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Impact of subsidy policies on recycling and remanufacturing using system dynamics methodology: a case of auto parts in China

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ABSTRACT

The aim of this paper is to explore the impact of subsidy policies on the development of the recycling and remanufacturing industry in China using system dynamics methodology and by simulating Chinese auto parts industry. Firstly, we introduced four subsidy policies – initial subsidy, recycling subsidy, R&D subsidy and production subsidy – and established system dynamics models to characterize the remanufacturing dynamics system considering government subsidies. Then we analyzed the impact of four subsidy policies and mixed-subsidy policies individually and comparatively based on Chinese auto engine remanufacturing on recycling and remanufacturing activities. The results showed that varied subsidies have different incentive objectives and characteristics. The initial subsidy plays an active role in improving remanufacturing activities and is suitable to be used at the initial stage of industry development. When the remanufacturing industry develops to a certain extent, the production subsidy or R&D subsidy can reasonably control the quantity of remanufacturers and maintain remanufacturing industry scale and stability. The recycling subsidy plays a significant role in overcoming the bottleneck problem of "lack of cores". The mixed-subsidy policies have the better positive effects on remanufacturing promotion than single subsidy policies, but involve higher costs.

1. Introduction

Remanufacturing is the process by which used products are recovered, processed, and sold as like-new products in the same or separate markets (Guide and Wassenhove, 2001; Thierry et al., 1995; Fleischmann et al., 2000). As an important part of closed-loop supply chain, remanufacturing has gained more attention because the economic and ecological benefits of striving for a circular economy are clear (Guide et al., 2006; Atasu et al., 2008; Seitz, 2007).

Many countries and regions are concerned with remanufacturing industry, and have enacted a range of laws and regulations to support recycling and remanufacturing. For example, European Union (EU) enacted End-of-Life Vehicles (ELVs) Directive (Directive 2000/53/EC) in 2000 and Electronic Equipment Directive (2002/96/EC) in 2003 (Mazzanti and Zoboli, 2006). In the state of Maryland and California in US, the legislation assigns recycling fee on electronic products (SBE, 2009). The subsidy fees have been implemented in Canada and Japan (Hicks et al., 2005).

In China, the main focus of remanufacturing is auto parts remanufacturing, which officially began in 2008 when the National Development and Reform Committee of China (NDRC) announced 14 enterprises as pilot remanufacturers of auto parts. However, Chinese enterprises do not actively participate in recycling and remanufacturing activities due to the low level of consumer acceptance, and the lack of used auto parts and advanced remanufacturing technologies (Zhang et al., 2011, Wang and Chen, 2011). So in this initial stage of growth, government incentives are important driving forces for remanufacturing activities in China.

Actually, the Chinese government has been playing an important role in the promoting and formation of remanufacturing industry. In order to accelerate the development of remanufacturing, the government starts to use a range of subsidies, which are relatively common in some other industries in China, to promote the development of remanufacturing industry. For example, the government of Liuyang in Hunan province provided a one-time subsidy to motivate enterprises to launch remanufacturing activities (LMCMI, 2010), and the government of Wuhan in Hubei province gave Sevalo Construction Machinery Remanufacturing Co. Ltd. 1 million RMB as an R&D subsidy (IRDRI, 2013).

A number of studies have explored the close relationship between government incentive policies and remanufacturing.

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Webster and Mitra (2007) and Atasu et al. (2009) studied the efficiency of recycling regulations. Mitra and Webster (2008) used a two-period game-theoretic model to research the affect of government subsidy policies on remanufacturing activities. Zhao and Chen (2011) compared the laws for ELVs and discussed strategies for developing the recycling industry in China. Simic and Dimitrijevic (2012) established a linear program to formulate the optimal processing for vehicle recycling factories in EU legislature. Wang and Chen (2013) classified the policies and regulations about China's ELVs recycling industry and indicated that an appropriate old-for-new subsidy standard could motivate vehicle owners to return ELVs. Ma et al. (2013) focused on how consumption-subsidy influenced dual-channel closed-loop supply chain. However, these studies mainly used game theory or optimization methods which have more assumptions. Actually, remanufacturing system with government incentive policies is a complex dynamic system.

System dynamics (SD) approach is closely related to agent-based modeling and can be used to study highly complex systems based on the foundation of feedback control theory. (Forrester, 1958, 1961). Some studies have established SD models of reverse logistics and production recovery (Sterman, 2000; Spengler and Schroter, 2003; Georgiadis and Vlachos, 2004; Georgiadis and Besiou, 2008). Schaik and Reuter (2004) discussed the effects of time on engine recovery with system dynamics. Georgiadis and Besiou (2008) established a SD model to research the effects of environmental regulations, ecological motives, and technology innovation on recycling and remanufacturing behavior. Zhao et al. (2011) selected Chongqing in China as a case and used SD model to evaluate alternative types of recycling center under low profit, low revenue, and low cost policies. Dong et al. (2012) used an SD model to analyze the effects of cleaner production policies on electroplating enterprises in Shenzhen of China. Farel et al. (2013) adopted an SD approach to investigate the costs and benefits of ELVs recycling and economic balance in various scenarios.

