Study on Adaptive Management Model and Key Factors under Extended Producer Responsibility

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1 Introduction

With rapid industrialization, modernization and urbanization, billion tons of wastes including used and discarded products are produced every year worldwide. These wastes not only deteriorate the already seriously polluted environment but also make numerable useful resources dumped to "wrong places", the landfills. As a result, natural resource exhaustion and environmental pollutions are deteriorated to be major obstacles for sustainable development. Based on practical experiences of waste management and cleaner production promotions, T. Lindhqvist initially raised the concept of extended producer responsibility (EPR) in 1988 [1], which proves to be an effective policy principle to motivate effective solutions for "end-of-pipe" problems.

In the past two decades, EPR has drawn nearly 20 countries' wide attentions, and has been applied in the solid waste management of about 20 industries. EU members, Japan [2] and other countries have established relatively mutual EPR system of mandatory programs. Countries that characterized by voluntary agreement, such as United States and Canada, have also embarked on the study of EPR policies and regulations, and started the transferring process from voluntary agreements to more mandatory regulations management. Those countries who have not yet established a system for EPR policies and regulations are also actively exploring the formulation of relevant laws and specific implementation plan. For example, from 2004 China has begun to explore the application of EPR principles in the field of waste management, especially in the electronics and automobile industries. EPR principles have been incorporated in the "Solid Waste Law" and "Circular Economic Law". Throughout the world, EPR presents its different characteristics in different countries, different industries and different periods of time, as well as the diversity of applications.

However, as in its infancy, the implementation of EPR is also facing various problems. One of the most important problems is the participation of single company. T. Lindhqvist [3] indicates that individual company's active participation to achieve product life-cycle improvement is critically important for successful EPR implementation. And product life-cycle system is complicatedly composed by various stakeholders in the dynamic market environment. Unfortunately, recycling-related knowledge and fast system learning capabilities processed by producers are mostly limited. As a result, a number of companies behave passively, which highly hinders the implementation of EPR programs. "Free rider" is one of the most undesirable phenomena during EPR's implementation, which has been always drawing attention since the beginning stage that EPR was introduced [4]. In general, the difficulties for companies taking their responsibilities are concluded as the following aspects: (1) the financial deficiency; (2) the lack of technological solutions [5][6]; (3) unnatural development of the related supply chain system [6]; (4) difficulty in finding an efficient and effective method for collecting their own products [7]; and (5) less scale economy of the returning wastes to be recycled.

It is concluded in our previous research that, the greatest challenges that EPR brings to the responsible companies is the physical and economic responsibilities, which are extended beyond the original scope of enterprises' business. The extended responsibilities require the enterprises not only adjust the existing supply system, but also integrate the recycling practice with the production process. From the management perspective, this involves plenty of unknown knowledge for the enterprises, and increases the uncertainty of management. Just because the involved life-cycle stakeholder system is diverse, complex and dynamic, the enterprises must re-examine the system in question from a new perspective to better understand the new scenario. In other words, to investigate the challenges that responsible companies are facing under EPR with systematic framework, and to study the beneficial responsive strategies from integrated and dynamic viewpoints is of great practical significance for responsible companies as well as for the smooth implementation of EPR.

As important as the problem is, few in-depth studies or effective solutions have been intended or provided to enhance individual company's actively responding capabilities from more systematic and integrated life-cycle

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viewpoints yet [5]. Based on adaptive management theory we analyze the functioning mechanism of EPR especially producer's responsive reactions within a life-cycle stakeholder system. Then the key influencing factors in terms of adaptive decision-making for key stakeholders are studied based on game theory. Suggestions are made for both producer and government as well.

2 Adaptive Management Framework for EPR

Adaptive management (AM) is innovative environmental assessment and management idea which could be traced back to 1970s when it was developed by C.S. Holling [8]. Distinctive from traditional management method which takes management intervenes as pure solutions to the environmental problem in question, AM seeks aggressive use of management intervenes to probe and learn about the functioning of objective ecological system. Due to the fact of managers' ignorance and the limit of people's learning abilities at a certain period, AM is considered to be an effective model for dynamic system management which is highly complicated with plenty of uncertainties. Instead of statistic management scheme, a continuous learning and improving process is intended to achieve through AM.

