The Input-Output Analysis of the Circular Economy

Liu Yifang Tong Renchen Xu Jian

School of Management of Graduate School of the Chinese Academy of Sciences, Beijing, China, 100080

***Abstract*:**

Currently, people do not discuss the significance and the effect of the sustainable development any longer. But how to practice the sustainable development takes more and more attentions of academes in both here and abroad. It is thought that the research of the bio-efficiency and the circular economy are two available tools and approaches for practicing the sustainable development, which the former started earlier and the latter had proposed much earlier but had been focused just recently, which concerned and approbated by more and more researchers and governments of many countries. In China, especially, the development and practice of the circular economy have been formulated in "the 11th Five-Year Plans for National Economic and Social Development (2006-2010)" which is the most important plan gist for the nation's short time development proposed by Communist Party of China (CPC). And it is indicate that the development of the circular economy has been upgraded to a national development stratagem from an academic theory or a common practice.

In this paper, the ideology of the circular economy development is analyzed and concluded systemically based on the ancient theory researches of the circular economy. Then the development pattern of the circular economy is proposed and some correlative conceptions is distinguished strictly. The concrete form and the process of the circular economy function in the macro-economy have been described by using of the input-output analysis. Further, some indexes which can reflect the development level of the circular economy is proposed and conclude, and the measure model of the development level of the circular economy is composed. All these will bring some new ideas and approaches for the theory researches and the appliance quantificational researches of the circular economy

***Keywords*: Circular Economy; Reused; Recycled; Input-output analysis; Circular Level**

Catalogue

The input-output analysis of the circular economy

Liu Yifang Tong Renchen Xu Jian

School of Management of Graduate School of the Chinese Academy of Sciences, Beijing, China, 100080

1 Introduction

Nowadays, the nature resources and the energy sources are becoming less and less while the pollution is more and more serious. It is realized that a new developing pattern is needed to propose to substitute the present one that achieves industrialization by the cost of using a plenty of nature resources and energy sources, which is named the “Line-type Pattern”. The development pattern of the circular economy is just the right approach to solve this contradiction. So more and more researchers have begun to focus the circular economy pattern in which the material is be used circularly.

The ideas of the circular economy germinated in the “Space Ship Theory” in the 1960's, which the “Circular Pattern” has been raised to substitute the “Line-type Pattern” for the first time. (Rachel Carson, 1962) However, the ideas of circular economy were only some conceptions and the focus of researches stayed still on the terminal management of the environment protection in the 1970's. Since 1980's, some developed countries had begun to deal with the scraps from the economic actions recycling. The conception of the “Feedback Loops” was raised by Bill Mckibben, which brought people to realize the limited of the environmental capability. (Bill Mckibben, 1997) In 1992, a masterstroke -- minimizing the use of natural resources and energy sources together with maximizing the pollution – had been established on the United Nations world Summit Conferences on environment and development. And the Clear Production, Resources comprehensive utilization, and Sustainable Consumption had been summarized step by step to a suit of developing stratagem for circular economy.

Up to now, the most of the researches on circular economy concentrate in these countries: China, Euro, USA, and Japan. In China, Zheng Yunhong (2004) pointed the fiscal charges policy for the demand of developing the circular economy. Yu Liying et. al. (2005) built the evaluation indexes system of the intercity circular economy based on the international evaluation indexes system of the society development. Zhou Guomei and Ren Yong (2005) raised the development pattern of the circular economy and the corresponding policy framework of China. Zhu Dajian et. al.(2005) designed the C-model for the development of the circular economy in China based on the conception of the eco-efficiency. Li Huiming (2006) analyzed the hinge for developing the

circular economy and pointed that the hinge was to strengthen the material flow analysis research. Tomohiro Tasaki, Atsushi Terazono, and Yuichi Moriguchi（2005）appraised the validity of the circular system law in Japan, etc. But these researches are almost rest on the debating on the theory, such as the conceptions or development principle. There is not any quantitative research or integrated theory systems until now.

The researches in occident and Japan are partly consistent with the idea of the circular economy. We conclude them to be the following three aspects: the material flow analysis in the ecologic industry and the evaluation of the eco-efficiency, the waste management research in the environmental protection, and the methods for treating the by-production and joint-production in the producing process. We explain them in detail:

The researches of ecology industry and eco-efficiency are corresponding to the "reducing" which is one of the principles of the development of the circular economy. Reid Bailey, Bert Bras, and Janet Allen (2001) studied the measuring of the material flow analysis in the industry system. Peter Saling, Andreas Kicherer, et al.（2002）introduced the analyzing methods of eco-efficiency based on the BASF. Tohru Morioka, Noboru Yoshida, and Yugo Yamamoto（2003）introduced the cycle-closing product chain management with appropriate production site metabolism zero-emission in an industrial machinery corporation. Gjalt Huppes and Masanobu Ishikawa（2005）concluded the methods of eco-efficiency analyzing and raised the framework of the quantified researches on the eco-efficiency.

Most of researches on the environment management are the waste management. The mainstream methods are the environment input-output (EIO) analysis and waste input-output analysis (WIO). The input-output technology was raised in the early 1970's by Leontief. And it is the fundamental of the following researches. (Leontief, 1970) Based on the EIO, the WIO was raised in 1992, and had been deepened in the recent years. （Nakamura Shinichiro, 1999& 2002） In the application researches, Shigemi Kagawa, Hajime Inamura, and Yuichi Moriguchi（2004） introduced a simple multi-regional input-output account for waste analysis. Koji Takase, Yasushi, and Ayu Washizu（2005）gave an analysis of sustainable consumption by the waste input-output model et al.

The treatment of the by-productions and joint-productions in the producing process provides a basis for treating the reused scraps and recycled scrapes in the circular economy. The method for analyzing is also the input-output technique, in which the coefficients is calculated by deducing and named the UV- table. The commodity technology assumption refers to commodities that are produced by activities, as opposed to by-products obtained from principal or secondary production. The methods was proposed by ten Raa et al. (1984) and Londero (1990). Elio Londero (1999) raised the secondary products, by-products and the commodity technology assumption based on

the methods above. Comparatively, this view differs from that of Kop Jansen and ten Raa (1990) who called the method proposed by ten Raa et al. (1984) a “mixed technology model”, because they thought it as a mix of the commodity and the by-product technology assumptions. Otherwise, Shigemi Kagawa Hajime Inamura, and Yuichi Moriguchi (2002) described the invisible multipliers of joint-products. Louis de Mesnard（2004）understood the shortcomings of commodity-based technology in input-output models, and raised an economic-circuit approach etc.

The researches above succeeded in obtaining some valuable conclusions. The EIO and WIO are effectual tools for researching the waste emission and waste management in the economy. The management of by-productions and joint-productions is used for reference when we turn to the circular materials in the circular economy. But the EIO, WIO, and the methods of analyzing by-productions and joint-productions based on UV-table have a deathful disadvantage when analyzing the circular economy. It is that the methods in the researches proposed only describe the single way of the material flows. Describing and analyzing the cycle way of the material flows could not be achieved. It is a pity that these are the most important parts in the circular economy. For example, the reused scraps and recycled scraps which are the most important process for the material flowing. There are not any researches about them, even the academic analysis or model. In fact, the process of the circular material flow in the circular economy is very clear and obvious. So it is possible to be described and analyzed. (Jiang Wenying, 2006; Liu Yi, 2006)

Based on those mainstream perspectives, the research of the circular economy should be started with the following aspects:

(1) Describe the process of the circular economy exactly. Nowadays, the mainstream method for analyzing environmental questions is the input-output technique. So, we will try to describe the circular economy process by IO technique. Input-output model as a partly equilibrium model which could calculate indirect impact easily is better choice than other econometric models. We even can say that IO model is the only choice for us.

(2) Analyze and evaluate the development level or degree of the circular economy exactly. And calculate the influences and contributions by the society and the environments, which is the test of the significances and effects of the circular economy. （Garrett Hardin, 2001 & Barry Commoner, 1997）

Concerning the problems above, in this paper, we pay attention to studying how to apply IO model to describe the circular economy, and abstract the evaluation indexes of development level of circular economy.

The paper is organized as follows: **section 2** will introduce the theory of the circular economy, containing the conception and principle to realize circular economy, the development pattern of

the circular economy, the boundary of some interrelated conceptions, and the circular paths. **Section 3** will propose a theoretical framework of the circular economy. It contains the industry classifying in the circular economy, the input-output table of the circular economy and the differences between it and the input-output table of the traditional economy, and the basic input-output model of the circular economy. In **section 4,** some indexes will be proposed to evaluate the development level of the circular economy.

