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A bibliometric study of China's resource recycling industry policies: 1978–2016

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ABSTRACT

Because the resource recycling industry can effectively resolve both resource and the environmental constraints, the Chinese government has integrated it into the national strategic emerging industries system and has enacted a series of policies to promote its development. To better understand these policies, we performed a bibliometric analysis to probe the evolution of China's resource recycling policies from 1978 to 2016 and the roles of core government agencies in policy-making. Co-word analyses and social network analyses were applied to map the topics of resource recycling policies and collaboration among agencies, respectively, yielding the following findings. (1) The developmental process of China's resource recycling industry policies can be divided into four stages: an exploratory stage (1978–2002), a preliminary formation stage (2003–2008), a rapid growth stage (2009–2011), and a strategic deepening stage (2012 onward). The number of policies issued at each stage has increased steadily. (2) Four topic clusters were identified from keyword networks: policy themes, waste categories, industrial chains and policy instruments. Across the four stages, policy themes evolved from macro to specific; waste categories evolved from industrial waste to production and living waste; industrial chains evolved from the recycling chain to the whole industrial chain; and policy instruments evolved from single policy instruments to mixed policy instruments. (3) Increasing numbers of government departments are becoming involved in formulating resource recycling industry policies, and cooperation among them has gradually strengthened. Our results have important policy implications for the healthy development of China's resource recycling industry.

1. Introduction

With China's rapid industrialization and urbanization, resource and environmental constraints have generated increasingly prominent contradictions. According to research by the United Nations University, from 2010 to 2015, mobile phones, computers and other electronic equipment have produced 12.3 million tons of electronic waste on the Asian continent. During this period, the amount of e-waste generated by the Chinese has more than doubled to 6.7 million tons (Goodship and Ab, 2012). As a resource consuming country, how to effectively and rationally use resources and break through the bottleneck of economic development has become an urgent problem in China. Resource recycling is not only an important means of resource conservation and a way of ensuring the supply of resources but also an effective way of curbing the deterioration of the environment and promoting the development of ecological civilization in China (Du and Zhang, 2013). Resource recycling mainly includes the comprehensive utilization of resources and the utilization of renewable resources. To standardize and promote the development of the resource recycling industry, the Chinese government has promulgated a series of policies. With the unprecedented strategy emphasis on achieving ecological civilization in China, the development of the resource recycling industry has gradually risen to the national strategic level. In 2015, the State Council clearly set out to comprehensively improve resource utilization efficiency and to promote a fundamental change in the way resources are used. The Opinions on Accelerating the Construction of Ecological Civilization in the 13th five-year plan on the development of strategic emerging industries issued by the State Council in 2016 reiterated the need for more resource recycling and for the improvement of the resource recycling system. In the past 40 years of reform and opening up, China's resource recycling industrial policy has been a continuous process of development and evolution, reflected in changes in the law and in policy concepts, priorities, objectives and instruments in different stages. Therefore, examining and analyzing the law and the direction of the evolution of China's resource recycling industrial policy has considerable theoretical and practical significance in terms of exploring the

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internal logic of policy evolution, optimizing the policy system, and promoting the steady development of China's resource recycling industry. Currently, research related to resource recycling policies has mainly focused on the following aspects: the policy status quo (Shih, 2017; Mallawarachchi and Karunasena, 2012; Wang et al., 2017a,b), policy instruments (Keiko and Kenji, 2016; Faten and Lamia, 2012), policy effect evaluation (Jaeger and Eyckmans, 2008; Shinkuma and Managi, 2010; Lu and Tam, 2013) and policy system design (Liu et al., 2014). Although papers related to many aspects of resource recycling policies have been published, none of them have been based on bibliometric analyses, meaning that such policy dynamics have not been systematically investigated. To fill this research gap, we performed a bibliometric analysis to probe the evolution of China's resource recycling policies from 1978 to 2016 and the roles of core government agencies in policy-making.

The remainder of this paper is organized as follows. Section 2 describes the research methods. Data sources and the division of research periods are presented in Section 3. Section 4 provides the results and discussion. Finally, in Section 5 we present our research conclusions and derive policy implications.

2. Methodology

2.1. Bibliometric analysis

Bibliometrics is a useful tool to map the literature around a research field, using quantitative and visual processes to identify patterns and dynamics in scientific publications (Pritchar, 1969). The aim of bibliometric analyses is to reveal development trends in certain areas of research (Tarkowski, 2007). The aspects of a body of literature utilized by bibliometric methods include both quantitative information (e.g., annual outputs, mainstream journals, leading countries and institutions) and qualitative data (e.g., hotspots and future research directions) (Fu et al., 2013). Early Chinese policy documents contain terms that characterize the core content of the policy (called keywords), similar to the concept of keywords in academic literature (Li et al., 2015). However, in 2012, the government began to exclude keywords from the constituent elements of policy documents. Therefore, to determine policies' keywords, we set a threshold according to the frequency of the words' appearances in the documents, and the words with high frequency were analyzed as the keywords representing the core content of the policy. In this paper, the bibliometric analysis method was used to screen for keywords with high frequency and explore potential relationships between them. We also studied the characteristics of resource recycling policies in different phases.

2.2. Co-word analysis

Co-word analysis, which is used in this paper, is a content analysis method that originated in the late 1970s. Because it is easy to perform, co-word analysies has been used to search management information systems, analyze research trends (Du et al., 2014), discover research hotspots (Du, 2015) and identify the evolution of research topics (Li et al., 2011). Similarly to co-citation and co-author analysies, co-word analysies aims to identify co-words and the co-absence of keywords (Ronda and Guerras, 2012). The co-word frequency of entries is used to measure the strength of relationships among them. Based on the co-word analysis method, there are three main steps for the extraction of core words from a policy text (Su and Xu, 2013; Luo and Zhu, 2014): (1) Extract keywords—retrieve keywords from existing policies in which keywords with high frequency are identified. In this study, we manually labeled the topics of each policy with six to ten keywords. (2) Merge adjustment—some keywords differ only very slightly from each other, which may affect the rationality of the analysis results. Therefore, these similar keywords are unified in a standard form for further study. (3) Build a co-word matrix—a co-word matrix is established by counting the frequency with which each pair of keywords occurs in the same policy text. This matrix serves as a critical input in the social network visualization software.

2.3. Social network analysis

Social network analysis (SNA) is a visual method of analyzing the connections between actors, e.g., people or groups, which can reflect the centrality of the actors and the strength of relationships among them from a statistical perspective (Newman, 2001). In a network graph, actors and relationships are represented by weighted nodes and edges, respectively (Ye et al., 2012). Due to the development of network theory and software tools, SNA has been widely utilized to investigate the evolution of research and policies. It mainly includes co-word network, cooperation networks and citation networks (Li et al., 2015). In this research, co-word networks are used to explore shifts in topics in resource recycling industry policies, while cooperation networks are used to reveal relationships among the relevant departments.

