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SPECIALTY SECTION
This article was submitted to
Environmental Economics and
Management, a section of
the journal
Frontiers in Environmental Science

RECEIVED 22 June 2022
ACCEPTED 13 October 2022
PUBLISHED 03 November 2022

CITATION
Gu Q, Wu Z and Xie D (2022),
Transformation and development of
resource-based cities in China: A review
and bibliometric analysis.
Front. Environ. Sci. 10:975669.
doi: 10.3389/fenvs.2022.975669

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Transformation and development of resource-based cities in China: A review and bibliometric analysis

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With increasingly serious environmental and resource problems, resource-based cities have attracted unprecedented attention at home and abroad. In recent years, resource-based cities have become a hot research topic that has produced fruitful results. However, few articles have comprehensively and systematically reviewed the research on resource-based cities, which makes it difficult to carry out further research. This study introduces the influencing factors of the urban transformation of resource-based cities, the path of urban transformation, and the evaluation index system of urban transformation in detail. At the same time, a total of 2,182 articles related to resource-based cities in the CNKI and WOS from 2002 to 2022 were taken as the research objects. CiteSpace software was used to conduct statistical analysis of publication dates, journals of publication, institutions, and highly cited literature. Using the co-occurrence network of literature keywords and the analysis of emergent words, the research status of resource-based cities at home and abroad is visually analyzed. It is found that Chinese universities attach the most importance to research on resource-based cities. Chinese-language journals focus on urban and economic transformation, while English-language journals focus on sustainable development and the circular economy, which are quite different. The overall research content of Chinese journals is scattered, the co-occurrence ability of keywords is weak, and the duration of hot research topics is short. In contrast, the overall research trend of English-language journals is more concentrated, the key words' emergence intensity is high, and the duration is long. This study aims to systematically sort out the theories and research related to resource-based city development in China and internationally, clarify the key issues of resource-based city research and the shortcomings of existing research, and put forward feasible suggestions for future research.

KEYWORDS

resource-based city, bibliometrics, urban transformation, sustainable development, visualization

1 Introduction

Resource-based cities are a typical kind of city in China's urban system. Their development mainly depends on the exploitation and processing of nonrenewable resources such as minerals, forests, and oil in the region. Resource-based cities have played a vital role in China's economic development. According to the National Sustainable Development Plan for Resource-Based Cities (2013–2020) issued by the State Council in 2013, 262 resource-based cities were identified, accounting for 40% of the total number of cities in China, including 126 prefecture-level administrative regions. These resource-based cities were further divided into four types: growth (31), mature (141), declining (67), and regeneration (23). The principal resource types of these resource-based cities include coal, metal, oil, and forestry resources. Cities with coal as the main resource are mainly distributed in central China, such as Datong in Shanxi Province; resource-based cities with metal as the main resource are mainly distributed in northwest China, such as Baiyin in Gansu Province and Tongchuan in Shanxi Province; and oil and forestry resources are scattered. With the continuous exploitation of resources, the recoverable reserves of some cities have reached 70% of the recoverable reserves, which has a huge impact on the local environment, population, and economy. These cities have become resource-exhausted cities. In 2008, 2009, and 2012, China identified 69 resource-exhausted cities in three batches, including 37 coal cities, 14 nonferrous metal cities, 6 ferrous metal cities, 3 oil cities, and 9 other cities, involving a population of 154 million.

For many years, the extensive development mode of resource-based cities in China inevitably faced a series of problems, such as gradual depletion of resources, a single industrial structure, an abnormal economic structure, and serious damage to the ecological environment (Yu et al., 2015; He et al., 2017). Miachel (2015) showed that the excessive dependence on natural resources makes resource-based cities depend on a single industrial structure; that is, the secondary industry accounts for too much of the economy. The lock-in and crowding-out effect caused by such an industrial structure not only excludes the expansion of the manufacturing industry but also restricts the development of primary and tertiary industries (Fan and Zhang, 2021). Due to the large scale of operations, low technical level, and short industrial chain, economic accumulation is mainly based on the exploitation of a large number of raw materials. When resource stocks fall to a certain level, production declines, which further affects the local economy. Resource-based cities gradually lose their investment attraction in the process of resource depletion and economic growth slowdown, which further hinders economic development (Takatsuka et al., 2015; Liu and Meng, 2018). This phenomenon is known as the "Dutch disease" or the "resource curse." Shao and Qi (2009) explained the negative relationship between resource development and economic growth through China's interprovincial panel data from 1991 to 2006, proving the phenomenon of a serious resource curse in China.