As discussed above, EPR's implementation not only changes the original supply chain system, but also introduces new stakeholders to formulate a new and more complicated stakeholder system. As shown in Fig.1, our proposed life-cycle stakeholder system under EPR includes six stakeholders: the upstream suppliers, producers, distributors and retailers, consumers, collectors and recyclers and government. According to the definition of EPR, the producer here refers to the core manufacturers or importers of certain products or certain brand of products. This is due to the fact that within a supply chain, there is normally a "central" manufacturer who assembles the finished goods or owns the brand of the products. In addition, with the development of international trade, the scope of "producer" in EPR is also expanded to not only the core manufacturers but also importers [3]. The upstream suppliers provide the components, materials or semi-completed goods. In this case, this manufacturer possesses the actual decisive power or controllability over the product design and material/component adopting standards. In other words, it has the controlling power over the operation of the whole supply system such as the car manufacturer. Therefore, it is taken as the core entity in both supply chain management and environmental supply chain management [9]. In EPR, the end-of-life responsibilities are also supposed to be extended to this producer so as to both economic and ecological pressures caused by the discarded products could be effectively transferred back to the production system.

As implementing EPR, the government intervenes in the market in a comprehensive way. As shown by the double-line arrows in Fig.1, government directly assigns full or major end-of-life responsibilities to producers, and sets new requirements to retailers, customers and recyclers etc through policies or regulations. As a result, some new relationships occur among the other stakeholders. As shown by double-line dashed arrows in Fig.1, in response to the collecting-related requirements, end users are supposed to return their used products through the collecting system to the recyclers. In response to the recycling-related requirements, suppliers are also involved to make the design improvement to increase product's recyclability. Besides, third-party organizations are found to serve financial, physical or informative responsibilities. Except to the above direct relationships, some of the newly emerged mutual influences are indirect but also significant, as shown by dashed arrows in Fig.1. For example, the customer's behaviors highly influence the producer's performance of soundly taking the extended responsibilities as the same as the recyclers. The R&D capabilities of the suppliers affect

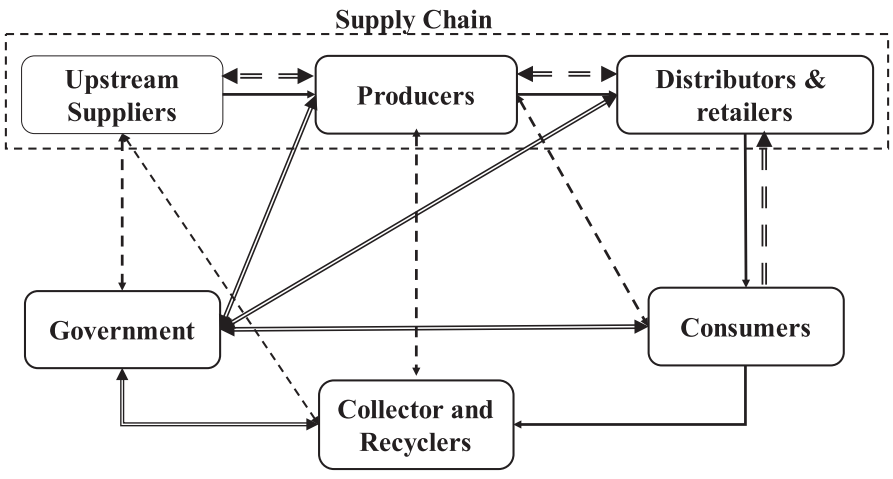

Fig. 1 Life-Cycle Stakeholders System under EPR Program

the performance of design improving and indirectly influence the recycling performance. This complexity could impliedly explain why a government is very slow in carrying out a new or higher environmental requirement sometimes.

Actually, the mutual relationships and interactions among the life-cycle stakeholders under EPR in reality are even more complicated than the above explanation. For example, in different countries the government could be further divided into the central government and municipalities, as in federal regime as the US. Thus division and distinguishing in some sense can be infinitely continued. Thus in order to simplify the system as well as the relationships inside, we set up the theoretical framework with only key interrelationships being focused as shown in Fig.1.