In SNA, clusters are called communities, groups or modules. In this study, clustering analysis was employed to examine the comprehensive relationship between keywords in co-word networks, indeed, clustering analysis was designed to measure the structure of networks (Wang, 2015). Cluster (or community) structure detection is crucial to revealing the underlying structure of complex networks (Jacomy et al., 2014). In general, nodes in the same cluster play similar roles in the network (Kauffman et al., 2014).

Modular functions in the Gephi software were used in this study to detect these clusters. The first important part of the Gephi software is the Layout module, in which Force Atlas2 algorithms are used to reposition the nodes in the graph. This algorithm can be used in typical networks in the Gephi environment; it spatializes a network by simulating the associated physical system. As a result, the association of a node with its 'home' cluster is identified (Kauffman et al., 2014). The second important part of the Gephi software is the Modularity module. A "Modularity Class" value is computed by means of the community detection algorithm for each node via the Louvain method. As a state-of-the-art technique, the Louvain method (LM) provides a useful tool for examining large-scale weighted networks (P. De et al., 2011). Subsequently, the partition module can be used to colorize clusters. The Gephi algorithms flow charts shown in Fig. 1.

2.4. Event sequence analysis

As policy evolution is a process-based phenomenon, analytical methods suitable for the study of social processes are required (Jiao and Frank, 2015). We adopted and followed the analytical steps of event sequence analysis (ESA) to investigate the evolution process of China's resource recycling industry policies. Event sequence analysis is a collection of methods specifically developed for longitudinal research (Spekkink, 2015). The application of ESA involves at least 4 steps: (1) defining the process, (2) collecting longitudinal data, (3) coding and grouping the data (colligation), and (4) data analysis (Spekkink, 2015). These steps, as well as their application in this research, are described in the section on the division of research periods.

3. Data sources and division of research periods

3.1. Data sources

The comprehensiveness of data collection directly affects the analytical results. Before the reform and opening up, the problem of environmental pollution in China was not serious, and there were few relevant policies. However, after the reform and opening up, the country's extensive mode of development led to increasingly serious environmental pollution and source shortages. The Chinese government began to issue relevant policies to solve this problem. This paper thus

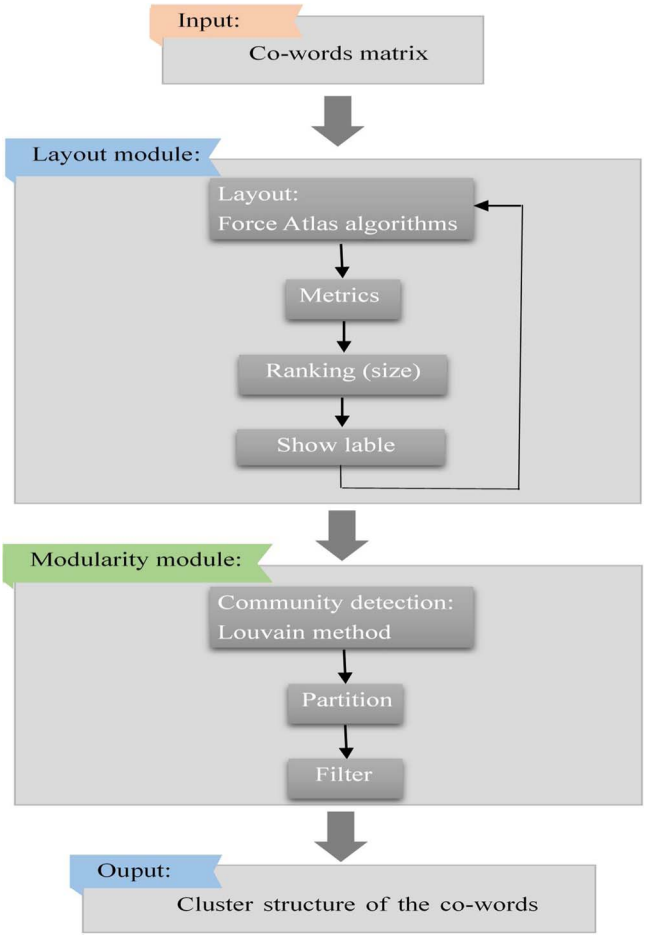

Fig. 1. Gephi algorithm flow chart.

collected all policies related to the resource recycling industry for the 1978–2016 period. According to the definition of resource recycling industry given in the 13th five-year plan on the development of strategic emerging industries issued by the State Council in 2016, the resource recycling industry mainly includes the comprehensive utilization of symbiotic ore and tailings, the development of urban mining, the recycling of agroforestry waste, the utilization of industrial solid waste and the comprehensive utilization of water resources. Based on this definition, resource recycling industry policies were collected via a search of the pkulaw database (Peking University Legal Information Database) which compiles public polices promulgated in mainland China since 1949, using the keywords “resource recycling” “circular economy” “symbiotic ore and tailings” “urban mining,” “agroforestry waste,” “industrial solid waste,” “water resources,” and so on. The data covers the period from 1978–2016. From the database, we initially collected 264 policies related to the resource recycling industry during the period of 1978–2016. To ensure the correctness and validity of the selected policies, we used the following criteria to filter the collected policies. First, the policy-issuing organization had to be a central government organization and not a province, municipality, or autonomous region. This research used a broad definition of central government organization, including entities such as the Standing Committee of the National People's Congress (NPCSC), the National Development and Reform Commission (NDRC), the State Environmental Protection Agency (SEPA), the Ministry of Science and Technology (MOST), the Ministry of Finance (MOF), and other departments. Through this process, 74 policies were eliminated. Second, the policy had to be in the form of a law, regulation, opinion, measure, notice or other document representing government policy, excluding industrial standards, supervision and review and technical collection and promotion reflected in other policies. Eighteen policies were excluded based on these criteria. According to these principles, 172 policies related to resource recycling during 1978–2016 were ultimately obtained.

3.2. Division of research periods

As mentioned in Section 2 event sequence analysis was adopted to divide the stages in the development progress of China’s resource recycling industry policies. The analytical steps, and their application in this research, are described below. Because step (1) defining the process, and step (2) collecting longitudinal data, were completed in the section on data sources, in this section, we mainly introduce the detailed process of step (3) coding and grouping of data (colligation), and step (4) data analysis.

Upon completion of policy collection, we constructed a chronologically ordered policy dataset. All the policies collected per Section 3.1 were scanned. We recorded information regarding which agency issued the policy and when, as well as what regulations the policy promulgated with regard to the development of the resource recycling industry.