Urban shrinkage is also an important feature of resource-based cities, which is manifested by population loss caused by low fertility rates, aging, and out-migration (He, 2014; Long et al., 2015). Due to technological change and product market transfer, resource-based industries will lose their competitiveness in the market. Another cause of the contraction of resource-based cities is the weak connection between resource-based industries and other businesses, such as knowledge and innovation transfer, which isolates resource-based cities from global knowledge networks (He et al., 2017).

Promoting the industrial transformation and upgrading of China's resource-based cities is a path to overcoming the historical fate of mine exhaustion and urban decline and is also an important part of guiding the transformation of China's economic development from high-speed growth to high-quality growth. Therefore, it has become urgent to promote the industrial transformation of resource-based cities and accelerate the transformation of the new economic development mode. Research on resource-based cities covers a wide range and involves many fields, which is of great significance for national development. The purpose of this study is to clarify the existing research context and hotspots of resource-based cities to help researchers carry out more targeted research on resource-based cities.

In recent years, discussions on the influencing factors of the industrial transformation of resource-based cities have been intensified. It has always been the focus of government and academic circles to help resource-based cities escape the predicament of the "resource curse" and undergo urban transformation. Van der Ploeg (2011) pointed out that resource-based cities' excessive dependence on resources creates rigid economic structures, underlying the resource curse. Bai et al. (2014) found that the adjustment of the industrial structure, attention to scientific education, and development of the ecological economy are conducive to the transformation of resource-based cities. Shao and Yang (2014) showed that the lack of human capital is an important factor hindering the sustainable development of resource-based cities. The government plays an important role in the process of urban transformation and is a key factor in the ability of a region to reduce or eliminate the negative impact of resource dependence (He et al., 2017). Local governments will be subject to many constraints in the process of urban transformation, which will lead to large externalities in the process of urban transformation; for example, the financial pressure on local governments will increase the emission of air pollutants (Hui et al., 2022). The transformation efficiency of resource-exhausted cities depends on local political incentives. Local government officials play an important role in the process of urban transformation (Zhang et al., 2018). Government policies can promote the industrial transformation of resource-based cities through economic simplification and diversification (Li et al., 2020).

Most studies on the transformation of resource-based cities and resource-depleted cities take specific cities as cases for targeted analysis. For example, [Zhu \(2013\)](#) studied the Wan Sheng district of Chongqing and found that resource-depleted cities should focus on geological structures and groundwater hazards in agricultural transformation. Based on the carbon emission data of Xuzhou, Jiangsu Province, [Guo et al. \(2019\)](#) showed that there is a decoupling phenomenon between the urbanization transformation of resource-depleted cities and the environment. [Yin \(2020\)](#) studied the ecological transformation of six resource-depleted cities in Jilin Province and found that the level of science and technology plays a role in promoting ecological efficiency. In addition, education investment ([Zeng et al., 2016](#)), trade structure, and the tax system ([Li et al., 2018](#)) have an impact on the transformation of resource-exhausted cities. [Wang et al. \(2022\)](#) researched Benxi (a typical mineral resource-based city in China) to understand the economic and environmental performance and existing problems in the process of local transformation and compared it with the successful transformation model of the global mineral resource-based city.

Urban transformation can be divided into two main approaches: active adaptation to contraction and growth-oriented sustainable transformation. China's urban transformation is mainly led by multilevel governments ([Li et al., 2015](#)). The central government makes special annual transfer payments to resource-exhausted cities to help them carry out transformation strategies. [He et al. \(2017\)](#) summarized three strategies for the sustainable transformation of foreign mining cities, namely, industrial substitution, industrial chain extension, and a combination of the first two. For example, transforming mining heritage into tourism destinations is a popular industrial alternative strategy in many post-mining cities worldwide ([Armis and Kanegae, 2020](#)). [Yu et al. \(2016\)](#) identified the tension between the difficulties in industrial transformation and environmental policies and the limited impact of the circular economy in the process of sustainable transformation.