2 Theory of the Circular Economy

2.1 The conception and pattern of the circular economy

The "Circular Economy" is the short for the "Closing Materials Cycle", and it is a new economic pattern and a new pattern of economy development. The meaning of circular economy is on the character of resource cycle, using the resources by a friendly way, and combining the environment protecting with the economy development. It takes the production of the human being into the process of nature cycle, and the nature resources and energy resources will be taken full advantage of in the perpetual cycle. So the economic activities will lessen the influence as much as possible to the nature. (William McDonough and Michael Braungart, 2005)

The broad sense of the circular economy is the social production and reproduction activities enclosing the use of high-efficiency resources and environment friendly. It mostly involves the resource saving and using, the recycle of scraps, and environment protecting. The technical methods are clean production, material flow analysis, and environment management et al. The aim is to gain the economic benefits and social benefits mostly with the least payment of the nature resource and environment, and to implement harmonious development of Human Societies. (Wu Jisong,2005)

The narrow sense of the circular economy is to develop economy by the social production and recycling activities such as reused scraps and recycled scraps. It is equal to the "Recycling Economy" or "Cycle Economy". (Wu Jisong,2005)

To regulate material flow mode and flux of traditional economic development pattern, the principle is "Reduced, Reused, and Recycled". Obviously, "Reduced" is to reduce the resource energy input in production and waste discharge in production and consumption, which belongs to the headstream control. "Reused" has two means. One is to consider prolonging the utility time of product and service in the process of design and production, and the other is reuse the scrap in the condition that the physical form and construction of waste are mostly unchanged, like the reusing of waste paper to product new paper. So "Reused" is both process control and terminal control. "Recycling" is to transform waste into new economic resource by physical and chemical process

and put the new resource into production, which belongs to terminal control.

The circular economy is a development that solving the contradiction between the band of nature resources and the pollution of the environment. It is a new type of development that transforms the pattern to the “Resource- Productions- New Resources” from the “Linear Pattern” and transforms the increasing pattern to the one that is based on both the nature resources and to cycle resources from the one that is based only on the nature resources. It is a multi-wins development which can progress the efficiency of using while taking the economy developing and environment protecting into account. In a word, the circular economy is one of the most effective approaches for the sustainable development.（Qu Geping, 2004）In addition, the circular economy will bring some social benefit, such as prolonging the industry chain, increasing jobs for employees. That is spilling benefit of circular economy, but not the main body.

The development pattern of traditional economy is named “Linear Pattern”, as shown in figure 1.

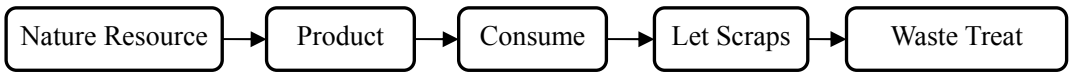


Fig 1. The “Linear Pattern” of the traditional economy

The pattern of the circular economy is shown in figure 2.

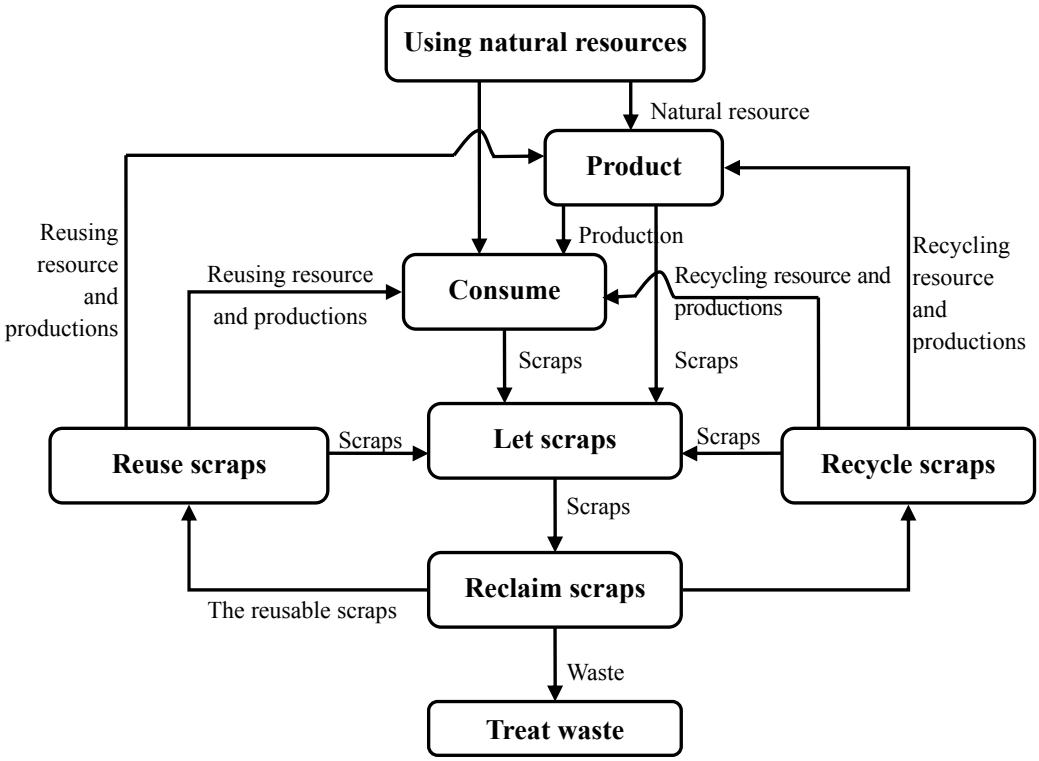


Fig. 2 The pattern of circular economy

To regulate the material flow pattern and flux in economic activity is the core feature distinguished from classic economy theory and also the spirit of circular economy. In other words,

the distinction between linear material flow pattern of “resource – product – waste” and cycling pattern of “resource – product – renewable resource” is the basic feature that distinguishes circular economy from traditional economy. It is noted that the statement of “closed material cycling pattern” should be avoided. Closed circulation is relative; however, open circulation is absolute. For example, the whole earth geographic circulation is closed but it is impossible that the material circulation in an enterprise, an industry, even a country or a region is closed. In addition, available technology cannot effectively recycle all the waste now; even there is not such technology. Some waste will eventually be discharged into ecologic system. Circular economy is to minimize waste discharge in a certain technology and economic condition.

2.2 The dissimilarity of some interrelated conceptions

In the circular economy, some indistinguishable conceptions in the traditional economy must be distinguished strictly. It is also the basis for the further analysis and research. So in this paper, we will distinguish four groups of analogical conceptions. That is scrap and waste, scraps let-sector and scraps reclaim-sector, the scraps reuse-sector and scraps recycle-sector, and reused resource and recycled resource.

Waste and Scrap

Wastes are the materials and productions which do not have any value or the value could not be reused any more. Up till now, three treatments for dealing with the wastes are fire, landfill, and compost.

The conceptions of scraps are openness that contains the materials and productions which flow out of the process of production and consumption. So they compose of the reusing scraps which can be reused directly as the reused resources, recycled scraps which can be recycled only after recycling and as the recycled resources, and the wastes. There are three ways to disposing the scraps correspondingly. Firstly, the reused scraps would be reused and turned into the reused resources. Secondly, the recycled scraps would be recycled and turned into recycled resources. Finally, the scraps which could not be reclaimed or could not be disposed would be let into the waste sectors and turned into wastes.

Scraps let-sector and Scraps reclaim-sector

There are a lot of scraps in the producing and consumption. Some of them will recycle in the sectors which they come from, or let to the others sectors through the let-sector. So the scraps will be let into the others sectors by let-sectors, which is the primary work of the let-sectors.

Reclaim-sectors collect the scraps from the let-sectors. Further, trim and classify these scraps into three kinds as follow: 1) the scraps which can be reused will be put into the reuse-sectors, 2) the scraps which can be recycled will be put into the recycle-sectors, and 3) the scraps only can be detruded into the waste sector.

In practically, most of the reclaim-sectors have been separated from the product-sector and there are still parts left in the product-sector. But the let-sectors almost combine with the product-sector because they belong to a part of the product process, so it is difficult to have them separated. Therefore, in this paper we separate the process of scraps letting in order to describe the flowing and letting of the scraps. At the same time, this is one of essential difference between the circular economy and the traditional economy.

Reuse and Recycle

We had pointed above that there are two approaches to reused the scraps—reusing the scrape and recycling the scrape. And there is essential difference between the two approaches. Furthermore, it has the order in the development of the circular economy. (William and Michael Braungart, 2005;Dai Beijun, 2006)

The reusing processes of scraps don't do any machining to scraps, namely, in the process the physical structures and the chemic characters don't change. The only thing is to reallocate reused scraps and this is related to the characters and the using of the scraps. Such as the reclaim of plastic bottles, it only needs simple choice to become the reusing resources of the plastic product sector to produce new plastic. In addition, reused scraps also mean the total reused resources, but in the process of production, because of the high cost and technique, there are little using spaces of it.

Recycled scraps are the process during which the physical structures could be changed, even the chemic characters. So it is more complicated than the reusing. It needs to say that in the process of production, the process of recycled scraps belong to a degenerated cycle and this reclaim will decrease the characters of the resource, so this will decrease the values of the resource in the process of cycle.