Within the life-cycle stakeholder system the stakeholders are complicatedly interrelated to each other. Meanwhile, each stakeholder will react differently according to a certain responsive strategy carried out by the producer against EPR. These reactions will keep changing with the development of economy, technology or other conditions; and will affect the outcome of producer's strategies in return. Since produce is unfamiliar with the interaction knowledge and the influences, rather than providing a statistic management solution to EPR for producer through traditional management ideas, continuous monitoring, understanding and adapting by producer are more deeply and practically needed. Therefore, AM is introduced in this research to facilitate producer's effective response to EPR as shown in Fig.2.

Briefly speaking, producers or responsible companies will start the management process with potentially effective measures to respond to EPR programs based on their existing knowledge and assumption about the situation and features of the new stakeholders system, and interrelationships among various parties, as shown by the "Key factor" in upper-left, grey-background square in Fig.2. Both the "implementation" process of the initial measures and the consequent "output result" will be "monitored", including the reacting and mutual influencing process among various stakeholders. All the key factors will also be informed to and the ideas be exchanged with the other stakeholders. Together with the monitoring result, the "Key factors" will be re-evaluated to facilitate the producer better understanding the newly emerged environment and be adjusted to compose the producer's new knowledge as shown by the black square in Fig.2. With the improved understanding of the key factors and the combined action by the other stakeholders, the producer's comprehension about effective EPR management measures will be advanced, which then contributes to the producer's new knowledge for another round of "probing and learning" management process. In general, the AM process mainly includes four steps, the first of which is shown in the upper part of Fig.2 and the last three are shown in the lowest area of Fig.2: (1) to implement responsive measures based on current understanding of the key factors; (2) to monitor the results and make self-evaluation by responsible companies; (3) to assess the stakeholder system, and (4) to identify opportunity and challenge so as to improve the management. The kernel of this AM process is that the producer's comprehension about the changing environment and their identification of key factors will be continuously advanced, which results in that their management capabilities in response to EPR will be continuously improved along with the development of various internal and external conditions.

One of the crucial steps to realize the above adaptive management is to identify the "Key factors". Therefore on the basis of the proposed adaptive management framework and life-cycle stakeholder system, this research will further focused on the analysis of the stakeholders and to identify key factors for this system to reach the goal of providing

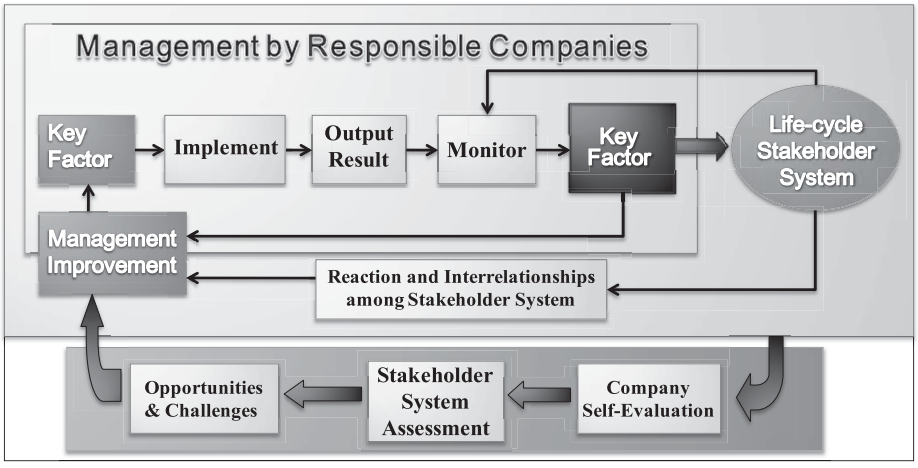

Fig. 2 Adaptive management framework for EPR

fundamental references for adaptive management initiation.