After coding each policy, we conducted data analysis. We analyzed the information recorded for each policy in the previous step and found that there were four signature policies enacted in 1979, 2003, 2009 and 2012. The first was the Environmental Protection Law of China promulgated in 1979, which explicitly regulated the comprehensive utilization of industrial waste. This was the first time that China formulated regulations on the comprehensive utilization of recyclable resources. In a sense, this regulation marks the beginning of China's resource recycling industry. Subsequently, the government introduced a series of related policies, and China’s resource recycling industry entered the initial stage of exploration. In 2003, the clean production promotion law was formally implemented. The Chinese government began to shift from end-of-pipe treatment to prevention at the source, indicating that China's resource recycling industry had entered a new period of preliminary formation (Xi and Zhao, 2010). Another important policy was the circular economy promotion law enacted in 2009. It was the first comprehensive circular economy law in China, clearly setting forth the 3R principle of “reduce, reuse and recycle” and noting that resource recycling is conducive to ensuring the supply of resources, protecting the environment and achieving sustainable development (Hu et al., 2011). Its promulgation marked the point at which China's resource recycling policy began to enter a rapid growth stage. A unique Waste Electrical and Electronic Equipment (WEEE) fund system was implemented in China in 2012. This system is an important measure to promote extended producer responsibility (EPR), which is significant in terms of achieving a sustainable recycling-oriented resource recycling system (Gu et al., 2017). The implementation of the Chinese Fund Policy was not only a landmark event in the WEEE disposal industry but also a landmark event in the recycling industry, indicating that the resource recycling system had moved from a framework design to the implementation of specific policies and that policy system had deepened.

The above analysis indicates that the four policies may be viewed as crucial stepping stones in China’s resource recycling industry policies. Therefore, we took the four policies as nodes and divided the overall evolution of China’s resource recycling industry policies into four stages: an exploratory stage (1978–2002), a preliminary formation stage (2003–2008), a rapid growth stage (2009–2011), and a strategic deepening stage (2012 onward), as shown in Fig. 2.

4. Results and discussion

4.1. Quantity of resource recycling policies

As noted above, 172 state-level policy documents closely related to

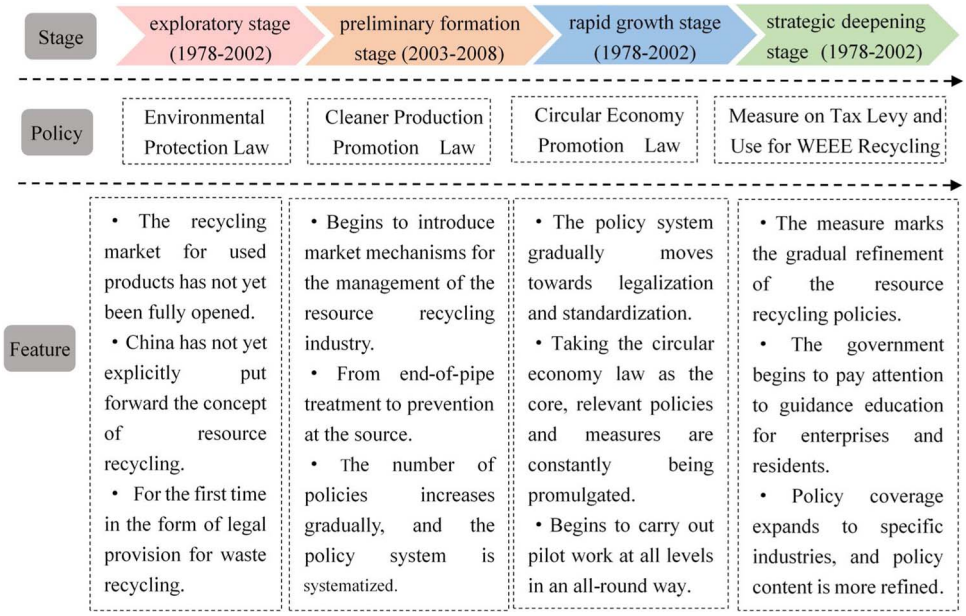

Fig. 2. The main Chinese resource recycling industry policies at different development stages.

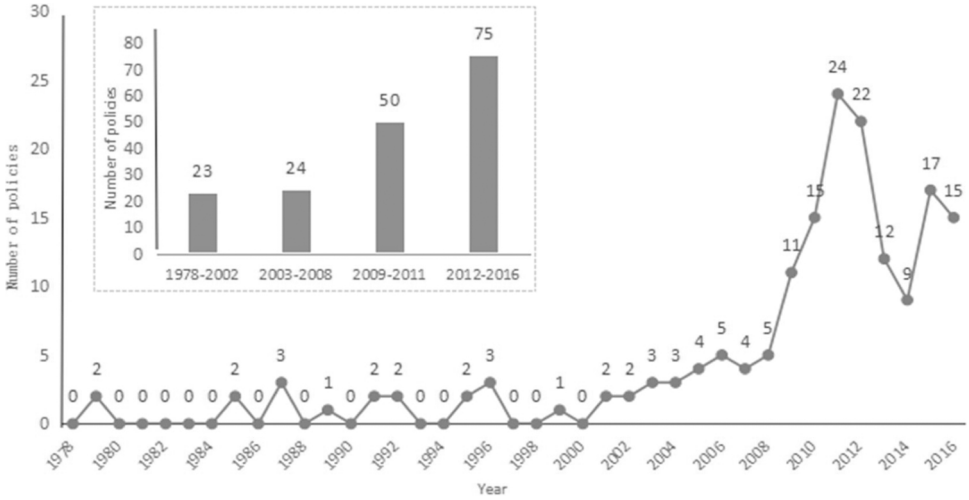

Fig. 3. Phases and time distribution of China's resource recycling policies (1978–2016).

the resource recycling industry from 1978 to 2016 were analyzed. Fig. 3 shows that policies before the 21st century were few in number but since the year 2000, the quantity of resource recycling policies has increased significantly. The upward trend in the curve began in 2002 when the waste recycling market was fully opened, and the curve peaks in 2011 and then decreases. The top left box of the graph shows that the annual number of policies in each of the four stages rapidly increased from 23 in 1978–2002 to 75 in 2012–2016, with an average annual growth rate of 5.95%. The growth in the number of resource recycling policies indicates that resource recycling received increasing attention, especially in the last decade.

4.2. Shifts in topics in resource recycling industry policies

The structural features of the total policy assemblage did not remain static; instead, they changed across the four stages. We analyze these dynamic features of resource recycling policies in this section. To understand the focus areas of one subject in a particular region or during a particular period, it is necessary to study keywords since they can provide valuable information (Wei, 2015). A cluster of keywords can be understood as a short description of major policy themes during the four stages of policy development. Gephi was used to visualize the most frequently used keywords and their network graph during the four stages. The social network graphs of each stage are shown in Figs. 4–7. Policy topics are marked in different colors so that the relevant keywords can be linked together.