The transformation path of resource-based cities has always been the focus of both Chinese and international scholars ([Sliuzas et al., 2015](#); [Huang et al., 2017](#)). [Li et al. \(2020\)](#) concluded that the transformation path has three types: industrial substitution mode, industrial chain extension, and a combination of the first two. Regions such as Lorraine (France), Kitakyushu (Japan), and Pittsburgh (United States) mainly applied the industrial substitution model ([Liu, 2013](#)). In Pittsburgh, the industrial structure changed from heavy industry to a high-end service economy, with an emphasis on health care and higher education. Houston (United States) presents a restructuring pattern characterized by the extension of the industrial chain. By developing its machinery, cement, steel, electric power, transportation, and paper industries, Houston has gradually been transformed from an oil-based city into an integrated technology city, and NASA's location

in Houston has facilitated high-tech industries related to aerospace, such as electronics, precision machinery, and instruments. Zaozhuang (China) also adopted the industry chain extension transformation mode, relying on scientific and technological progress and innovation, and promoted the development of greater benefits and added value of science and technology industries that rely on resources and geographical advantages to develop new energy sources, new building materials, ecological tourism, and other alternative industries to adjust and optimize the industrial structure. By accelerating the construction of infrastructure, optimizing the urban spatial pattern, creating a good ecological environment, and improving the functional level of the city, an appropriate environment was created for urban transformation ([Wang and Li, 2012](#)). Ruhr (Germany) is a good example of the third model, which combines the first two types. In the early stages, the Ruhr region adopted the method of industrial chain extension and changed the leading industry from mining to processing. Later, it began efforts to develop new industries and diversify and enrich its economic structure.

[Jiao et al. \(2021\)](#) pointed out that both industrial substitution and industrial extension should follow several basic principles. First, according to the profit principle, new industries need to be high-tech or market-oriented to ensure high economic profits. The second is the linkage principle, according to which a new industry should have extensive and firm connections with other industries to form industrial agglomerations and create new sectors ([Zhu and Qiang, 2012](#)). Connectivity between different regions can improve industrial dexterity and proficiency ([Zhang and Zhu, 2022](#)). The third is the adaptation principle, according to which industry should be competitive and make full use of various local resources to adapt to the actual and objective conditions at the local and regional levels. Last, based on the environmentally friendly principle, development must be environmentally friendly, consume little energy or resources, and help ease the local pressure of resource extraction.

The development of a circular economy is also an important link in the path of urban economic transformation ([Andersen, 2007](#); [Zhu et al., 2010](#); [Mathews and Tan, 2011](#)). The circular economy is a closed-loop process that transforms resource processing waste into inputs to another process. Since the circular economy promotes more efficient use of resources, it should be widely applied in resource-based cities to reduce resource extraction, improve resource utilization, and reduce waste disposal and waste stock. The traditional resource-based urban development model that relies on extensive resource development to realize industrialization and modernization is unsustainable. By adopting energy-efficient and clean technologies, the circular economy is an effective way to address these challenges ([Fan and Zhang, 2021](#)).

Methods to evaluate the effects of industrial transformation in resource-based cities can be roughly divided into three categories. The first is the direct evaluation method, which

uses one or more indicators to evaluate the development of urban industries. Guo et al. (2016) used four indicators to analyze the impact of technological progress on the transformation of China's energy consumption structure. Chen et al. (2018) evaluated the industrial transformation efficiency of resource-based cities in Shanxi Province from three dimensions: economic, social, and environmental. The second is data envelopment analysis (DEA), which is commonly used to estimate efficiency. Sun et al. (2012) used the DEA method to study the differences in urban efficiency among different types of resources. Li and Dewan (2017) used it to measure the efficiency of resource-based cities, analyze the differences in efficiency levels among cities, and identify the main determinants. Zhang et al. (2020) used data envelopment analysis with a slack-based model (DEA-SBM) to evaluate the efficiency of China's green transition. On this basis, Zhao et al. (2021) used a model based on system dynamics to evaluate the transformation effect in Jiaozuo city. The third is a comprehensive evaluation method that identifies the characteristics of the evaluation object through the system. Yu et al. (2005) constructed an index system including resources, economy, society, environment, and other factors to evaluate the sustainable development of mineral resources in Huangshi, China. Chen et al. (2018) evaluated the industrial transformation and upgrading level of six resource-based cities in Shanxi Province from 2001 to 2015 using the improved TOPSIS method and sequential weighting method.