3 System Analysis

3.1 Stakeholder mapping framework

As a concept used in corporate administration or project management, stakeholder is viewed as any person or organization that can be positively or negatively impacted by, or cause an impact on the actions of a company. In order to clarify the consequences of envisaged changes, or at the start of new projects and in connection with organizational changes generally, analysis needs to be carried out to all the stakeholders including the primary stakeholders, secondary stakeholders and more significantly those identified as the "KEY" stakeholders. Different method of stakeholder mapping are developed for different analytical aims and system situations. In this section, stakeholder analysis is carried out with three aims: (1) to analyze each stakeholder's features and major influences on the producer; and (2) to identify the "KEY stakeholders" and important interaction during the implementation and strategy-making of EPR. Therefore, based on the theory of stakeholder analysis, we adopt a three dimensional framework, including attitude, power and interest. Attitude describes the manner that a stakeholder is related to EPR program as well as major functions it has during the whole process. In this dimension, discussion will be focused on whether a stakeholder is an active influencer or passive influencee for the producer's responsive strategies. Power describes strengthens of the influence that a stakeholder has on the design and results of the manufacture's strategy. Whether a stakeholder could strongly influence the producer's strategy making, and the potential outcome as well, will be judged in this dimension. Interest describes the extent to which a stakeholder is willing to get involved and informed. With the understanding of whether higher or lower involvement and informing level more acceptable for a certain stakeholder, suitable management measures for each stakeholder will be identified. Three types of key stakeholders are intended to be identified. The active influencers with strong power and higher interest are primary key stakeholders. The passive influencees with strong power and higher interest are secondary key stakeholder. The passive influencees with strong power but lower interest are also key stakeholders who need special incentives to keep them playing positively cooperative roles.

3.2 Stakeholder Analysis and Features

According to the above three dimensional analytical framework, five stakeholders will be analyzed, including government, suppliers, distributors and retailers, customers, and recyclers.

Attitude analysis:

Government is the only active initiator of EPR programs. With the increasing environmental problems caused by end-of-life products and growing resource detraction pressures, more and more government are implementing EPR to assign producers with responsibility of product life-cycle environmental management, especially the post-consumption wastes. As the government starts conceiving to adopt EPR, the producer will firstly get involved into the process of dialogue. As for the other stakeholders such as customers, recyclers, suppliers and so on, are involved after a real EPR program is implemented. In other words, both producer and the other stakeholders except government will be passively influenced by EPR. However, the introduction and implementation of EPR is quite an interactive process, where dialogue and negotiation between government and major producers could be several-year long before a specific EPR program is finally introduced to an industry. During this process, producers' awareness is educated and economic system gets time to make necessary preparation before the regulation gets through. On the other hand, status and willingness of the whole economic system greatly influence the process resulting in some voluntary programs and even no EPR at all. In other words, how an EPR program is designed and implemented is resulting from the balance between the environmental problems managed by government, and the status as well as the capabilities contained by the economic system. In some special cases, producers will actively engage into the end-of-life products recycling and managing driven by attractive economic benefits. For example, Ford GM and Chrysler co-founded an R&D center to increase the recyclability of automobiles in Detroit. Ford also merged some recycling companies in Europe.

Power analysis:

The government has stronger power or influence in terms of advocating the idea of EPR and initiating its development as well. Furthermore, the power of the government for an EPR program depends on whether a mandatory or voluntary program is applied. As the worldwide acknowledged successful models of EPR implementation, Europe and Japan have adopted mandatory EPR programs through related legislations. In this case, government has the strongest power. Recyclers also have strong power since the technological capabilities and operating performances significantly affect the realization of the final recycling performances both ecologically and economically. Thus as producers making their responsive strategies, they must take the current recycling level and potential improvement possibilities into consideration, where some of the questions are not technological but

political and managerial. A side-effect worthwhile to mention here is that a disordered recycling market could be a big hindering factor for EPR implementation, even if sounder eco-design and recycling technologies are ready for the market. Another stakeholder with strong power is suppliers because almost all the design improvement practices need participation and cooperation of the suppliers. R&D ability of suppliers and the possibility of changing new suppliers are consequently a decisive factor of the source design improvement by producers not only in terms of R&D competency but also the economic issues. Roles supposed to be played by the customers and distributors are important but not so strong, since a certain economic incentives and institutional arrangement will soundly ensure the involvement distributing system and customers. Comparatively, secondary market for used products is an important factor though an external factor as well. Discussions on this issue is very significant for some economies but beyond the scope of this research.