4.2.1. Phase 1: exploratory stage (1978–2002)

Waste recycling was identified as a special industry in 1955, but very few resource recycling policies were enacted. Since reform and opening-up, the problem of environmental pollution in China has become increasingly prominent, and policy initiatives related to resource recycling have begun to emerge in environmental protection policy. The Environmental Protection Law of China promulgated in 1979 explicitly regulated the comprehensive utilization of industrial waste, which was the first time that China formulated regulations on the comprehensive utilization of recyclable resources (Zhou, 2008). In a sense, this regulation marks the beginning of China's resource recycling industry. Subsequently, the government introduced a series of relevant policies, and China's resource recycling industry entered the initial stage of exploration. A total of 23 policy documents were collected for this stage. Based on the co-word matrix of keywords, the text mining

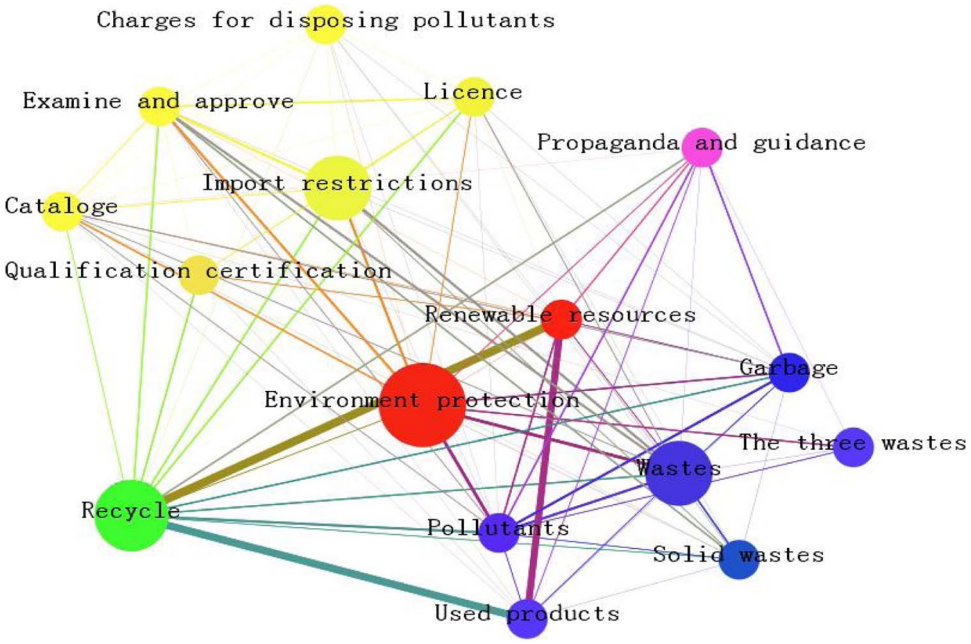

Fig. 4. Network of the most frequently used keywords during 1978–2002.

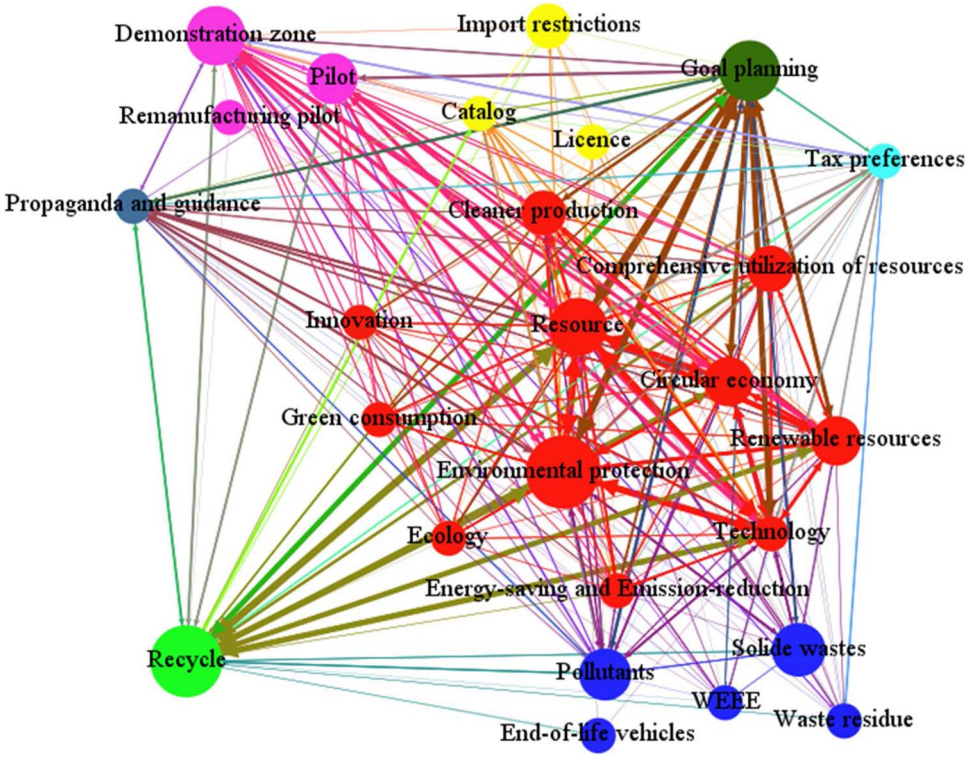

Fig. 5. Network of the most frequently used keywords during 2003–2008.

software Gephi was used to draw the network diagram, and cluster analysis was performed. The focus of resource recycling industry policies in 1978–2002 was clustered into four topics (see Fig. 4): policy themes, waste categories, industrial chains and policy instruments.

In Fig. 4 we can see that “environmental protection” is the highest frequency key-word in the exploratory stage (1978–2002), which shows that most of the policies promulgated in this stage are related to environmental protection. In addition, the Environmental Protection Law of China promulgated in 1979 explicitly regulated the comprehensive utilization of industrial waste, which was the first time that China formulated regulations on the comprehensive utilization of recyclable resources. In a sense, this regulation marks the beginning of China's resource recycling industry (Zhou, 2008). The Opinions on Accelerating the Development of Environmental Protection Industries, promulgated in 2001, noted that incentives and support policies should be introduced for priority areas, including the resource recycling industry (SETC, 2001). In this stage, China had not explicitly set forth the concept of resource recycling and had not formed an independent policy system. The relevant regulations for resource recycling are mainly included in environmental protection policies. From the perspective of