Reused resource and Recycled resource

Reuse resources are corresponding to reusable scraps and the reuse of scraps, in fact, by the process of reuse of scraps, reusable scraps can bring cycle resources. Likely, recycle resource are corresponding to recycle scraps and the recycle of scraps; by the process of recycle of scraps, recycle scraps can bring cycle resources. The key difference is the reuse resources are corresponding to the reuse scraps, namely, by the recycle process a recycle scraps will become one or several recycle resource, but by the same process different recycle scraps may become the same recycle resource. In addition, it needs to explain that in the present production process of preliminary circular economy, we find that reuse resources can be put into the process of product and consumption, but the recycle resources are little put into consumption process directly.

2.3 The industrial chains and the circular paths in the circular economy

It can be seen that the core of the circular economy are the ones concerning with the scraps

reused and scraps recycled showed in figure 2. This can be distinguished as the following two routes. （1）Scraps → Reusing → Circular Resources ;（2）Scraps → Recycling →Circular Resources.

Further, in the development of circular economy, the origin of the scraps is the producing and the consumption. (The scraps from the consumption are raised scarcely in the ancient researches; even if it has been pointed that the scraps from the consumption should not be neglected.（Koji Takase, 2005）But there are not any researches involved them.)

The usages of the reused and recycled scraps are also in the producing and consumption. So by the analysis of permutation and combination, eight circular paths could be concluded. These eight circular paths and their instances corresponding are shown in table 1. These instances corresponding shown in table 1 are referenced in (Dai Beijun, 2006).

Table 1. The circular links in the circular economy and the instances corresponded

No.	The circular links	the instances corresponded
①	**Scraps from the product → Reusing resource or productions → Product**	**Reusing scraps irons in the steel mill to produce new productions**
②	**Scraps from the product → Reusing resource or productions → Consume**	*Inexistence*
③	**Scraps from the product → Recycling resource or productions → Product**	**Guigang Ecological Demonstration Area of Recycle in China.**
④	**Scraps from the product → Recycling resource or productions → Consume**	*Inexistence*
⑤	**Scraps from the consume → Reusing resource or productions → Product**	**Reusing waste paper to produce new paper**
⑥	**Scraps from the consume→ Reusing resource or productions → Consume**	**Reusing domestic water to use in the horizon life**
⑦	**Scraps from the consume→ Recycling resource or productions → Product**	**One-off dining boxes recycle in Shanghai province in China.**
⑧	**Scraps from the consume→ Recycling resource or productions → Consume**	*Inexistence*

It is clear that there are only five reasonable cycle paths in table 1: ①,③,⑤,⑥,and ⑦. Simply analyzing the practical circular paths, we conclud that: 1) the recycled resources can not be used in the consumption process directly neither the scraps come from product process nor they come from consumption process. 2) The reused resources come from the production process can not be used into the consumption process directly.

The five cycle paths in the circular economy are shown in figure 3.

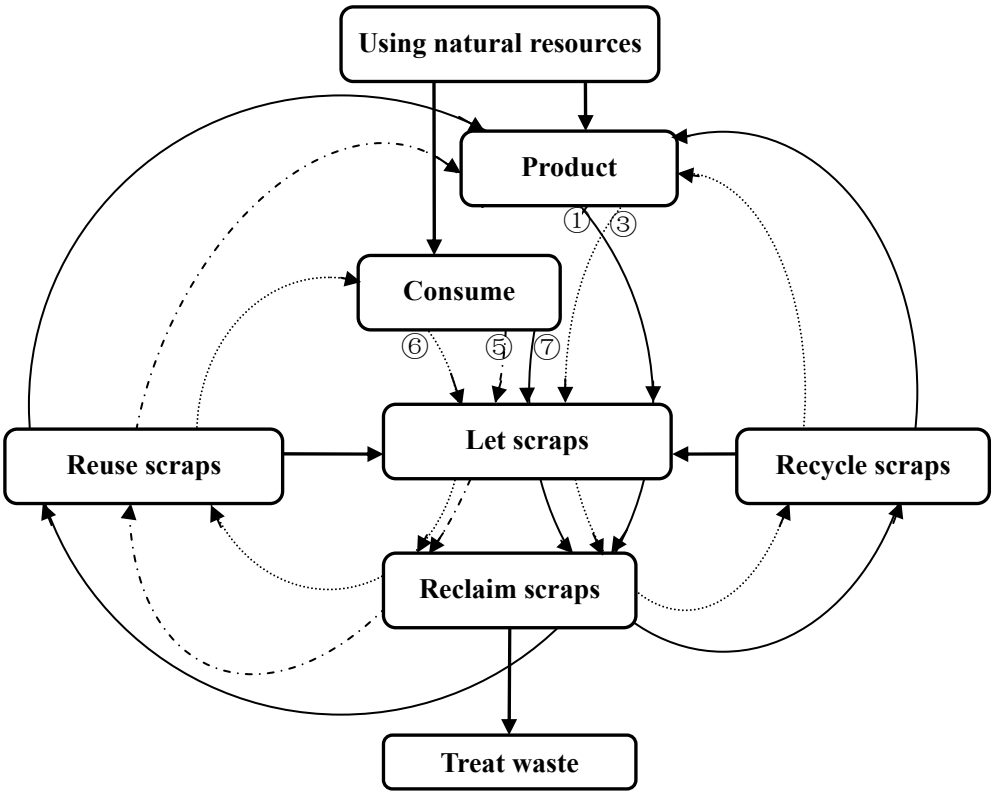


Fig 3. The circular links in the circular economy

There are two keynotes to conclude the industry links in the circular economy based on these circular paths in figure 3. 1) The product-sectors and consume-sector must be contained in the industry chains, so the production of the scraps can be included roundly; 2) Increase the let-sectors, reclaim-sectors, reuse-sectors, and the recycle-sectors, and set them to be a node of the industry chains, so the resources flows in the circular economy can be embodied, not only the single direction described.

3 Methodology

3.1 The industry classified and the input-output table of the circular economy

In the development of macro-economy, there are many differences between circular economy and traditional economy, and they are mainly appeared in the industry chains. The difference will result in the difference of the classification of sectors in the two patterns and it will determine the built of the input-output table and the construction of models. In this subsection, according to the pattern of circular economy and its industry chains to classify the industry sectors and constructs the input-output table of the circular economy.

In the case of circular economy, the process of production, consumption, the letting and reclaim of scraps are the processes of matter flowing. In this paper, we conclude the following 7 key steps: production process, construction process, the process of scraps let, the process of scraps reclaimed, the process of scraps reused, the process of scraps recycled, the process of waste treatment.

Table2. Structure of the circular economy input-output table

			Intermediate Demands							Final Demands	Total Output
			Product-sectors	Consume	Reuse-sectors	Recycle-sectors	Let-sectors	Reclaim-sectors			
								Reuse	Recycle		
			1,…,n	1	1,…, k	1,…,l	1,…, m	1,…, k	k+1,…,m		
Inter. Input	Product	1 … n	x_{ij}^{pp}	x_i^{pc}	x_{ij}^{pu}	x_{ij}^{pl}	x_{ij}^{pd}	$x_{ij}^{pr_u}$	$x_{ij}^{pr_l}$	Y_i^p	X_i^p
	Consume	1	x_j^{cp}	0	x_j^{cu}	x_j^{cl}	x_j^{cd}	$x_j^{cr_u}$	$x_j^{cr_l}$	Y^c	X^c
	Scrapes Reuse	1 … k	x_{ij}^{up}	x_i^{uc}	x_{ij}^{uu}	x_{ij}^{ul}	x_{ij}^{ud}	$x_{ij}^{ur_u}$	$x_{ij}^{ur_l}$	Y_i^u	X_i^u
	Scrapes Recycle	1 … l	x_{ij}^{lp}	x_i^{lc}	x_{ij}^{lu}	x_{ij}^{ll}	x_{ij}^{ld}	$x_{ij}^{lr_u}$	$x_{ij}^{lr_l}$	Y_i^l	X_i^l
	Scrapes Let	1 … m	s_{ij}^p	s_i^c	s_{ij}^u	s_{ij}^l	s_{ij}^d	$s_{ij}^{r_u}$	$s_{ij}^{r_l}$	Y_i^s	S_i
	Scrapes Reclaim Reuse	1 … k	0	0	x_{ij}^{ru}	0	0	0	0	$Y_i^{r_u}$	$X_i^{r_u}$
	Scrapes Reclaim Recycle	k+1 … m	0	0	0	x_{ij}^{rl}	0	0	0	$Y_i^{r_l}$	$X_i^{r_l}$
Primary Input			V_j^p	V^c	V_j^l	V_j^l	V_j^l	V_j^u	V_j^r		
Total Input			X_j^p	X^c	X_j^u	X_j^l	X_j^l	$X_j^{r_u}$	$X_j^{r_l}$		
Waste Emission		1 … m	w_{ij}^p	w_i^c	w_{ij}^u	w_{ij}^l	w_{ij}^d	$w_{ij}^{r_u}$	$w_{ij}^{r_l}$	Y_i^w	W_i

From table 2, it can be see that six of the above seven steps are the key steps of circular flowing, and each step has the effect that any others don't have. So they are relatively independent. And this is the main index of the classification of the sectors in the circular economy. Therefore, the key sectors in the circular economy should be classified into six sectors as follows: Product-sectors, Consume, Reuse-sectors, Recycle-sectors, Let-sectors, and Reclaim-sectors

which compartmentalized into the reuse and the recycle sectors. These sectors would be used for describing the circular process of the resources, so they should be put into the first quadrant. The waste sector is the last one. It would be put into the last line alone in the third quadrant because it doesn't in the circular process. In addition, the input of the labor forces which is in the third quadrant of the traditional economy's input-output table should be put into the first quadrant in order to correspond the consume sector in the first quadrant also. There are not any changes in the third quadrant except for this. And there are not any changes in the second quadrant except for the consumption of the residents who had been peeled off the final demands. So we construct the input-output table of the circular economy based on the principles above and is shown in table 2.