Interest analysis:

Government has the highest interest toward EPR programs. Beside the design of an EPR program at the starting stage, the government also considers how it is monitored and improved during the implementation process. Recyclers could be interested if well informed of the details of product structure, component and materials adopted would contribute to higher recycling performance and earning. On the contrary, suppliers are always lack of interest in EPR programs as extra costs will be caused, though suppliers have also strong power. The supply-demand incentives will drive the suppliers to cooperate. The public with higher environmental awareness and environmental NGOs also have higher interest in the process of EPR and the strategies taken by the producer, or the green image. It has contributed to a driving factor for company's environmentally friendly actions in for example Europe and Japan etc. Features of each life-cycle stakeholder under an EPR program are summarized as Table 1. By summarizing the above analysis, government is the most important stakeholder in EPR program. Interaction between government and the producer is significant so that game model will be developed in next constraining conditions for producers' trade-offs economically. Meanwhile, information needs to be passed to customers, suppliers, recyclers and third-party organizations, vise verse.

Table 1 Life-cycle stakeholder mapping under EPR

	Attitude	Power	Interest
Government	Active	Strong	High
Recycler	Passive	Strong	High
Supplier	Passive	Strong	Low
Customer	Passive	Weak	Low
Distributors	Passive	Weak	Low
Public	Passive	Weak	High

4 Two-party Game Model

4.1 Hypothesis and Pay-off Analysis

Game theory is considered as one of most effective research methods for strategic decision making analysis. From the stakeholder analysis in the previous section, the producer and government are the two significant players that involved in the game analysis. In order to achieve reasonable simplification, the following analysis is based on one assumption that the player "government" includes administration departments of all level, who has the authority to make and the power to enforce regulations, or rules. The other assumption is that the player "producers" refers to the manufacturers and importers who have the decisive power on the product design and material/component adoption.

In terms of the government's side, we suppose the cost of implementing EPR program includes: administration cost for running the EPR program, "a"; the expenses for monitoring the environmental performance achieved by the producer, "mo". When adopting commendatory program, the government will penalize "p" on the producers who are found regulation violation. On the other hand, under EPR programs well performed producers will undertake the extended responsibilities of recycling the end-of-pipe products and of re-designing their products for better environmental performance. This will contribute to the increase of recycling level of end-of-life products and to the decrease of the toxicity and increase of recyclability of the ecologically designed products respectively. As the representative of social public interest, the government will benefit from the enhanced ecological performance or the reduced negative ecological impacts achieved above, e^r and e^d. In Specific, "e^r" stands for the ecological benefits resulting from improved environmental performance of recycling, and "e^d" stands for the ecological benefits resulting from improved environmental performance of product design or eco-design. Calculation of e^r and e^d can be achieved by following the methods of Life Cycle Assessment or by utilizing the software of Eco-Indicator 99 etc [10].

In terms of the producers' side, those who implement recycling and collecting have to arrange the corresponding cost, "rc". In case that the producer not only implements recycling but is also self-motivated to carry out eco-design of new products, an extra expense "d" should be arranged from the producer side. While, producer may have potential benefit "m^r" from recycling due to such facts as elevated

Table. 2 Pay-off Matrix for the game between government and producers

		Producers		
		Recycle Only	Recycle & Eco-design	Free Riders
Government	Mandatory Program	$-a - mo + e^r$, $-rc + m^r$	$-a - mo + e^r + e^d$, $-rc - d + m^r + m^d$	$-a - mo + p$, $-p$
	Voluntary Program	$-a + e^r$, $-rc + m^r$	$-a + e^r + e^d$, $-rc - d + m^r + m^d$	$-a$, 0

corporate image through environmentally friendly behavior. Moreover, the extra market benefits "m^d" will also be achieved through the innovative investment for eco-design improvement. However, a free rider producer of EPR program will be found guilty and receive punishment "p", in accordance with the above description.

4.2 Game Modeling

The government players have two strategies for promoting the EPR program: mandatory programs, and voluntary programs. The former is composed of strict standards for recycling percentage, harmful material forbiddance, financial responsibilities and information distribution requirements; any violation of this program will be punished. This program is comparatively effective for implementing EPR. However, the government must effective measures in place to monitor and control the EPR project implementation; and besides, it should conduct a reasonable allocation of funds to carry out the necessary monitoring and regulatory. For the alternative of government strategy, voluntary programs initiate the dialogue among various stakeholders, especially the producers, with a voluntary agreement for the aim of toxic substances restriction. This initiative is the Government-to-business based on trust arising. Government will only be required to pay the EPR program operating costs, such as publicity, thus the total expenditures can be significantly reduced. Nevertheless, this option is only applicable to the society that has a better understanding on environmental protection, meanwhile the leading enterprises that have a higher awareness of environmental situation.