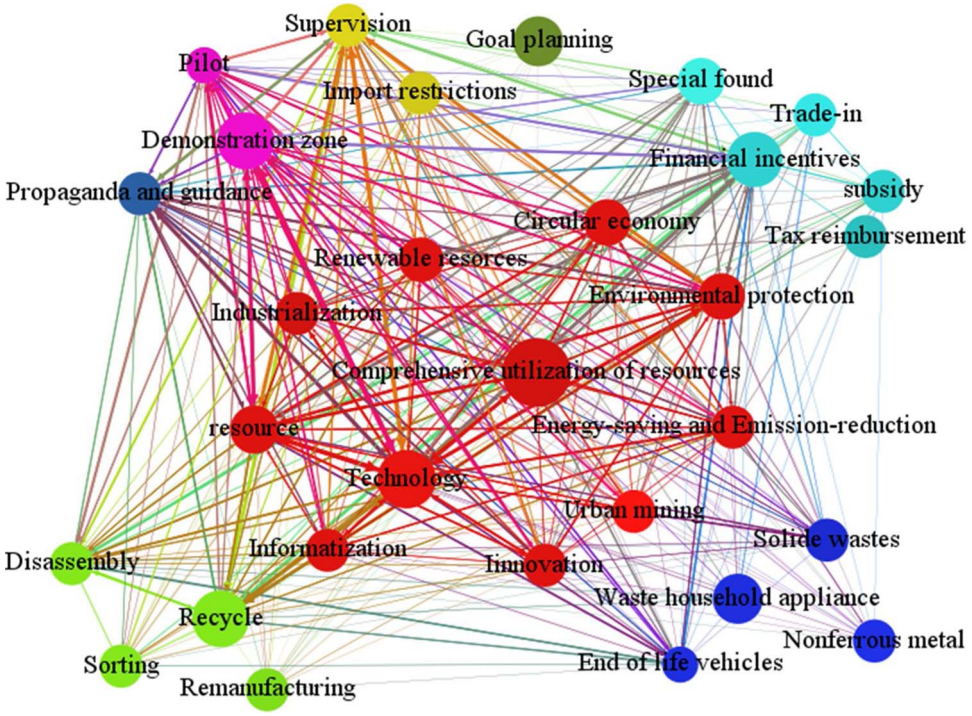

Fig. 6. Network of the most frequently used keywords during 2009–2011.

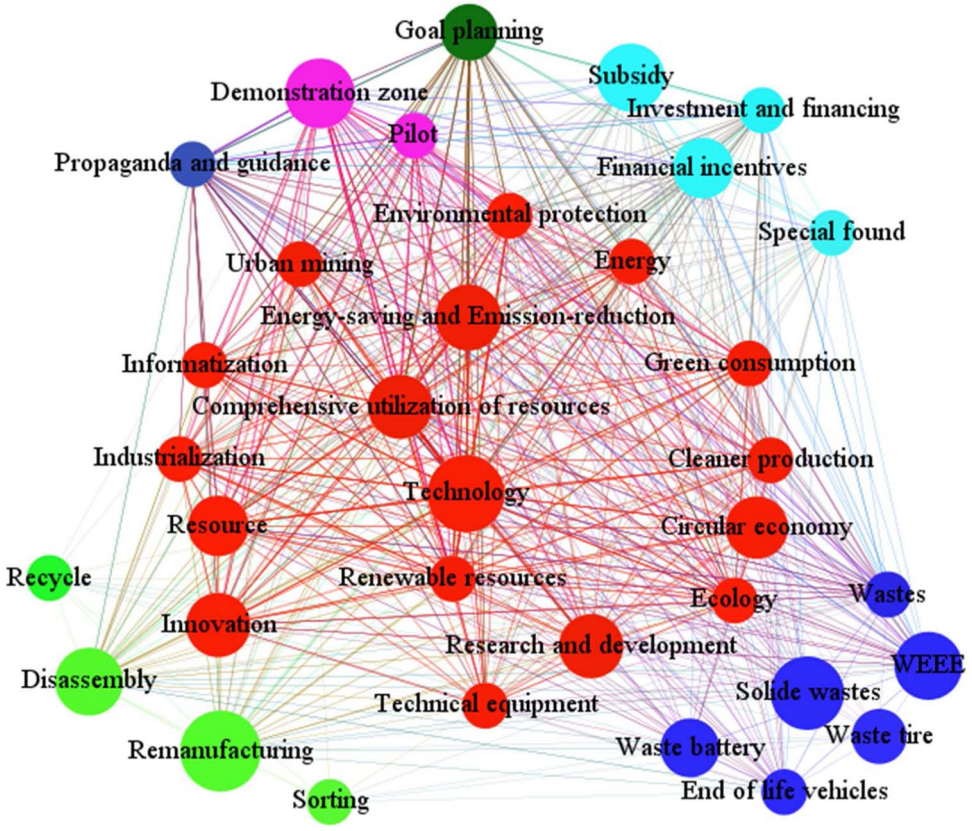

Fig. 7. Network of the most frequently used keywords during 2012–2016.

waste categories, this stage mainly involved the recycling of waste materials and the 'three wastes' (waste gas, waste water, and industrial waste). After the reform and opening up, rapid development of China's industrial economy led to resource waste and environmental pollution. To solve this problem, resource recycling related policies in the field of environmental protection mainly focused on the comprehensive utilization of solid wastes and the industrial 'three wastes'. The high frequency keyword 'recycling' indicates that the main content of the policy at this stage was to regulate the industrial chain's recycling process. For example, in 1989 the former Ministry of Commerce promulgated the

Notice on the Rectification of Renewable Resource Recycling Companies, and in 1991 the State Council promulgated the Notice on Strengthening the Management of Renewable Resource Recycling. Through analysis of the policy documents in this stage, it can be seen that the government considered the recovery chain as the premise and foundation of the resource recycling industry. From the perspective of policy instruments, regulatory policy was the main policy instrument used by the government to manage the resource recycling industry. The keywords 'import restrictions' appear with the highest frequency among the words that represent policy instruments. In addition to import restrictions, the government also adopted the practice of levying sewage charges and formulating catalogs and other mandatory policy measures to control environmental pollution. Therefore, the resource recycling industry was governed by laws and regulations during this period, and the relevant behaviors were supervised and managed through strict standards.

4.2.2. Phase 2: preliminary formation stage (2003–2008)

In 2002, the State Council decided to cancel the first batch of administrative examination and approval items, and the recycling market for waste materials was completely opened. With the implementation of market-oriented economic reform, the number of resource recycling policies gradually increased, and policy content was also constantly enriched. A total of 24 policy documents were collected for this stage, and the social network graph is shown in Fig. 5.

As seen in Fig. 5, the keywords "environmental protection" and "resources" appear with high frequency in this stage, indicating that the core ideas of resource recycling policies rose beyond environmental protection to achieve the dual objectives of protecting the environment and ensuring the supply of resources. With the advancement of industrialization and urbanization, many resources are mined underground, and when products made from such resources are scrapped it pollutes the environment. Facing the dual pressures of resource shortages and environmental pollution, the focus of the Chinese government changed from preventing environmental pollution to turning wastes into recyclable resources. In this stage, the frequency of the keywords "cleaner production," "green consumption" and, "energy-saving" and emission-reduction" increased compared with their frequency in the previous stage, which illustrates that resource recycling policies began to focus on pollution prevention instead of end treatment. The government advocated for the use of a resource-based approach to address waste, and the concept of environmental protection was further sublimated. In addition, the keywords "electronic wastes" and "electronic and electrical appliances" and other waste categories began to appear in this stage. Due to rapid technological development as well as more demanding customers, the life of electronic products grew shorter than ever before, resulting in more waste composed of electrical and electronic equipment. With the change in types and quantity of waste, the scope of the resource recycling industry also expanded, but policy still concentrated on the provisions of recycling. From the perspective of policy instruments, apart from regulatory policy, the government began to implement other policy measures, such as goal planning, financial support and demonstration projects. Based on the development characteristics of the resource recycling industry, the government began to formulate targeted plan and objectives and guide the development of the resource recycling industry from a macro-perspective. In terms of financial support, this stage is mainly notable for the implementation of a preferential tax on the resource recycling industry. With a value-added tax as the core consideration, several possible preferential measures were set forth, such as income tax, consumption tax and import tariff. The emergence of the high frequency word "pilot" shows that the pilot work of industrial parks and some provinces was also carried out in an comprehensive way, and resource recycling industrial policy entered a preliminary formation stage.