The factors in table 2 are explained as follows:

(1) A lot of scraps have been let from consumption, which is one of the most important resources of the scarps. So the consume-sector should be designed in the first quadrant, in order to have the scraps produced by consumption to enter the disposal of reuse or recycle that are the disposal of circular.

In table 2, x_i^{pc} represents the consumption of production *i* produced by product-sector *i*, and x_i^{uc} represents the consumption of the reused resources or production, and x_i^{lc} represents the consumption of the recycled resources or productions. s_i^c represents the quantity of the scraps let by consume-sector. It is necessary to point that the consumption of the reused scraps reclaimed by the reclaim-sector can only be used by the reused-sector, as the recycled scraps only used by the recycle-sectors. So the consumptions of the reused scraps and the recycled scraps reclaimed by the reclaim-sector are zero except for them, which can be seen clearly in table 2. In addition, we make the consumption of consume-sector itself to be 0.

In table 2, x_j^{cp} represents the payment for the labor forces which are used for product-sector, and x_j^{cu} represents payment for the labor forces which are used for reusing scraps, and the same as $x_j^{cl}, x_j^{cd}, x_j^{cr_u}$ $x_j^{cr_l}$.

w_i^c represents the quantity of each kind of the waste emission from the consume-sector.

Finally, Y^c represents the payment for the labor forces used in final demand, X^c represents the total of the payment for the labor forces, V^c represents the primary input for the consume-sector.

(2) Add the reuse-sector, recycle-sector, and let-sector in the first quadrant. So the circular

economy can be described by the model in table 2. Take the reuse- sectors as an example, x_{ij}^{up} represents the consumption of the reusing resource or production produced by the reuse-sector i by the product-sector j, x_i^{uc} is explained above, and x_{ij}^{uu} represents the consumption of the resource or production produced by the reuse-sector i of the reuse-sector j, and x_{ij}^{ul}, x_{ij}^{ud}, $x_{ij}^{ur_u}$, $x_{ij}^{ur_l}$ represent the consumption of the resource or production produced by the reuse-sector i of the recycle-sector j, the let-sector j, the reused scraps reclaim-sector j, and the recycled scraps reclaim-sector j, respectively.

Y_i^u represents the consumption of the resource or production i for the final demands, and X_i^u represents the total reused resources and productions produced all by the reuse-sectors.

(3)There are some relationships between the reclaim-sectors and the waste sectors. It is that the quantity of the scraps reclaimed from each sectors is equal to the quantity of the waste subtracted from the quantity of the scraps let in each sectors. So it is easy to calculate the quantity of the scraps reclaimed from each sectors. In order to avoid the surplus information, the scraps reclaimed from each sectors is not described in table 2. For example, the scraps reclaimed by the reclaim-sector of product-sector are calculated by $s_{ij}^p - w_{ij}^p$.

3.2 The differences between the input-output tables of the circular economy and the traditional economy.

In this paper, we take the 2002 input-output table of China as an example for the traditional IO table, which is published in 2006 by the NBS (National Bureau of Statistics) in China. The newest IO table is 122-sector input-output table for 2002. Its basic structure is shown in table 3.

Table 3. Structure of Chinese input-output table

		Intermediate demand	Final demands			Import	Total output
		1, 2, ……， n	Consume-sector	Invest	Export		
Intermediate input	1 2 ⋮ n						
Primary input							
Total input							

There are three major differences between the circular economy input-output table and the traditional economy input-output table.

（1）The scraps let by the consume-sector could not be ignored. In the traditional input-output table, the consumptions are concluded in the final demand and the primary input. Although it can describe the consumption and input of the other production process, it never refers to the process of scraps letting, so it can't describe the resources circular process completely which has consumption process in. However, in the circular economy input-output table, consume-sector lies in the first quadrant, and this is a part of intermediate input. The process of scraps circular using can be totally described. That is the contents do not appear in the traditional input-output table.

（2）In the circular economy input-output table, the product of the produce-sector and other sectors and the consumption of the consume-sector could be understood expressly through classifying the produce-sector, the reuse-sector, and the recycle-sector. And through it we can know the kinds and the quantity of the circular resources or productions use in each sector. But in the traditional economy input-output table, we can only know the total gross of the resources, in which the nature resources and the circular resources are mixed.

（3）In the traditional economy input-output table, the quantity of the waste let is calculated. But in the practical production process, many processes contain the waste treatment from their own sectors. So the calculated wastes are the wastes which have been reclaimed. But in the circular economy input-output table, the processes are much more amply and the scraps let-sectors and reclaim-sectors are added. Thus, it not only computes the waste net let of the whole society but also clearly describes the quantity of the scraps which can be transformed into the circular resource.

To describe the whole process of the circular, nothing but to describing the way of the resource using, the way of the product producing, the way of the scraps reclaiming and the way of the scraps transforming into the circular resource. These would not be achieved by using the traditional economy input-output table. In order to describe them clearly and integrally, these process should be self-existent with each other.

It is necessary to explained that the traditional economy input-output table can be described by value and it satisfies both the balance relationship in row and in column. But in the circular economy input-output table, there are scraps, recycle resource, reuse resource and waste, and in the present we can not give these value evaluations exactly. Therefore, the circular economy input-output table is only described by scales in present, and it only satisfies the balance relationship in row. From the definition of circular resources (recycle resource and reuse resource), it is found that the circular resources have excellent characters that these units can be consistent with the productions produced by produce sectors and the scraps. The good consistency has been embodied when the indexes defined. This point is one of the breakthrough points of the value

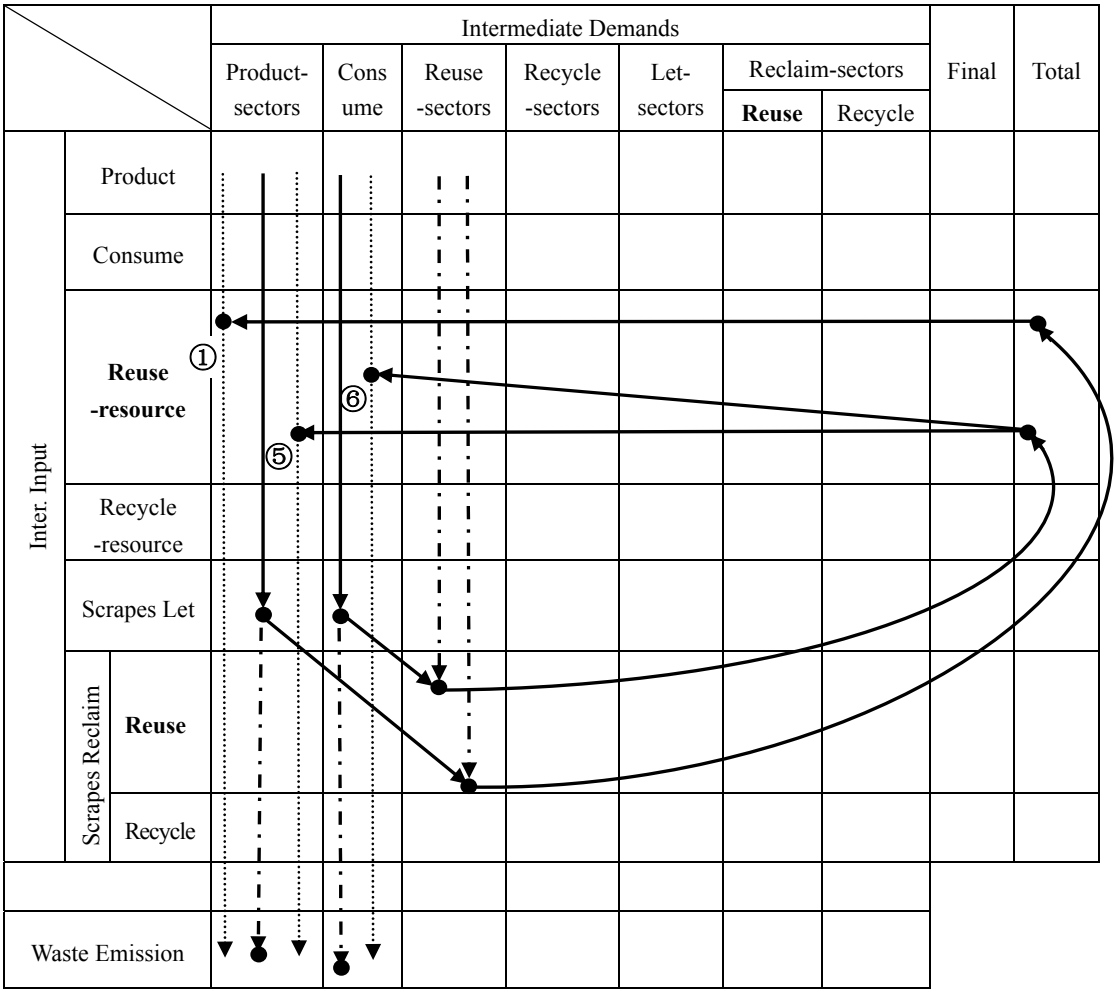
input-output table of the circular economy, and this is one of the keystones of the following work of our following research.