While valuable research has been carried out there remain gaps in the literature: (1) the existing literature mainly employed methods of game theory or optimization modeling, and were based on simple policy assumption without taking the interplay of decision-makers into account. Actually, there are multiple decision-makers, such as recyclers, remanufacturers, consumers and government, in remanufacturing system. The interplay between these decision-makers results in a complex dynamic system; (2) few literature explored the impact of different subsidy policies on the development of remanufacturing industry in China from the view of system engineering. Remanufacturing industry in China is different from that in many other countries, so there must be some distinctive features with regard to the problems of remanufacturing. It is clear that subsidy policies are being used to motivate a wider use of recycling and remanufacturing in China, but the effectiveness and efficiency of different subsidy policies need to be verified and the reasoning behind the policies is unclear.

In this paper, we focus on the government subsidy policies, which are relatively common in China, and use SD methodology to explore the impact of different subsidy policies on the development of recycling and remanufacturing in China. The purpose of this study is to answer the following questions: How do single subsidy policies or mixed-subsidy policies affect the recycling and remanufacturing activities of enterprises in China? What kinds of policies are effective at improving the development of recycling and remanufacturing in China?

The paper is organized as follows. Section 2 describes the subsidy policies and presents system dynamics models. Section 3 describes the data and core equations. Section 4 analyzes the impact of the subsidy policies individually and comparatively. Section 5 presents the results and discussion. Finally, Section 6 presents the most relevant conclusions.

2. Subsidy policies and model description

2.1. Subsidy policies

The subsidy policies in this paper are government financial subsidy policies. For example, China established the "Waste Electrical and Electronic Products (WEEE) Collection and Use of Management Practices Fund" on July 1, 2012. The government uses this fund to give enterprises a fixed subsidy in accordance with the amount of WEEE dismantled.

In light of a few subsidy policies that have been proposed or implemented in cities like Wuhan in Hubei province and Liuyang in Hunan province in China, we will classify subsidy policies into four types.

2.1.1. Initial subsidy

Initial subsidy is a one-time subsidy and allocated by the government to the new remanufacturers who start to launch remanufacturing activities. The main purpose of the initial subsidy is to attract enterprises to make greater investment in remanufacturing and accordingly promote the development of remanufacturing industry.

For example, the government of Liuyang in Hunan province provided a one-time subsidy to motivate enterprises to launch remanufacturing activities, which covered 20% of the total investment of remanufacturing construction and equipment (LMCMI, 2010).

2.1.2. Recycling subsidy

Recycling subsidy means that the government gives recyclers a fixed subsidy per collected used part. The purpose of a recycling subsidy is to help recyclers to buy back more used products.

The acquisition price is a powerful control in remanufacturing systems (Guide and Wassenhove, 2001). Acquisition price and profitability directly affect the quantities of gained used parts. Unfortunately, as governmental supervision over the disposal of scrapped and damaged cars is weak in China, repair shops usually prefer to sell collected used parts to chop shops at higher prices. These parts are then illegally refurbished or reassembled and sold at discounted prices. This kind of illegal activity makes it difficult for legal remanufacturers and legal recyclers to gain used parts from the after-sales markets. So an important issue faced by the Chinese Pilot Automotive Parts Remanufacturers is to ensure a sufficient supply of cores to support remanufacturing operations. Now NDRC are planning to make a new recycling subsidy to help the pilot remanufacturers obtain sufficient cores.

Recycling subsidy policies are often used in China. As shown in Table 1, the Ministry of Commerce of China issued an old-for-new

Table 1
The old-for-new subsidy standards of per scrapped vehicle in China (2009 and 2012).

Type of vehicle	Description	2009 (RMB)	2012 (RMB)
Bus in Rural Area	6year $\leq$ Life Time<15 year, 4.8m $\leq$ Length<7.5 m	10,000	11,000
Bus in Urban Area	8year $\leq$ Life Time $<$ 15 year, Length $\geq$ 6 m or Seats $\geq$ 20	15,000	18,000
	Length $<$ 6 m or 10 $<$ Seats $<$ 19	10,000	11,000
Heavy truck	All	5000	18,000

Source: Ministry of Finance of the PRC, Announcement No.20, 2009; Ministry of Commerce of the PRC, Announcement No.27, 2012

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