At present, there are few studies that have systematically analyzed the development of resource-based cities in China. With the help of CiteSpace as a bibliometric analysis tool, this study sorted out the publishing trends, journals, authors' relevant information, and keywords in the field of resource-based city transformation and development in the past 20 years (2002–2022), summarized their development context and research hotspots, and then provided guidance for the future construction of resource-based cities in China. The structure of the study is as follows. The first section expounds the mainstream hot issues in the current research on resource-based cities. The second section explains the data and methods used in the research, the third section uses graphs to show the analysis results, the fourth section shows the correlation between the studies through visualization, and the last section summarizes the shortcomings of the existing research and identifies future research prospects.

2 Data and methods

2.1 Data

In this study, the China National Knowledge Infrastructure (CNKI) and Web of Science (WOS) databases were used as the main data sources. In CNKI, “resource-based city” and

“resource-exhausted city” were used as the search terms. The search scope was Peking University core and CSSCI, the time range was 2002–2022, and the deadline was 9 June 2022. A total of 1,750 Chinese articles were retrieved, and 18 articles without authors were manually eliminated to obtain 1,732 valid Chinese articles. In the Web of Science database, the search formula “TS = resource-based cities or TS = resource-exhausted cities” was constructed. The search range was the core collection, the time range was 2002–2022, and the deadline was 9 June 2022. Finally, 450 valid English-language studies were retrieved, of which the title, abstract, keywords, author, reference, and other full records of the search results were exported to construct the research dataset.

2.2 Methods

Bibliometric analysis combines visualization, graphics, and scientometrics to research evolving scientific knowledge (Niu et al., 2014). It is used to quantitatively assess the quality of research results, research trends, and tacit knowledge structures to gain a comprehensive and in-depth understanding of the academic literature (Chen, 2006). Since keywords indicate the central content of research, high-frequency co-occurrence keywords reflect popular research topics, which can be further aggregated into higher levels of abstraction. The frequency changes of keywords in a given period of time reflect hot spots. The importance of keywords not only depends on their high frequency but also depends on the intensity of their frequency change in a given period. The rapid growth of keyword frequency in a specific period reflects that the research topic may become a research hotspot and new trend (Lin et al., 2015). These keywords, known as burst terms, reflect a sudden increase in research interest and buzz. Therefore, the detection of keywords with high frequency and rapid frequency change in a specific period reveals different aspects of research trends. The former indicates an important research topic, while the latter reflects a new research trend.

This study mainly adopted the bibliometric analysis method and content analysis method, using the visual analysis software CiteSpace developed by Dr. Chen to conduct in-depth analysis and research on the retrieved articles on resource-based cities. Bibliometric analysis objectively evaluates the research history, current state, and future development of a research field among different countries, regions, scientific research institutions, and scholars based on quantitative research methods such as mathematical statistics. The visual analysis method can explain the internal relationship of different studies more intuitively to predict the trend of future research. Content analysis is a research method that effectively combines qualitative and quantitative analyses. It conducts statistical analysis of the content of the research object to draw qualitative conclusions. By combining the aforementioned