4.2.3. Phase 3: rapid growth stage (2009–2011)

The Circular Economy Promotion Law of the People's Republic of China implemented in 2009 was the first comprehensive circular economy law in China. This shows that China's circular economy had complete the stage of preparation and began to enter the critical period of rapid development. The government set forth legislation and carried out strategic planning in various areas, and the policy system began to take the form of legal norms. In this stage, the number of resource recycling policies issued by the central government increased significantly compared with that in the previous two stages, reaching 50. The social network graph is shown in Fig. 6.

Looking at Fig. 6, it is apparent that the keyword "comprehensive utilization of resources" has the highest frequency, which shows that the idea of resource recycling gradually expanded to the level of comprehensive utilization of resources. Comprehensive utilization of resources is of considerable significance not only to improving the efficiency of resource utilization and environmental protection but also to promoting the transformation of economic growth modes and optimize the allocation of resources. At the end of 2011, the National Development and Reform Commission issued the Guidance on the Comprehensive Utilization of Resources in the 12th five-year plan, proposing that the comprehensive utilization of resources include three fields: comprehensive exploitation and utilization of mineral resources, comprehensive utilization of industrial waste and recycling of renewable resources. Therefore, the resource recycling industry was included in the national macro support plan because of its comprehensive utilization of resources as well as its rapid development. In addition, in this stage, the new term "urban mineral" began to appear in policy text. This is because in 2010 the National Development and Reform Commission along with relevant departments jointly issued the Notice on Carrying out Construction of Demonstration Bases for Urban Mining Resources. This is a landmark policy in the field of urban minerals in which the concept of "urban mining" appears for the first time in the policy documents of the Chinese government. At the same time, to promote the large-scale development of the urban mining industry, this notice proposed building 30 urban mining demonstration bases in China within 5 years through financial, taxation and other policy measures (NDRC, 2010). Thus, China's industrial policy system for resource recycling was constantly refined and deepened. From the perspective of waste categories, the frequency of the keywords "waste household appliance" and "end-of-life vehicles" increased substantially compared with their frequency in the previous two stages. The considerable shortening of the update cycle of electronic products resulted in the accumulation of electronic waste, which caused serious environmental pollution. Therefore, the government attached more importance to the recycling of electronic appliances and set forth specific and feasible solutions to the increasing amount of electronic waste. From the point of view of the industry chain, resource recycling policies were extended from the recycling chain to the dismantling chain in this stage. This is because the fourth chapter of the Law of the People's Republic of China on Promoting a Circular Economy implemented in 2009 specified the details of waste recycling; this policy clearly stipulates the dismantling of waste, such as scrapped vehicles, waste lead acid batteries and waste electronic products. From then on, the focus of resource recycling industrial policy was no longer just on the recycling link but extended to the whole industry chain. From the perspective of policy instruments: government departments began to adopt more diversified financial support policies, such as the establishment of special funds and subsidies for activities related to resource recycling. The frequency of the keywords "demonstration zone" and "pilot" increased compared with their frequency in the previous stage, indicating that the establishment of the recycling system pilots and construction demonstration areas was an important policy measure for the government in promoting the development of the resource recycling industry. Among these measures, the construction of urban mineral demonstration bases became the most distinctive policy in the demonstration project. Thus far, China

has established 49 national level urban mineral demonstration bases. The industrial policies in this stage covers a wider range than those in the previous two stages, and the policy measures adopted are more flexible, promoting the rapid development of China's recycling industry.

4.2.4. Phase 4. strategic deepening stage (2012 onward)

In 2012, the Ministry of Finance, the State Environmental Protection Administration, National Development and Reform Commission, the Ministry of Industry and Information Technology, and the General Administration of Custom and State Administration of Taxation jointly issued the Administrative Measure on Tax Levy and Use for WEEE Recycling (Gov.cn, 2012). The related regulations and measures are named the Chinese Fund Policy. The Chinese Fund Policy states that producers and importers must pay disposal fees, while qualified dismantlers and disposers obtain subsidies under the allocation and supervision of the government. The implementation of the Chinese Fund Policy is not only a landmark event in the WEEE disposal industry but also a landmark event in the recycling industry. In this stage, the number of central government policies related to the resource recycling industry grew rapidly, reaching as many as 75. The growth trend in policy texts shows that China's resource recycling industry entered a strategic deepening stage. The social network graph is shown in Fig. 7.

As seen in Fig. 7, the keyword “technology” has the highest frequency, and the frequency of the keywords “R & D,” “innovation,” and “technical equipment” also increased compared with their frequency in the previous stages. Policy began to focus on technological innovation in the resource recycling industry. In 2012, the State Council promulgated the 12th Five-Year National Strategic Emerging Industry Development Plan, which clearly noted that the key direction and main task in developing a circular economy is to strengthen the key technology development of the resource recycling industry through the formulation of an R & D subsidy policy to speed up technological innovation. In addition, the frequency of the keywords “energy-saving and emission-reduction” and “green consumption” increased substantially compared with their frequency in previous stages, indicating that the scope of resource recycling policies was extended from production to consumption. In the production process, industrial enterprises are required to carry out cleaner production activities and reduce waste generation at the source. On the consumer side, a green consumer guidance mechanism was created that steers residents and enterprises toward buying renewable products. In this stage, the scope of policy was gradually expanded from the recycling of waste materials to the recycling of discarded cars, lead-acid batteries, waste tires and other subdivision items. With the introduction of several specific policies, China's resource recycling industry policy system has been enriched and improved. In addition, with the change in the type of waste and technology upgrades, policy no longer just focuses on the recycling process, but regulates the whole industry chain of recycling, dismantling and remanufacturing by constantly promoting the intensive and large-scale development of the resource recycling industry. From the perspective of policy instruments, the proportion of financial support policies substantially increased in this stage. The fund subsidies, tax incentives and other financial policies play important roles, which are closely related to the Administrative Measure on Tax Levy and Use for WEEE Recycling promulgated in 2012. This administrative measure determines the qualification licensing and fund subsidy system for waste electrical and electronic products. The fund subsidy is the core of China's waste electronic products disposal policy. The frequency of the keywords “demonstration base” and “pilot” also increased significantly. During the 12th five-year plan 49 national urban mining demonstration bases, 118 circular transformation parks and 37 circular economy education demonstration bases were built with the support of the National Development and Reform Commission (NDRC, 2017). Through the construction of demonstration pilots, the concept of resource recycling was widely disseminated, and policy mechanisms were continuously improved. In addition, throughout the four phases, the Chinese government has attached considerable importance to strengthening society's understanding of resource recycling through various publicity activities, encouraging households to consciously buy remanufactured products and implement garbage sorting such that activities closely related to the development of resource recycling gradually become part of the conscious behavior of all citizens.