3.3 The circular path described in the circular economy input-output table

The descriptions of the resources circular process (circular paths) in the circular economy can be realized in the circular economy input-output table (table 2). According to the five circular paths of table 5, we will figure out them in the circular economy input-output table.

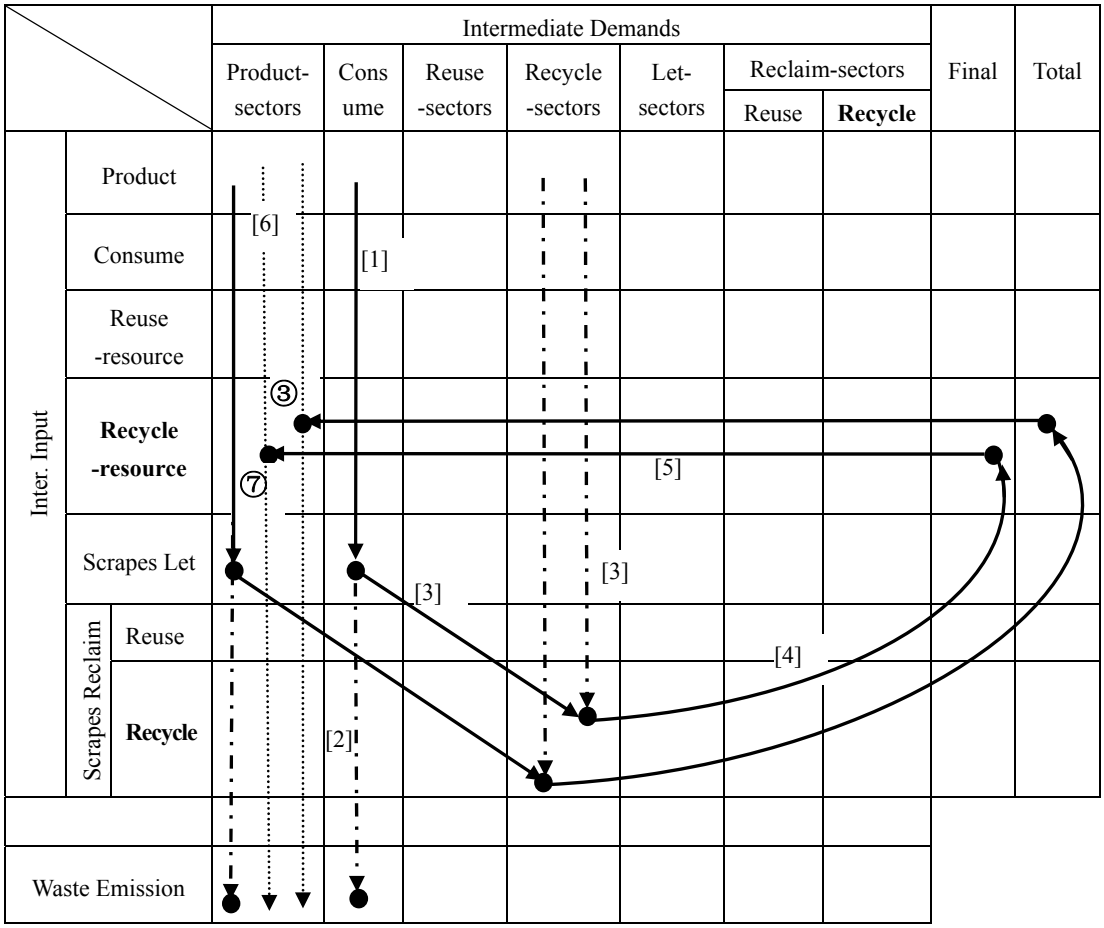
It is one of the circular processes which the scraps are transformed into the circular resource by the circular treating way of reusing. And it is described in the table 4-(a) as path①, path⑤, and path⑥.

Table 4-(a). The circular paths described in the input-output table of circular economy



Similarly, it describes the others circular courses in table 4-(b), in which the scraps are transformed into the circular resource by the circular treating way of recycling. It is described in the table 4-(a) as path③ and path⑦.

Table 4-(b). The cycle path described in the input-output table of circular economy



Take circular path ⑦ as an example to introduce each stage and process in it. Path ⑦ has the following six stages: [1]In the consumption process of the consume-sectors, they consume the products produced by product-sectors and the products produced by reuse-sectors and recycle-sectors (reuse resources and recycle resources). [2]In the consumption process, many scraps will be brought and they would be let out by the scraps let-sectors. The scraps which do not have any value and scraps which are failed to be reclaimed will enter waste-sectors. [3]The other scraps will be reclaimed by reclaim-sectors and become reusable scraps and recycled scraps. [4]Put the recycled scraps into the scraps recycle-sectors to recycle dispose and to be recycled resources or products. [5]Put the recycled resources or products into the produce process [6]. Finally, process [6] use them once again and end their circle process of resources.

3.4 The basic model of the circular economy input-output analysis

Based on the table 2, we can get the following balance equations in row:

$$\sum_{j=1}^{n} x_{ij}^{pp} + x_i^{pc} + \sum_{j=1}^{k} x_{ij}^{pu} + \sum_{j=1}^{l} x_{ij}^{pl} + \sum_{j=1}^{m} x_{ij}^{pd} + \sum_{j=1}^{k} x_{ij}^{pr_u} + \sum_{j=k+1}^{m} x_{ij}^{pr_l} + Y_i^{\,p} = X_i^{\,p} \quad i = 1, \cdots, n \qquad (1)$$

$$\sum_{j=1}^{n} x_j^{cp} + \sum_{j=1}^{k} x_j^{cu} + \sum_{j=1}^{l} x_j^{cl} + \sum_{j=1}^{m} x_j^{cd} + \sum_{j=1}^{k} x_j^{cr_u} + \sum_{j=k+1}^{m} x_j^{cr_l} + Y^{\,c} = X^{\,c} \qquad (2)$$

$$\sum_{j=1}^{n} x_{ij}^{up} + x_i^{uc} + \sum_{j=1}^{k} x_{ij}^{uu} + \sum_{j=1}^{l} x_{ij}^{ul} + \sum_{j=1}^{m} x_{ij}^{ud} + \sum_{j=1}^{k} x_{ij}^{ur_u} + \sum_{j=k+1}^{m} x_{ij}^{ur_l} + Y_i^{u} = X_i^{u} \quad i = 1, \cdots, k \quad (3)$$

$$\sum_{j=1}^{n} x_{ij}^{lp} + x_i^{lc} + \sum_{j=1}^{k} x_{ij}^{lu} + \sum_{j=1}^{l} x_{ij}^{ll} + \sum_{j=1}^{m} x_{ij}^{ld} + \sum_{j=1}^{k} x_{ij}^{lr_u} + \sum_{j=k+1}^{m} x_{ij}^{lr_l} + Y_i^{l} = X_i^{l} \quad i = 1, \cdots, l \quad (4)$$

$$\sum_{j=1}^{n} s_{ij}^{p} + s_i^{c} + \sum_{j=1}^{k} s_{ij}^{u} + \sum_{j=1}^{l} s_{ij}^{l} + \sum_{j=1}^{m} s_{ij}^{d} + \sum_{j=1}^{k} s_{ij}^{r_u} + \sum_{j=k+1}^{m} s_{ij}^{r_l} + Y_i^{s} = S_i \quad i = 1, \cdots, m \quad (5)$$

$$\sum_{j=1}^{k} x_{ij}^{ru} + + Y_i^{r_u} = X_i^{r_u} \quad i = 1, \cdots, k \quad (6)$$

$$\sum_{j=1}^{l} x_{ij}^{rl} + + Y_i^{r_l} = X_i^{r_l} \quad i = k+1, \cdots, m \quad (7)$$

The direct input coefficient had been introduced and calculated in table 4.

Table 4 The symbol and estimation formula of the direct input coefficient in each sector.