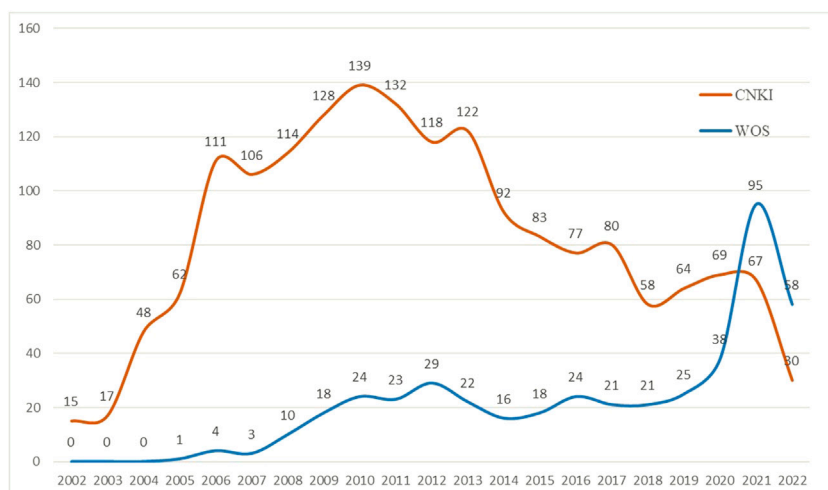


FIGURE 1
The number of articles in resource-based cities changes with time.

TABLE 1 Journal of resource-based city research (top 10).

Rank	Journal (CNKI)	Number of articles	Journal (WOS)	Number of articles
1	China Population Resources and Environment	33	Sustainability	31
2	Economic Geography	28	Advanced Materials Research	19
3	Journal of Natural Resources	23	Journal of Cleaner Production	16
4	Geographical Studies	16	Resources Policy	15
5	Geographical Sciences	16	Environmental Science and Pollution Research	14
6	Reform	11	Applied Mechanics and Materials	11
7	Journal of Ecology	9	Frontiers in Environmental Science	8
8	Chinese Soft Science	6	Advances in Social Science Education and Humanities Research	7
9	Acta Geographica Sinica	5	Chinese Geographical Science	7
10	Chinese Land Science	5	Ecological Indicators	7

three methods and referring to the relevant practices of [Wei et al. \(2014\)](#) and [Li et al. \(2014\)](#), the literature on resource-based cities is analyzed to objectively and scientifically identify the status of research and development trends related to resource-based cities in China and around the world.

3 Dynamic data analysis

3.1 Published dating analysis

When the bibliometric method is used to analyze the development process of a research field, according to the growth and aging laws of the literature, annual statistical

analysis of the number of relevant articles reveals the current development status of the field and predicts future research prospects and development trends. In the early stages of research studies in a certain field, due to the lack of relevant theories and foundations, the number of relevant articles published is low. As in-depth research studies increases, the number of scholars and institutions entering the field of research studies grows. As a result, the number of articles published grows rapidly, and after the research becomes mature, the number of articles published tends to be stable. [Figure 1](#) is based on the analysis of the chronological distribution of 1,732 Chinese and 450 English articles retrieved from CNKI and WOS.

In [Figure 1](#), the horizontal axis is the publication date, and the vertical axis is the publication volume. The red curve represents

TABLE 2 Number of publications published by research institutions in resource-based cities (top 10).

Rank	Institution (CNKI)	Number of articles	Institution (WOS)	Number of articles
1	Northeast Normal University	60	Chinese Academic of Science	38
2	China University of Mining and Technology	51	China University of Mining and Technology	35
3	China University of Geosciences (Beijing)	41	China University of Geosciences	29
4	Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences	40	University of Chinese Academy of Sciences	17
5	Peking University	35	Wuhan University	17
6	Lanzhou University	35	Ministry of Natural Resources	10
7	China University of Geosciences	32	Shanghai University of Finance and Economics	10
8	Jilin University	29	Jiangsu Normal University	9
9	Sichuan University	26	Northeast Petroleum University	9
10	Henan Polytechnic University	26	China University of Mining and Technology (Beijing)	8

TABLE 3 Highly cited Chinese studies on resource-based cities (top 10).