On the contrary, the producer player has the following strategies: (1) only meet the recycling responsibility; (2) implement recycling and eco-design of the new product; and (3) free rider. For choice (1), the producer only considers the recycling of its end-of-life products' collection and recycling, for which it needs corresponding recycling cost, but has potential marketing profit from the recycling behavior. For choice (2), the implementation for both recycling and eco-design will cause extra development expenditures besides the recycling cost, including environmentally friendly product development, better material requirement for its upstream suppliers. As reward, the producer may have the chance to win new markets share, as well as leading image for its design concept, thus to become more competitive. The last choice "free rider" will not be a wise alternative if the producer with enough funds for the improvement of environmental issue, especially under an EPR program that mandatorily carried out by the government. Though this passive altitude can avoid further cost for either recycling or eco-design inputs, it has the risk of punishment, as well as potential loss in market. According to the above analysis, a pay-off matrix for this game between government and producer is demonstrated as Table 2, where six possibilities with respective pay-offs is shown.

5 Results and Discussions

5.1 Mixed Strategy Analysis

The game analysis in this paper is carried out by assuming the government takes "Mandatory Program" and "Voluntary Program" at the probabilities θ and $(1 - \theta)$ respectively. So that, from the producer's viewpoint we have the following equations hold:

$$P_1 = \theta \cdot (-rc + m^r) + (1 - \theta) \cdot (-rc + m^r)$$
$$= -rc + m^r \quad (1)$$
$$P_2 = \theta \cdot (-rc - d + m^r + m^d) + (1 - \theta) \cdot (-rc - d + m^r + m^d)$$
$$= -rc - d + m^r + m^d \quad (2)$$
$$P_3 = -\theta \cdot p \quad (3)$$

where, P_1, P_2 and P_3 are expected utility functions with respective to each strategy. By concatenating each two of Eq. (1) ~ Eq. (3), we can conclude that under the Mandatory Program, if the pure profit from the eco-design improvement is positive and greater than the pure profit from the recycling, "Recycle & Eco-design" is the best strategy. On the contrary, the producer would rather choose the "free rider" strategy, if the loss by the other two strategies is even worse than the punishment. Because "free rider" is the most undesirable strategy toward the government's target, punishment should be a considerable value according to the minus environmental performance. On the other hand, in order to avoid punishment, as well as potential loss for strategies 1 and 2, producer should develop effective and efficient ways for implementing at least recycling. In case that the producer has the capability to fund new product's development, it is wise to take

strategy "Recycle & Eco-design" for promising eco-designed product, since the ecological product will be the mainstream tendency for the future society.

5.2 Scenarios Discussions with real cases

Based on above analysis, four scenarios could be identified including: (1) $P_1 > 0$ & $P_1 > P_2$; (2) $P_1 > 0$ & $P_1 < P_2$; (3) $P_1 < 0$ & $P_1 > P_3$; and (4) $P_1 < 0$ & $P_1 < P_3$. These four scenarios' meaning and considerations in terms of the practical operations in reality as well as the key influential factors will be further discussed below.

Scenario I: as $P_1 > 0$ & $P_1 > P_2$, "Recycling only" will be the preferred strategy for producers and "Voluntary program" is the best choice for government. Under this scenario that $(-rc + m^r) > 0$, meanwhile, $(-d + m^d) < 0$. This means the net profit of recycling the end-of-life products or the ELPs are positive but that of R&D on improving the recyclability of the product is negative. In this case, concerned producers would have higher motivation to carry out the collecting and recycling rather than eco-design improvement. Thus there is no need for government to carry out mandatory programs in order to solve the problem of ELPs. The end-of-life vehicle recycling market in US is a best example for this case, where the recyclers benefit over billion US dollars aurally even if there is no EPR policy at all. Meanwhile the recyclability rate of discarded vehicles exceeds 95%.