THE NAME OF THE COEFFICIENT		THE SYMBOL AND THE ESTIMATION FORMULA						
		PRODUCT-SECTOR	CONSUME-SECTOR	REUSE-SECTOR	RECYCLE-SECTOR	LET -SECTOR	RECLAIM -SECTOR	
							Reuse	Recycle
direct input consumption coefficient of productions		$A^{pp}=\left(a_{ij}^{pp}\right)$ $=x_{ij}^{pp}/X_j^{p}$	$A^{pc}=\left(a_i^{pc}\right)$ $=x_i^{pc}/X^{c}$	$A^{pu}=\left(a_{ij}^{pu}\right)$ $=x_{ij}^{pu}/X_j^{u}$	$A^{pl}=\left(a_{ij}^{pl}\right)$ $=x_{ij}^{pl}/X_j^{l}$	$A^{pd}=\left(a_{ij}^{pd}\right)$ $=x_{ij}^{pd}/X_j^{d}$	$A^{pr_u}=\left(a_{ij}^{pr_u}\right)$ $=x_{ij}^{pr_u}/X_j^{r_u}$	$A^{ur_l}=\left(a_{ij}^{ur_l}\right)$ $=x_{ij}^{ur_l}/X_j^{r_l}$
direct input coefficient of labor forces		$A^{cp}=\left(a_j^{cp}\right)$ $=x_j^{cp}/X_j^{p}$	0	$A^{cu}=\left(a_j^{cu}\right)$ $=x_j^{cu}/X_j^{u}$	$A^{cl}=\left(a_j^{cl}\right)$ $=x_j^{cl}/X_j^{l}$	$A^{cd}=\left(a_j^{cd}\right)$ $=x_j^{cd}/X_j^{d}$	$A^{cr_u}=\left(a_j^{cr_u}\right)$ $=x_j^{cr_u}/X_j^{r_u}$	$A^{cr_l}=\left(a_j^{cr_l}\right)$ $=x_j^{cr_l}/X_j^{r_l}$
direct input coefficient of reused productions		$A^{up}=\left(a_{ij}^{up}\right)$ $=x_{ij}^{up}/X_i^{p}$	$A^{uc}=\left(a_i^{uc}\right)$ $=x_i^{uc}/X^{c}$	$A^{uu}=\left(a_{ij}^{uu}\right)$ $=x_{ij}^{uu}/X_j^{u}$	$A^{ul}=\left(a_{ij}^{ul}\right)$ $=x_{ij}^{ul}/X_j^{l}$	$A^{ud}=\left(a_{ij}^{ud}\right)$ $=x_{ij}^{ud}/X_j^{d}$	$A^{ur_u}=\left(a_{ij}^{ur_u}\right)$ $=x_{ij}^{ur_u}/X_j^{r_u}$	$A^{uc_l}=\left(a_{ij}^{cr_l}\right)$ $=x_{ij}^{cr_l}/X_j^{r_l}$
direct input coefficient of recycled resources		$A^{lp}=\left(a_{ij}^{lp}\right)$ $=x_{ij}^{lp}/X_i^{p}$	$A^{lc}=\left(a_i^{lc}\right)$ $=x_i^{lc}/X^{c}$	$A^{lu}=\left(a_{ij}^{lu}\right)$ $=x_{ij}^{lu}/X_j^{u}$	$A^{ll}=\left(a_{ij}^{ll}\right)$ $=x_{ij}^{ll}/X_j^{l}$	$A^{dl}=\left(a_{ij}^{dl}\right)$ $=x_{ij}^{dl}/X_j^{d}$	$A^{lr_u}=\left(a_{ij}^{lr_u}\right)$ $=x_{ij}^{lr_u}/X_j^{r_u}$	$A^{lr_l}=\left(a_{ij}^{lr_l}\right)$ $=x_{ij}^{lr_l}/X_j^{r_l}$
direct let coefficient of scrapes		$A^{dp}=\left(a_{ij}^{dp}\right)$ $=s_{ij}^{p}/X_j^{p}$	$A^{dc}=\left(a_{ij}^{dc}\right)$ $=s_i^{c}/X^{c}$	$A^{du}=\left(a_{ij}^{du}\right)$ $=s_{ij}^{u}/X_j^{u}$	$A^{dl}=\left(a_{ij}^{dl}\right)$ $=x_{ij}^{dl}/X_j^{l}$	$A^{dd}=\left(a_{ij}^{dd}\right)$ $=x_{ij}^{dd}/X_j^{d}$	$A^{dr_u}=\left(a_{ij}^{dr_u}\right)$ $=x_{ij}^{dr_u}/X_j^{r_u}$	$A^{dr_l}=\left(a_{ij}^{dr_l}\right)$ $=x_{ij}^{dr_l}/X_j^{r_l}$
direct input coefficient of scrapes reclaimed	Reuse	0	0	$A^{ru}=\left(a_{ij}^{ru}\right)$ $=X_{ij}^{ru}/X_j^{u}$	0	0	0	0
	Recycle	0	0	0	$A^{rl}=\left(a_{ij}^{rl}\right)$ $=x_{ij}^{rl}/X_j^{l}$	0	0	0

The formulas in table 4 are reasonable in the condition of all kinds of scraps and circular resources which contain the reused resources and the recycled resources could be calculated in

value but not scale. And the value evaluation of the circular resources and the scraps are not discussed in this paper. It is supposed that the value of all kinds of scraps and circular resources are known. We rewrite formula（1） —（7）in partitioned matrix form based on table 4.

$$\begin{pmatrix} A^{pp} & A^{pc} & A^{pu} & A^{pl} & A^{pd} & A^{pr_u} & A^{pr_l} \\ A^{cp} & 0 & A^{cu} & A^{cl} & A^{cd} & A^{cr_u} & A^{cr_l} \\ A^{up} & A^{uc} & A^{uu} & A^{ul} & A^{ud} & A^{ur_u} & A^{ur_l} \\ A^{lp} & A^{lc} & A^{lu} & A^{ll} & A^{ld} & A^{lr_u} & A^{lr_l} \\ A^{dp} & A^{dc} & A^{du} & A^{dl} & A^{dd} & A^{dr_u} & A^{dr_l} \\ 0 & 0 & A^{ru} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & A^{rl} & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} X^{p} \\ X^{c} \\ X^{u} \\ X^{l} \\ S \\ X^{r_u} \\ X^{r_l} \end{pmatrix} + \begin{pmatrix} Y^{p} \\ Y^{c} \\ Y^{u} \\ Y^{l} \\ Y^{s} \\ Y^{r_u} \\ Y^{r_l} \end{pmatrix} = \begin{pmatrix} X^{p} \\ X^{c} \\ X^{u} \\ X^{l} \\ S \\ X^{r_u} \\ X^{r_l} \end{pmatrix} \tag{8}$$

Expressing the endogenous variables in terms of the exogenous variables and parameters:

$$\begin{pmatrix} X^{p} \\ X^{c} \\ X^{u} \\ X^{l} \\ S \\ X^{r_u} \\ X^{r_l} \end{pmatrix} = \begin{pmatrix} I-A^{pp} & -A^{pc} & -A^{pu} & -A^{pl} & -A^{pd} & -A^{pr_u} & -A^{pr_l} \\ -A^{cp} & I & -A^{cu} & -A^{cl} & -A^{cd} & -A^{cr_u} & -A^{cr_l} \\ -A^{up} & -A^{uc} & I-A^{uu} & -A^{ul} & -A^{ud} & -A^{ur_u} & -A^{ur_l} \\ -A^{lp} & -A^{lc} & -A^{lu} & I-A^{ll} & -A^{ld} & -A^{lr_u} & -A^{lr_l} \\ -A^{dp} & -A^{dc} & -A^{du} & -A^{dl} & I-A^{dd} & -A^{dr_u} & -A^{dr_l} \\ 0 & 0 & -A^{ru} & 0 & 0 & I & 0 \\ 0 & 0 & 0 & -A^{rl} & 0 & 0 & I \end{pmatrix}^{-1} \begin{pmatrix} Y^{p} \\ Y^{c} \\ Y^{u} \\ Y^{l} \\ Y^{s} \\ Y^{r_u} \\ Y^{r_l} \end{pmatrix} \tag{9}$$

Furthermore, introducing the quantities of waste W_i.

$$W_i = \begin{cases} S_i - X_i^{r_u} & i \in 1,\cdots,k \\ S_i - X_i^{r_l} & i \in k+1,\cdots,m \end{cases} \tag{10}$$

4 Application

In brief, the significance of developing circular economy is to increase the efficiency of the resources and to decrease the consumption of nature resources, the waste letting, and the pollution. The final aim is to achieve the sustainable development in society. In this process, the developing level of circular economy is higher and higher. So to evaluate the development level of the circular economy correctly has become the chief tasks of the application research of the circular economy.

In this section, we analyze the key factors which influence and decide the developing level of circular economy firstly. Based on it, the evaluation indexes of measuring the developing level of the circular economy are proposed. According to the practicality development of the circular economy, the measure model for evaluating the developing level of the circular economy.

4.1 The influence factors of development level of the circular economy

The developing level of circular economy is a measurement of the consummate degree of the development of circular economy. The core of the circular economy is the circular using of resources (or scraps, which is the same in essentially but the beginning of the circular is different). The simplest description is shown in table 4.