Rank	Title (CNKI)	Source publication	Publish time	Citation times
1	Definition and classification of resource-based cities in my country	Macroeconomics	2002.11	520
2	Research on environmental regulation, resource endowment, and urban industrial transformation: a comparative analysis based on resource-based cities and non-resource-based cities	Economic Research Journal	2018.11	363
3	Problems and strategic exploration of economic transformation of resource-based cities in China	China Population, Resources and Environment	2007.01	272
4	A review of the research progress on the development of resource-based cities in my country	Urban Development Studies	2006.05	228
5	Empirical analysis of influencing factors of sustainable development of resource-based cities	China Population, Resources and Environment	2014.07	227
6	Efficiency and changes of Chinese resource-based cities based on DEA model	Geographical Research	2010.12	222
7	Analysis on the current situation and countermeasures of sustainable development of resource-based cities in China	Journal of Central China Normal University (Humanities and Social Sciences)	2002.04	222
8	Practice, theory, and enlightenment of industrial transformation of foreign resource-based cities	Research on Financial and Economic Issues	2005.12	218
9	Analysis of sunk cost and transformation of resource-based cities	China Industrial Economics	2004.06	201
10	Urban space development model of intensive land use	Urban Planning Forum	2006.01	187

the variation trend of the volume of Chinese publications in CNKI, and the blue curve represents the variation trend of English publication volume in WOS. The number of Chinese documents published in the past 20 years can be divided into three stages: the rapid rise stage from 2002 to 2006, the high fluctuation stage from 2007 to 2013, and the mature development stage from 2014 to the present. The number of articles published in the rapid rise stage increased annually, and the research content was mainly focused on the transformation of a single

city or a city with the same resource type. At the stage of high fluctuation, the state began to gradually identify resource-exhausted cities and issued special transfer payments to support urban transformation. The research content during this stage was carried out around the transformation of resource-exhausted cities and the evaluation of resource-based cities, which was the golden period in the field. The number of publications in the mature development stage began to decline. Due to the accumulation of historical data, the focus of research

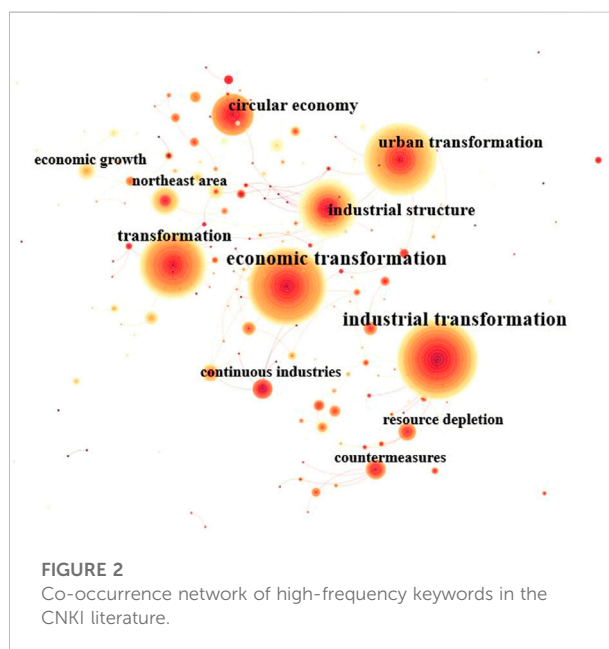
TABLE 4 Highly cited English studies on resource-based cities (top 10).

Rank	Title (WOS)	Source publication	Publish time	Citation times
1	The impact of low-carbon city construction on ecological efficiency: Empirical evidence from quasi-natural experiments	Resources Conservation and Recycling	2020.06	104
2	Effects of urbanization on ecosystem service values in a mineral resource-based city	Habitat International	2015.04	104
3	Shrinking cities and resource-based economy: The economic restructuring in China's mining cities	Cities	2017.02	102
4	Analyzing and modeling land use land cover change (LUCC) in the Daqing City, China	Applied Geography	2011.04	90
5	Economic transition policies in Chinese resource-based cities: An overview of government efforts	Energy Policy	2013.04	89
6	Heterogeneous green innovations and carbon emission performance: Evidence at China's city level	Energy Economics	2021.07	77
7	Research on sustainable development of resource-based cities based on the DEA approach: A case study of Jiaozuo, China	Mathematical Problems in Engineering	2016.01	66
8	Energy structure, digital economy, and carbon emissions: Evidence from China	Environmental Science and Pollution Research	2021.12	64
9	The determinants of urban sustainability in Chinese resource-based cities: A panel quantile regression approach	Science of the Total Environment	2019.10	64
10	Fiscal spending and green economic growth: Evidence from China	Energy Economics	2020.01	59