4.3. Core resource recycling policy-making agencies

Chinese resource recycling policy-making agencies have undergone frequent reforms since 1978, e.g., in the form of merging, separating, renaming or being abolished. Therefore, in some situations, the same agency may appear under a different name. For example, the State Economic and Trade Commission and the Ministry of Foreign Trade and Economic Cooperation were merged into the National Development and Reform Commission and Ministry of Commerce in 2003. In this research, the name of the department before merging was adopted. However, it is necessary to convert the agency name used in the past into the current name when an agency has been renamed. For example, the Ministry of Science and Technology was called the State Scientific and Technological Commission from 1977 to 1998, but subsequently, its current name was enforced. In this study, whenever “State Scientific and Technological Commission” appeared in policies, it was converted into the “Ministry of Science and Technology”.

The governance of resource recycling policies involves many central agencies. Some 28 agencies have appeared in resource recycling related policies since 1978, although 21.4% of them participated in the formulation of only one policy. The core Chinese government organizations involved in resource recycling policy -making are listed in Table 1 according to the number of policies issued since 1978. As the most active and important actor, the NDRC promulgated the largest number of policies related to resource recycling. Its functions related to the management of resource recycling industries are to formulate resource

Table 1
The core agencies of China’s resource recycling industry.

Administrative department	Acronym	Total publication
National Development and Reform Commission	NDRC	50
Ministry of Finance	MOF	49
Ministry of Commerce	MOC	48
State Environmental Protection Administration	SEPA	33
Ministry of Industry and Information Technology	MIIT	31
State Council	SC	20
Ministry of Housing and Urban-Rural Development	MOHURD	15
Ministry of Land and Resource	MOLD	12
Ministry of Science and Technology	MOST	10
National People’s Congress	NPC	9
State Administration of Taxation	MAOT	9
General Administration Quality Supervision, Inspection and Quarantine	AQSIQ	8
State Administration of Industry and Commerce	SAIC	6
Federation of Supply and Marking Cooperatives	FSMC	5
General Administration of Custom	GAOC	4
Ministry of Agriculture	MOA	4
State Economic and Trade Commission	SETC	4
Ministry of Education	MOE	3
National Tourism Administration	NTA	3
People’s Bank of China	PBOC	3
Ministry of Foreign Trade and Economic Cooperation	MOFTEC	2
Ministry of Transport	MOT	2
National Bureau of Statistics	NBOS	1
China Securities Regulation Commission	CSRC	1
China Banking Regulation Commission	CBRC	1
State Forestry Bureau	SFB	1
Chinese Academy of Science	CAOS	1
State Commodity Inspection Bureau	SCIB	1

saving and comprehensive utilization policies as well as to organize demonstration projects. The MOF, the MOC, the SEPA and the MIIT each published at least 30 policies. The MOF is responsible for devising special funds and subsidies for activities related to resource recycling. The SEPA introduced resource recycling into the national policy context by advocating for the implementation of cleaner production, eco-design, and "reduce, reuse, recycle". The SEPA continues to transform China's economic development mode with the policy goals of improving resource productivity as well as reducing waste discharge and lowering resource consumption. In addition to the above agencies, a number of other agencies are involved in resource recycling policies. As an apparatus of the state, the Standing Committee of the National People's Congress (SCNPC) reserves the power to make the highest-level laws. In addition to the SCNPC, other agencies are affiliated with the State Council. This indicates that the SC promotes the development of China's resource recycling industry; it guides reform in the resource recycling policy system and formulates strategies, priority areas, laws and regulations for the field, independently or jointly.

The formation and implementation of most policies are the result of the cooperation between government agencies. When studying the relationship between government departments, we can use co-authorship network analysis in bibliometrics to describe the cooperation between these departments. Based on social network analysis, the co-authoring relationship among the 30 agencies in the field of resource recycling policies is described by means of the cooperation network diagram (see Fig. 8). The Gephi software was employed to draw the diagram on the basis of co-word matrices, which intuitively reflect the relationships among high frequency keywords. Ultimately, the graph with nodes representing agencies presents intuitively clear cooperative relationships among them, and the thickness of the connecting lines demonstrates the intensity of cooperation. The thicker the connecting line, the more frequently the two agencies cooperate (Du, 2015).

From the perspective of the number of departments involved in policy making, the number of agencies involved in issuing resource recycling policies has increased since the reform and opening-up. The number of departments involved in the formulation of resource recycling policies in 1978–2003 was 18, while the number in 2012–2016 increased to 28. The increase in the number of policy-making departments shows that the resource recycling industry has received increasing attention. The analysis of collaboration between different agencies shows that the number of nodes and connections in the network of cooperation are increasing rapidly. This increase indicates that from 1978 to 2016, the density of the policy cooperation network between policy makers was rising, and the cooperation between government departments was generally strengthened. In the exploratory stage (1978-2002), the closest collaborative relationship existed between the MOFTEC, the GCA and the SEPA and between the MOF and the SAOT. However, in the subsequent stage, the NDRC, the SEAP and the MOF and the MIIT were the most closely associated with each other. From the perspective of the evolution of core policy-making agencies, during 1978–2002, the AQSIQ and the MOF played an important role in the process of resource recycling policy making. With the change from a planned economy to a market economy and the reform of the State Council, the departments related to the resource recycling industry underwent constant change. In the second stage, the AQSIQ was no longer in the central position and was replaced the NDRC and the SEPA. Within this group of agencies, the NDRC established an alliance with the SEPA and several other agencies. Among these connections, an alliance with the centralized coalition of the NDRC and the SEPA was established. In the next two stages, the alliance between the NDRC and the SEPA was weakened and interactions between the NDRC, the MOF and the MIIT and other agencies emerged. This alliance displayed a centralized structure with the NDRC as the core. Along with the enhanced importance of the NDRC, the idea of improving resource utilization became the most important idea in resource recycling. From the above analysis, we can see that in terms of the management of resource recycling, there is no one special organizations in China, as the issue is managed by many departments separately. With the development of the resource recycling industry, the number of policy making agencies is increasing, and the trend of issuing policies jointly between departments is increasingly obvious.