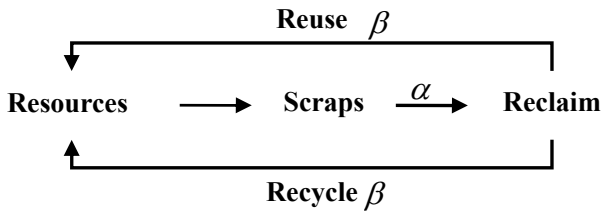


Fig. 4 Concise description of the circular economy

The analysis based on table 4, it is found that there are two key steps to influence the developing level of the circular economy: 1) The process of the letting scraps become recycled scraps by reclaiming, namely the reclaim process. 2) The other is the process that the reclaimed scraps become recycle resources, namely the process of reuse and recycle. These are the simplest and most preliminary influences.

Based on the two steps above, in this paper, we respectively define two evaluate indexes of developing level of the circular economy: Reclaimed Ratio index α_i and Circular Efficiency indexes β_i to measure the influence of these two key steps above.

4.2 The evaluation indexes of the development level of the circular economy

The Reclaimed Ratio Indexes α_i

The definition of the Reclaimed Ratio indexes are the proportion of the quantity of the scraps reclaimed in the quantity of the scraps let. Only the reclaimed scraps can be performed into the reused or recycled resource, but the scraps failed to be reclaimed will be put into waste-sectors. In the circular economy input-output table (table 2), the quantity of the scraps reusable, the scraps recycle and the scraps let have been described in table 2 separately. In addition, there some differences in the indexes calculation. The formula is as follows:

$$\alpha_i = \begin{cases} \dfrac{X_i^u}{S_i} & i \in 1,\cdots,k \\ \dfrac{R_i}{S_i} & i \in k+1,\cdots,m \end{cases} \qquad (11)$$

Where X_i^u denotes the *i*th reclaimed scraps (it also denote the gross of the *i*th reusable resources). When $i \in 1,\cdots,k$, S_i denotes the *i*th reused scraps; When $i \in k+1,\cdots,m$, S_i

denotes the *i*th recycled scraps. R_i denotes the quantity of the *i*th scraps reclaimed. X_i^u、S_i、R_i can be found in table 2 directly. In the computation, because X_i^u、S_i、R_i all denote the *i*th scraps and have the consistent unit, it could be calculated both in scale and value.

The Circular Efficiency Indexes β_i

We have pointed that in the practical production process, the recycle process of scraps is a kind of degenerated cycle and the reclaiming will degenerate the character of resources following the time pasting and the times increased of reclaim, so the values of resources will reduce in the circular process. Based on this principle, the circular efficiency of scraps is defined to be the proportion of circular resource unit value in their former resource unit value. In the practical production, the unit value of the former resource and the unit value of circular resource can be measured by their market price approximately. In this paper, we suppose $p_i^{u_0}$ and p_i^u denote the unit value of the former resource and circular resource respectively. The computing formula of circular efficiency β_i of scraps S_i is as follows:

$$\beta_i = \begin{cases} \dfrac{p_i^u}{p_i^{u_o}} & i \in 1,\cdots,k \\ \dfrac{x_{i1}^{rl}}{R_i}\cdot\dfrac{p_1^l}{p_1^{l_0}} + \dfrac{x_{i2}^{rl}}{R_i}\cdot\dfrac{p_2^l}{p_2^{l_0}} + \cdots + \dfrac{x_{il}^{rl}}{R_i}\cdot\dfrac{p_l^l}{p_l^{l_0}} & i \in k+1,\cdots,m \end{cases} \qquad (12)$$

Where $i \in 1,\cdots,k$ denotes the reusable scraps. As to the reusable scraps, because it can be totally reused, it is also to say that the reused scraps are the reused resources. According to the definition of reused resource, it does not have any differences to the former resource, so they are consistent with each other in the market price, namely they do not have any value loss. Therefore, to the reusable scraps, its circular efficiency is $\beta_i = p_i^u / p_i^{u_o} = 1$.

As to the circular use of recycled scraps, it must perform recycle treatment, so the unit value of recycle resource is generally less than the unit value of the former resource. Furthermore, in the practical production process, recycled scraps and recycled resource are not corresponding with each other. (After recycling dispose, a recycled scrap may be formed several recycled resources, and different recycled scraps may be formed the same recycled resource. This is one of differences between the reuse circular process and the recycle circular process.) Therefore, the calculation of the Circular Efficiency of recycled scraps is determined by the Circular Efficiency of the recycled resources which they formed. Take the *i*th recycled scrap as an example, suppose that the gross of the *i*th recycled scrap is R_i, and the inputs into each recycle-sector are x_{i1}^{rl}, x_{i2}^{rl}, ……,

x_{il}^{rl} (x_{ij}^{rl} can be found in table 2). p_i^l is the unit value of the *i*th recycled resource, and $p_i^{l_0}$ is the unit value of former resource corresponding to the *i*th recycled resource. The Circular Efficiency of the *i*th recycled scrap $\beta_i = \frac{x_{i1}^{rl}}{R_i} \cdot \frac{p_1^l}{p_1^{l_0}} + \frac{x_{i2}^{rl}}{R_i} \cdot \frac{p_2^l}{p_2^{l_0}} + \cdots + \frac{x_{il}^{rl}}{R_i} \cdot \frac{p_l^l}{p_l^{l_0}}$ is the weight average of the corresponding Circular Efficiency of circular resources. Because of $p_i^l \le p_i^{l_0}$, the spectrum of the Circular Efficiency of the recycled resources are $\beta_i \in [0, 1]$.

4.3 The measure model of the development level of the circular economy

In this research, we propose the Circular Level index to reflect the development level of the circular economy system. Firstly, we should determine the calculation formula of the Circular Level ***cl*** of resource (or scraps). The measure model of the Circular Level of the society is based on it.

The Circular Level cl_i of Scraps S_i

The circular level of scraps is the product of the Reclaimed Ratio of the scraps and Circular Efficiency. It represents the degree that the scraps from production process can efficiently recycle into circular resource. The formula of the circular level cl_i of scraps S_i is as follows:

$$cl_i = \alpha_i \cdot \beta_i \tag{13}$$

Where α_i is the Reclaimed Ratio of scraps S_i, and β_i is Circular Efficiency of scraps S_i. From formula (11) and (12), compute the Reclaimed Ratio α_i and Circular Efficiency β_i of *i*th recycle scraps, then take them into formula (13), we can calculate the circular level Circular Level cl_i of the scraps, where $cl_i \in [0, 1]$. The higher circular level of the scraps is, the larger reusable proportion is after disposing, and the smaller proportion they become waste, so the smaller influence they give environment.

The Circular Level *CL* of Economy System

The circular level of whole economy system is the synthetically evaluation of circular level of each resource (waste) in the economy system. It reflects the scraps reclaimed in the whole system and average level which the value in the circular resources recovered. In this paper, Circular Level *CL* is the weight average of all resources (wastes) in the economy system. The formula is as follows:

$$CL = \sum_i \frac{S_i \cdot p_i^s}{\sum_j S_j \cdot p_j^s} \cdot cl_i \tag{14}$$

Where S_i denotes the quantity of the *i*th scrap let, it can be found in table 2, but S_i shown as scale in table 2. So we can not calculate the proportion of scraps directly, we need to unify the form of quantity of value. Suppose p_i^s denotes the unit value of the *i*th scrap and cl_i is the circular level of the scraps, which can be obtained by formula (13). Circular Level *CL* lies in [0，1]. The closer the value of *CL* is to 1 the higher the Circular Level of economy system is. When *CL*=1, Circular Level arrives at the maximum and in this time the economy system is completely circular. In this condition, sustainable development will come to the ideal equilibrium state.

5 Conclusion and Prospect

In summary, we have analyzed and summarized the circular economy systemically, and described the way of the circular economy performs, and the key circular paths in the circular economy by using the tools of input-output analysis in this paper. Those conclusions enrich the theory of the circular economy, and break a new path for the quantitative analysis of it.

In section 2, the development pattern of the circular economy have been proposed (table 2 in subsection 2.1), and the key conception of circular economy had been restricted strictly. Further, combined with the practical development of the circular economy, the main circular paths (table 1 and figure 4 of subsection 2.3) have been abstracted.

In section 3, the circular economy input-output table has been constructed (table 2). The differences between the circular economy input-output table and the traditional economy input-output table (in subsection 3.2) had been conclude and the concrete representation of the circular path had been shown in table 2 (table 4 of subsection 3.3). Further, the basic model of the circular economy input-output analysis has been proposed. (in subsection 3.2)

The section 4 is applied analysis. Firstly, the key influence factors that affect the development level of circular economy and the corresponding influence paths have been concluded. The Reclaimed Ratio index and Circular Efficiency index of resources (or scraps) have been defined combined with table 2. Further, the evaluation pattern of circular level of circular economy has been defined (subsection 4.3) so that one can apply it into simply analysis and evaluate the development of circular economy.

