which caused a large number of waste home appliances. Table 1 is about the appliance recycling in some cities and regions from August 2009 to May 2010. TCL AOBO, which was founded in June 2009, located in Tianjin Ziya circular economy industrial zone. TCL AOBO has 16 technology equipment and production lines, can handle 100,000 tons of waste household appliances and electronic appliances every year. In the process of recycling of waste home appliances, TCL AOBO recycled the waste home appliances mainly by its large home appliances retailer. The appliance recycling can not only save consumers a lot of money, but also make a significant contribution to environmental protection. Thus the government gives a lot of subsidies to the recycling vendors to support home appliances recycling behavior.

Waste product recycling has received much attention in these years. Some people have done some research in the area of appliance recycling. Read [1] studied door-to-door household waste recycling in Chelsea and other UK regions, and found

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Table 1
Recycling statistics of appliance "old for new service" in the first pilot cities (million units).

Cites	Washer	Fridge	Air condition	Computer	TV
Beijing	20.3	13	2.2	9.6	78
Tianjin	7.3	4.3	0.5	2.9	38.5
Shanghai	10.8	7.1	1.1	7.6	233.6
Guangdong	26.4	14.6	6.5	5.4	125.2
Changsha	24	1.4	2.5	0.3	0.2
Fuzhou	29.4	0.9	1.9	0.1	0.5

that this model could effectively improve people's awareness of recycling. Melissen [2] analyzed the Dutch consumer several waste recycling behavior and appliance recycling pilot program, and draw some suitable measures to improve the recovery of waste household appliances. In recovery mode selection, Nagel [3] advocated the use of reverse logistics to recycle IT products. They proposed that Take-back-scheme would be compulsory in not only Europe but also some Asian market. Nagel and Meyer [4] established an EOL network model to analyze an electronics recycling company collection network in Germany. Krikke et al. [5] proposed a stochastic dynamic programming model for the largest net gain of product recovery. Istvan et al. [6] studied reverse logistics management system at the end electronic products. Nagurney and Toyasaki [7] used genetic algorithm to analyze production and price of logistics. Lee et al. [8] described the status of the recovery of waste electrical and electronic in Korea.

Closed-loop supply chain is considered as a good method for the waste product recycling analysis. Savaskan et al. [9] introduced three kinds of closed-loop supply chain models used by remanufacturer. They gave a detailed analysis on the relationship of the remanufacturer and the retailer and make a comparison of the profits, prices and demands for these three models. Hammond and Beullens [10] expanded a closed-loop supply chain based on a previous work dealing with oligopolistic supply chains. They got the equilibrium state when all the game players accepted the volumes shipped and prices charged. Kumar and Malegeant [11] built a closed-loop supply chain with an eco-non-profit organization. They showed the method for the manufacturer to create value with the help of an eco-non-profit organization and the eco-non-profit organization could also get benefits under the strategic alliances with the manufacturer. Östlin et al. [12] introduced seven kinds of closed-loop relationships for gathering cores for remanufacturing and made an analysis on the advantages and disadvantages for each model. Kenne et al. [13] considered a closed-loop supply chain with random failures and repairs. Based on numerical methods, the authors proposed a policy to minimize the holding and backlog costs for manufacturing and remanufacturing products.

As the game players will change the decisions based on the receive information all the time, the dynamic game should be considered when analyzing the closed-loop supply chain. Guo and Ma [14] presented a dynamic closed-loop supply chain with the retailer selling and recycling products. They analyzed the dynamic features of the closed-loop system and drew out the bifurcation and other diagrams to show the dynamic features clearly. Xie and Ma [15] showed the dangers of the price adjustment speed on the stability of the closed-loop supply chain system. After explaining the economic meanings for the cause of chaos system, the authors gave the improvement approaches to maintain supply chain system stability. In this paper, we will consider the dynamic game in the reserve logistic supply chain.

The rest of this paper is organized as follows: Symbols and Assumptions are shown in Section 2. In Section 3, the model and supply chain structure is analyzed. In Section 4, we introduce the method to control the chaos system. The sensitivity analysis is presented in Section 5, and Section 6 concludes. Some complex formulas are shown in the appendix.

2. Symbols and Assumptions

In this paper, we focus on recycling behavior of a professional recycling manufacturer. Remanufacturer need to pay consumers and recycling channel for recycling the waste household appliances. At the same time, the government will pay a certain amount of subsidies to disassembly process in order to encourage recycling business operations. In the home appliance recycling market, there are also a lot of "Informal Recyclers". They also participate in the competition of home appliance recycling, and sell the waste household appliances to remanufacturer. But unlike the formal recyclers, these informal recyclers will first dismantling off some parts of waste household appliances and sell them to the recycling market, and then sell the remaining to remanufacturer. Remanufacturer is hard to distinguish whether the home appliances have been preliminary treatment. Therefore, there are many shabby waste TVs in remanufacturer workshop. Based on this, the model in this paper is shown in Fig. 1.

In the model of this paper, a formal retailer (expressed in R1 below) recoveries of color TV sets in the market as one of the recyclers, competes with informal recyclers (expressed in R2 below) in the market for waste color TVs. As recycling business, remanufacturer (expressed in M3 below) recycles waste color TV from the recyclers R1 and R2 with the same price. The informal recycler R2 will first take apart some material from recycling discarded color TVs and sell them to the material recycling market, then sell the processed old color TV to M3. M3 will take apart some useful material and sell to material recycling market, and then get rid of useless parts.

The analysis in this paper is based on the following assumptions.