Scenario II: as $P_1 > 0$ & $P_1 < P_2$, "Recycling & Eco-design" is the preferred strategy for producers and "Voluntary program" is the best choice for government. Under this scenario, $(-rc + m^r) > 0$, meanwhile, $(-d + m^d) > 0$. This means, not only collecting and recycling ELPs business but also eco-design investment will bring the producers and related companies positive profits. As a result, enough incentives occurred to motivate the producers to participate in both recycling of ELPs and R&D for more recyclable and more environmentally friendly products in spite of ELPs recycling or EPR regulations. In fact, this is quite an ideal scenario as both economic and ecological needs are met in a natural way. Therefore, it is very hard to be realized and rarely exists. Only limited cases exist for this scenario. Although the situation has greatly changed ever since the worldwide economic crisis in 2008, the three automobile giants, FORD, GE and Chrysler, have cooperatively built a research center in Detroit to develop more recyclable cars as well as new recycling technologies. Meanwhile, FORD bought a series of recycling companies in Europe around the end of 20th century to extend their business chain from car production to cover recycling.

Scenario III: as $P_1 < 0$ & $P_1 > P_3$, "Recycling only" will be the preferred strategy for producers and "Mandatory program" is the best choice for government. Under this scenario that $(-rc + m^r) < 0$, but smaller than the punishment if violating the related regulations. This means the net profit of recycling the ELPs are negative but the producers will pay for even higher punishment if they failed to participate in recycling. In this case, problems of ELPs will be solved even if it is a pure cost for the producer, on the condition of very strict EPR regulation designs and implementations. The most natural EPR examples, namely the EC areas and Japan give the best example to this scenario. For example, in Sweden, there was great deal of used cars dumped illegally in natural forest because the collecting fees for discarding a used car charged to the end users were so high that they preferred to risk breaking the law. The higher collecting and disposal expenses made recycling a negatively costly business until EPR –based policies and programs came to implementation in 1990s. Mandatory requirements have been assigned to the end users to return their car to specified recyclers freely as well as to producers to pay for the extra cost for recycling. These kinds of mandatory programs achieved great success in Europe and Japan so that EPR attracted great attentions worldwide even till the time being.

Scenario IV: as $P_1 < 0$ & $P_1 < P_3$, "Free ride" will be the preferred strategy for producers and neither "Mandatory program" nor "Voluntary program" is the best choice for government. Under this scenario, $(-rc + m^r) < 0$, and bigger than the punishment if violating the related regulations. This means recycling the ELPs is purely costly for producers but they will pay less by violating EPR regulations. In other word, EPR programs will fail to be implemented or to be effective anyway. For example, in China act or proposals to implement EPR in both electronic and automobile industries had been enacted ever since the beginning of 21 century. However, related EPR regulations for these industries have not to be drafted yet. Reasons for current situation in China are quite complex. Brief factors will be further discussed in 5.3.

In general, the best strategy for the producers in scenario II is to become innovative leading company. For the producers in scenario I, it is actively following companies; for scenario III, passively following companies; for scenario IV, the free rider.

5.3 Analysis on Key Influencing Factors

Except to the net profit of recycling, R&D, and potential punishment for violation discussed above, there are more influencing factors to contribute different scenarios and different strategy making preferences made

by producers and government. These factors will be discussed in terms of economic performance of recycling ELPs, economic performance of design improvement and social factors as well.

As for the economic performance of recycling ELPs, it can be concluded from 5.2 that the better the economic benefits resulting from recycling ELPs are, the easier the implementation of EPR will be. Collecting amount and market for second-hand product/materials have higher impact on the total profit of ELPs collecting and recycling [11]. It can be proved by the case of the North American experiences that to promote the development of second-hand product/material market is a significant factor to enhance the economic attractiveness of environmental protection programs and policies. On the other hand, it should not be neglected that the disposal cost is another important factor. For example, in the Chinese case mentioned above, current recycling of ELPs is actually quite active and profitable for a lot of small-medium-sized recycling companies even though these existing operations are very polluting. Crucial reason to this situation is that in China the disposal fees are quite low almost all over the country. The polluting profit could not be acceptable by Chinese government and on the other hand shows more difficulties rather than incentives to the producers as they start thinking about carrying more responsibilities of the used products they produced. Therefore, it proves that reasonable and environmentally friendly profits are practically significant in terms of smoothly implementing EPR programs.