There is some advice which is received by analyzing the theory of the circular economy and taking the developing actuality into account for improving the development level and completing the circular economy. 1）Improve the reclaimed ratio as much as possible, and reduce the quantities of the scraps which will be transformed into waste. In practicality, the reclaimed ratio of the producing process depends on the technology level, but the ratio of the consumption process

depends on the degree of the understanding and the recognition to the scraps reclaimed. In addition, it is necessary to make great efforts to reduce the production of the scraps which could not be reclaimed, and it is important to take the same measures to deal with it at the beginning of the producing process. 2）Improve the circular efficiency as much as possible. The value lost in the circular dispose will be deduced, and resources will be reused or recycled more times. In practically, the circular efficiency depends on the technology level, especially on the technology level of the recycled sectors. 3）Using irreproducible resources as less as possible, and finding the reproducible resources or the resources which can be reused or recycled to substitute it.

Nowadays, the ideology of the circular economy has just been proposed. And the circular level is very low at the beginning of the circular economy developing in every national economy system. The circular level will be higher and higher by enlarging the scope of the circular pattern practiced in the society and improving the technology level, while the value of the reclaimed ratio and the circular efficiency are bigger and bigger. It needs long time and hard work of all the people in the world to strive for this, and the "ideal state" would be realized when the society is circular completely.

References

[1]. Zhou Hongchun, Liu Yanhua et al. THE CIRCULAR ECONOMY. ***China Development Press: Beijing***, 2005.09 (in Chinese).

[2]. Zhou Goumei, Ren Yong. THE DEVELOPMENT PATTERN AND POLICY FRAMEWORK OF CIRCULAR ECONOMY IN CHINA. IEEE conference, 2005

[3]. Dai Beijun. THE PRACTICAL CASES OF THE CIRCULAR ECONOMY. ***China Environment Economy Science Press: Beijing,*** 2006. (In Chinese).

[4]. RachelCarson, SILENT SPRING. ***Jilin People's Press: Changchun***.1997. (In Chinese)

[5]. Bill Mckibben. END OF NATURE. ***Jilin People's Press： Changchun***.1997. (In Chinese)

[6]. WCED. OUR COMMON FUTURE. ***Jilin People's Press: Changchun***. 1997. (In Chinese)

[7]. UN.RIO DECLARATION ON ENVIRONMENT AND DEVELOPMENT. ***United Nations publication***, No. E.73.II.A.14.

[8]. Zhu Dajian, Zang Mandan, Zhu Yuan. C-MODEL: THE STRATEGIC CHOICE FOR DEVELOPING THE CIRCULAR ECONOMY IN CHINA. ***China Population, Resources and Environment***. 2005, vol. 15, issue 6: p8-12. (In Chinese)

[9]. Yu Liying, Feng Zhihuan. DESIGN THE INDEX SYSTEM FOR THE CITY CIRCULAR ECONOMY EVALUATING. ***China Soft Science***. 2005, vol. 12: p44-53. (In Chinese)

[10]. Li Huiming, Wang Junfeng. THE KEY TO DEVELOP THE CIRCULAR ECONOMY IS TO REINFORCE THE MATERIAL FLOW ANALYSIS. ***Economic Review,*** 2006, vol. 2： p24-26. (In Chinese)

[11]. Qu Geping. TAKING THE ROAD OF SUSTAINABLE DEVELOPMENT AROUND CIRCULAR ECONOMY. Speech on 2004 Shanghai Forum on International Science Popularization. 2004. (In Chinese)

[12]. Zheng Yunhong, Li Kai, Wu Shan. THE FISCAL CHARGES POLICY FOR DEVELOPING THE CIRCULAR ECONOMY IN CHINA. ***Journal of Northeastern University.*** (Nature science), 2004. Vol. 7:p260-262. (In Chinese)

[13]. Leontief, W. ENVIRONMENTAL REPERCUSSION S AND THE ECONOMIC STRUCTURE: AN INPUT OUTPUT APPROACH. ***Review of Economics and Statistics***. 1970,52(3): 262–271.

[14]. Jiang Wenying, Chai Liyuan, He Dewen. THE RESEARCHING ACTUALITY AND THE HEADWAY OF THE MATERIAL FLOW ANALYSIS IN THE CIRCULAR ECONOMY. ***Industrial Safety and Environmental Protection***, 2006，vol. 32, issue 4: p 48-50. (In Chinese)

[15]. Liu Yi, Chen Jining. THE MATERIAL FLOW ANALYSIS OF THE PHOSPHORUS SYSTEM IN CHINA. ***China Environmental Science.*** 2006，vol. 26, issue 2: p 238-242. (In Chinese)

[16]. Garrett Hardin. Living Within LIMITS- ECOLOGY, ECONOMICS, POPULATION TABOOS. ***Shanghai Translation Publishing House***: Shanghai, 2001 (In Chinese)

[17]. Barry Commoner. THE CLOSING CIRCLE—NATURE, MAN AND TECHNOLOGY. ***Jilin People's Press: Changchun***.1997. (In Chinese)

[18]. Reid Bailey, Bert Bras, and Janet Allen. MEASURING MATERIAL CYCLING IN INDUSTRIAL SYSTEMS. IEEE conference, 2001

[19]. Tohru Morioka, Noboru Yoshida, and Yugo Yamamoto. CYCLE-CLOSING PRODUCT CHAIN MANAGEMENT WITH APPROPRIATE PRODUCTION SITE METABOLISM ZERO-EMISSION IN AN INDUSTRIAL MACHINERY CORPORATION. ***Clean Technology Policy***, 2003(6): p 7-17.

[20]. Londero, E. ON THE TREATMENT OF SECONDARY PRODUCTS AND BY-PRODUCTS IN THE PREPARATION OF INPUT-OUTPUT TABLES. ***Economic Systems Research***. 1990, Vol.2, p 312-322.

[21]. Ten Raa, T., Chakraborty, D., Small, J. AN ALTERNATIVE TREATMENT OF SECONDARY PRODUCTS IN INPUT-OUTPUT ANALYSIS. ***Review of Economics and Statistics.*** 1984, Vol.66, P88-97.

[22]. Peter Saling, Andreas Kicherer, et al. ECO-EFFICIENCY ANALYSIS BY BASF: THE METHOD. ***The International Journal of Life Cycle Assessment***, 2002, Vol. 7 No.4: p203-18.

[23]. Gjalt Huppes and Masanobu Ishikawa. A FRAMEWORK FOR QUANTIFIED ECO-EFFICIENCY ANALYSIS. ***Journal of Industrial Ecology***. 2005, Vol. 9, No.4: p 25-41.

[24]. Nakamura Shinichiro. INPUT-OUTPUT ANALYSIS OF WASTE CYCLES. IEEE conference, 1999.

[25]. Nakamura Shinichiro and Kondo Yasushi. ENVIRONMENTAL IMPACT AND ECONOMIC COST OF WASTE TREATMENT: ANALYSIS BY THE WASTE IO MODEL. ***14th International Conference on Input-Output Techniques***, Montreal, Canada , 1999.10

[26]. Shigemi Kagawa, Hajime Inamura, and Yuichi Moriguchi. A SIMPLE MULTI-REGIONAL INPUT-OUTPUT ACCOUNT FOR WASTE ANALYSIS. ***Economic Systems Research***. 2004, Vol.16, No.1.

[27]. Koji Takase, Yasushi, and Ayu Washizu. AN ANALYSIS OF SUSTAINABLE CONSUMPTION BY THE WASTE INPUT-OUTPUT MODEL. ***Journal of Industrial Ecology***. 2005, Vol. 9, No.1-2: p 201-219.

[28]. Tomohiro Tasaki, Atsushi Terazono, and Yuichi Moriguchi. EFFECTIVE ASSESSMENT OF

JAPANESE RECYCLING LAW FOR ELECTRICAL HOME APPLIANCES. IEEE conference, 2005

[29]. Shigemi Kagawa Hajime Inamura, and Yuichi Moriguchi. THE INVISIBLE MULTIPLIERS OF JOINT-PRODUCTS. ***Economic Systems Research***. 2002, Vol.14, No.2.

[30]. Elio Londero. SECONDARY PRODUCTS, BY-PRODUCTS AND THE COMMODITY TECHNOLOGY ASSUMPTION. ***Economic Systems Research***. 1999, Vol.11, No.2: p 195-203.

[31]. Louis de Mesnard. UNDERSTANDING THE SHORTCOMINGS OF COMMODITY-BASED TECHNOLOGY IN INPUT-OUTPUT MODELS: AN ECONOMIC-CIRCUIT APPROACH. ***Journal of Regional Science***. 2004, Vol.44, No.1: p 125-141.

[32]. Thijs ten Raa, Debesh Chakraborty, and J.Anthony Small. AN ALTERNATIVE TREATMENT OF SECONDARY PRODUCTS IN INPUT-OUTPUT ANALYSIS. ***The Review of Economics and Statistics***. 1984, vol. 66, issue 1, p 88-97.

[33]. William McDonough and Michael Braungart. CRADLE TO CRADLE-REMAKING THE WE TAKE THINGS. ACCA and China-U.S. Center for Sustainable Development. ***Tongji University Press: Shanghai***. 2005. (In Chinese)