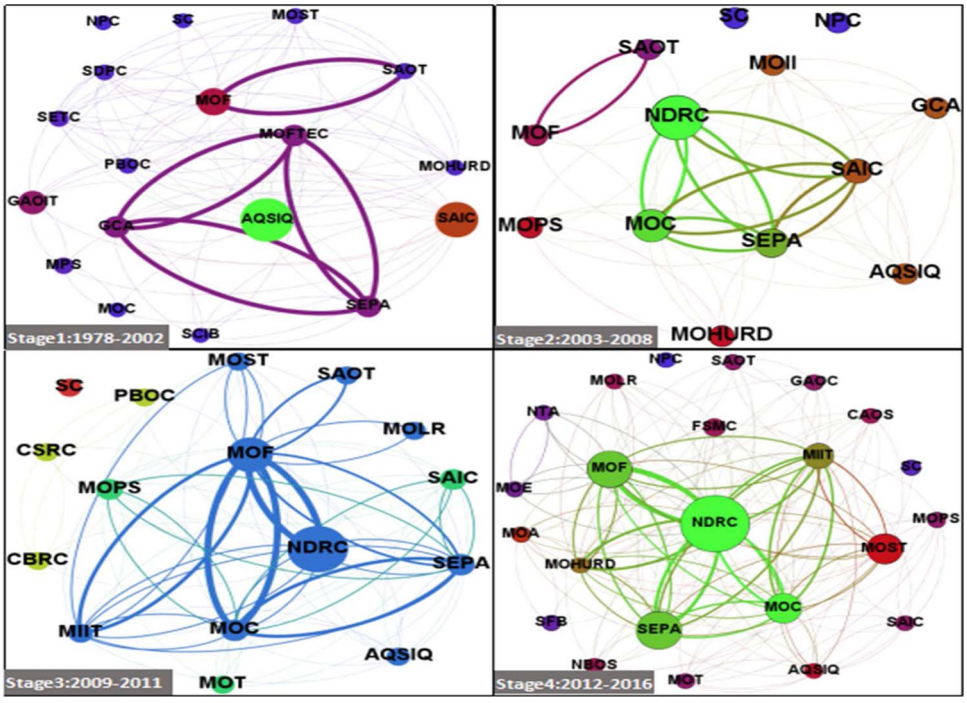

Fig. 8. Cooperation network of the core agencies.

5. Conclusions and policy implications

5.1. Conclusions

By using bibliometric methods, this article focused on the evolution of resource recycling policies in China and the roles of core government agencies in policy-making from 1978 to 2016. We reached the following conclusions.

In terms of the number of policies promulgated each year, the number of resource recycling policies increased exponentially during the period of 1978–2016. After a slow and gradual growth during 1978–2002, the number of resource recycling policies in China increased rapidly. The upward trend of the curve occurred in 2002 when the waste recycling market was fully opened, prior to which only a few policies related to resource recycling were enacted. In 2015, the Chinese government promulgated a record high 24 policies. The growth in the number of resource recycling policies indicates that resource recycling fields have received increasing attention, especially during the last decade.

The analysis of keywords showed that the focus of China's resource recycling policies is constantly changing with the development of China's economy and productivity levels. In the exploratory stage, resource recycling policies mainly aimed at environmental protection and regarded the recycling and reuse of waste as an effective means of controlling environmental pollution. In the preliminary formation stage, the frequency of the keywords "environmental protection" and "resource" was higher, which indicates that the core theme of resource recycling policies had changed to achieve the dual goal of protecting the environment and ensuring the supply of resources. In the rapid growth stage, the focus of industrial policy changes to a broader goal of "comprehensive utilization of resources". The comprehensive utilization of resources is of considerable significance to improving the efficiency of resource utilization, protecting the environment, promoting the transformation of economic growth modes, optimizing the allocation of resources, and developing a circular economy. In the strategic deepening stage, policy makers gradually realized that advanced science and technology is the driving force for the sustainable development of the resource recycling industry. Therefore, at this stage, the Chinese government began to focus on supporting the development of technology for the resource recycling industry through R & D subsidies. From the above analysis, we can see that the main direction of resource recycling policies shifted from protecting the environment in the 1978–2002 stage to focusing heavily on environmental protection and ensuring resource supply in the 2003–2008 stage, to advocating for comprehensive utilization of resources in the 2009–2011 stage, to fostering technological advancement from 2012 onward.

The analysis of agency cooperation showed that the formulation and implementation of resource recycling policies is endowed with typical collaboration characteristics. More and more government agencies are involved in the formulation of resource recycling policies. With the opening of China's resource recycling industry market and the reform of the State Council, the core departments of the resource recycling industry are changing constantly. The NDRC, SEPA, MOF, MIIT, MOC and other departments have gradually come to occupy core positions in the formulation and promulgation of resource recycling policy, and collaboration among them is being vigorously strengthened. China's recycling industry is a comprehensive industry with a dual focus of the environment and resources, and the formulation of policies involves the participation of many departments. The government also attaches considerable importance to the resource recycling industry, and multi-departmental collaborative supervision promotes the development of the recycling industry. However, there is no one special organizations supervising recycling policy in China, and the issue is managed by many departments separately.

5.2. Policy implications

The results of this paper have important policy implications for the healthy development of China's resource recycling industry.

First, in terms of improving the overall design of the policy system, we note that at present, China has few plans for the development of resource recycling industries and that there are few special laws in this field. Therefore, it is suggested that the Chinese government should learn from the experience of Germany, Japan and other countries that are relatively comprehensive with regard to circular economy legislation, plan a general strategy of industrial development and formulate comprehensive legislation in this field as soon as possible. In addition, policy makers should further strengthen the feasibility, pertinence and synergy of resource recycling policy. In the future, the government should formulate a feasible and pertinent industrial policy according to the country's industrial development background, current stage characteristics and existing bottleneck problems. It should also consider coordinating with policies in other related fields, such as energy saving and emissions reduction and ecological civilization.

Second, the Chinese government should further promote the flexibility and diversity of policy measures and optimize the combination of policy instruments. It should reduce dependence on regulating policies and give full play to economic and social incentive policies for the development of the resource recycling industry. On the one hand, the government should strengthen the direct correlation between resource recycling and the interests of residents and enterprises through economic incentive policies, stimulating price-conscious consumers and cost-sensitive enterprises to participate of their own volition in resource recycling, and strengthen the support of the resource recycling industry using fiscal, tax and financial policies. On the other hand, the government should enrich the content and form of social policies, and strengthen education with regard to resource saving and environmental protection, as well as green lifestyle and green consumption. It should guide social entities to actively participate in resource recycling, improve the implementation of social policy instruments, and create a social norm of resource recycling.

Third, the Chinese government should designate a lead department to manage the resource recycling industry. The analysis in Section 4.3, indicated that more organizations are becoming involved in the management of the resource recycling industry. This results in a more diversified, comprehensive and complicated situation. Therefore, it is necessary to establish a lead agency to strengthen inter-agency collaboration. The lead agency could govern the network through its core positions and act as an intermediary to increase the policy network's operational efficiency.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.resconrec.2018.03.008.

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