Economic performance of design improvement for more recyclable products has special significance, because the fundamental aim of applying EPR is to solve the ELPs problems through an integrated life-cycle way, or in other word, to solve the end-of-pipe pollution from the starting point of production. Practical examples such as the Detroit R&D center mentioned above proves that economic scale and it's influential power on the whole supply chain, or industrial concentration rate and responsible companies' economic capabilities are decisive factors. Although the development of second-hand product market will motivate the development of more recyclable products, it could be safely concluded that EPR policies and programs itself might not be able to promote important eco-design development as expected originally when this policy was proposed.

Last but not least, social factors have greater importance especially for developing countries such as China. The social factors talked about here include the environmental protection consciousness on one hand and the scale of vested interest group which are inconsistent with ecological protection benefits. This could explain why almost all of the successful EPR programs exist in developed countries. It also gives an important insight for developing countries which are going to apply EPR that to solve important social hindering problems would be the first step.

In general, seven factors have key influence on the implementation of EPR as well as on the strategy making by producers, including the amount of ELPs collected, market for second-hand problems, waste disposal costs, industrial concentration rate, economic scale of responsible companies, social environmental protection consciousness and scale of vested interest group. The better the induced economic benefits are, the more voluntarily or the more easily the EPR programs will be and the more actively the producer will be. In this case, recycling is more preferred to the producers compared with other strategies. Eco-design improvement strategy only has limited incentives for quite few producers. Last but not least, social environment is the first hindering factor for EPR application.

6 Conclusions

In this research, complicated and dynamic features of the life-cycle stakeholder system under EPR program is focused and analyzed. Adaptive management method is introduced to facilitate producers make adaptive strategies and to improve management continuously. Based on the study on features and interrelationships of key stakeholders, a game model is developed with the producer and government to identify the key factors for adaptive management. For the two key game players, voluntary and mandatory EPR program design are considered as strategies for government, and strategies are designed for the producer including collecting, collecting and eco-design combining ad free-rider. We identify the key factors in three scenarios. In case that during the recycling producers getting a deficit, which even costly than the punishment for violations; they are more likely to escape the desired responsibilities. As the recycling performance and economic system's R&D capabilities for design improvement are satisfying enough to ensure a higher profitability, more actively responsibility taking in terms of recycling and design improving will be the optimal strategy for producers.

For producers in different countries, strategies should be adopted according to local conditions. Take the United States as an example, current environmental pressures is not as big as its European counterparts. "Negotiation and talk" is the dominant manner for environmental regulations making in most states. And there is favorable regulatory and marketing environment for end-of-life recycling business especially for used products. Therefore, producers with certain capital and technological capacities could actively participate in the recycling business as well as

"design for recycling" practices. Those with less capital or technological capacities could ignore the EPR requirements for the time being and reserve safety cash flow particularly during current economic crisis. Long-term R&D programs should be considered even more carefully.

On the contrary, in those countries with more limited land space, such as Europe and Japan, more urgent environmental protecting requirements and much stricter environmental regulatory systems, a more active strategy should be taken as priority by producers. Strategy of "free-rider" will be considered as the last choice due to the higher punishment than costs required taking the responsibilities. Therefore, producers in Europe, Japan and other mandatory-preferred countries should make more efforts on how to reduce the recycling costs for higher economic profits or how to realize the regulatory recycling goals in more low-cost manner. Meanwhile, active publication should be made in order to set up a more environmentally friendly image, since the public in those countries are normally have higher environmental awareness that could be effectively influence their purchasing behaviors. Under the condition of abundant capital capacities or aggressive company strategy as an industrial leader, investment for greener and more recyclable products would be a sounder strategy. This could be convincingly proved by the past practices of the three automobile magnates in the US, Toyota in Japan and Shanghai GM Ltd in China.

In any case, a systematic and open management style is of crucial importance for the adaptive management. It is not only significant to pursue the learning by constantly understanding the life-cycle stakeholder system, but also to use the new knowledge to continuously adapt management strategies. Achievement of adaptive management needs both organizational and managerial reform and political and institutional supports. Dialogue mechanisms should be developed within the producer and the life-cycle stakeholder system. All the related stakeholders should be included and senior management support is required as well.

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