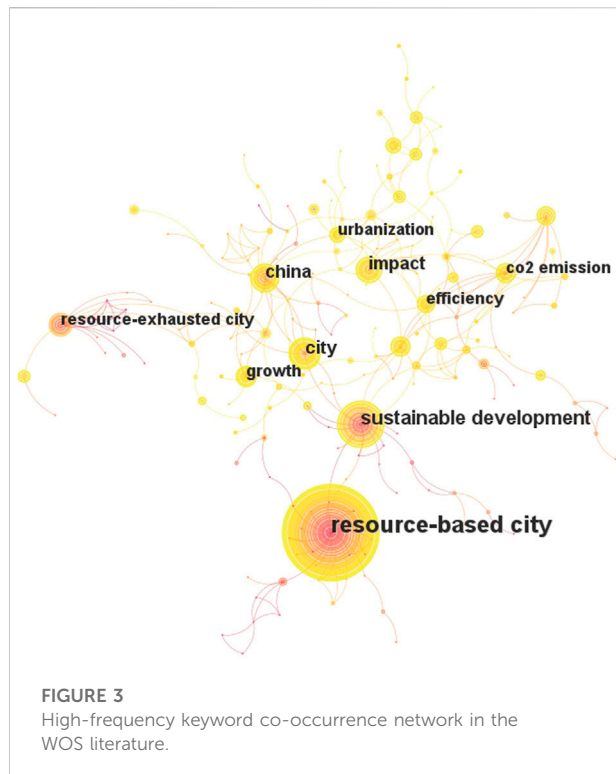
at this stage turned to the impact of policies on the transformation of resource-based cities. At the same time, the number of articles published in English started in 2005 and slowly increased until 2008. From 2009 to 2018, the number of articles remained stable, and starting in 2019, the number of articles increased sharply, with an increasing number of articles using quantitative methods to study the transformation of resource-based cities began to emerge.

3.2 Analysis of journals

A statistical study of the journals that published studies on resource-based cities illustrates the importance of different journals for the issue of resource-based cities, allowing scholars to identify the journals with the greatest number of published articles. In Table 1, we summarize the top 10 journals with the largest number of resource-based city articles in CNKI and WOS. From 2002 to 2022, the journal with the largest number of articles on resource-based cities in CNKI was China Population Resources and Environment, with a total of 33 articles. The journal with the second largest number was Economic Geography, with a total of 28 articles. The third was the Journal of Natural Resources, with a total of 23 articles. From the top three journals, journals with themes of resources, environment, and economy are more willing to accept articles on resource-based cities. From 2002 to 2022, the journal with the largest number of articles on resource-based cities in WOS was Sustainability (31 articles), the second was Advanced Materials Research (19 articles), and the third was Journal of Cleaner



Production (16 articles), and their themes are mainly around sustainability, materials, clean production, and environmental science. Compared with the journals in CNKI and WOS, the Chinese research articles paid more attention to the economic development of resource-based cities, while the English-language research articles paid more attention to the sustainable development of resource-based cities. At the same time, in terms of the number of articles published, Chinese journals



showed a trend of polarized development. The top few journals include the vast majority of articles, while the journals after the seventh place have only a small number of articles with no obvious difference between them. In contrast, the development of English-language journals is relatively balanced, with an equitable number of publications across journals, with the exception of sustainability.

3.3 Analysis of the issuing agency

Statistical analysis can also help readers understand where the main institutions that produce research on resource-based cities are distributed. As seen in [Table 2](#), the institution with the largest number of publications in Chinese journals is Northeast Normal University, which has published a total of 60 articles on resource-based cities from 2002 to 2022. The second is the China University of Mining and Technology. Other institutions, such as the China University of Geosciences (Beijing), the Institute of Geographical Sciences and Natural Resources Research, the Chinese Academy of Sciences, Peking University, the Commission University, and the China University of Geosciences, also showed strong research capabilities, with more than 20 articles published in each institution. Most of them specialize in humanities and social sciences. From 2002 to 2022, the Chinese Academic of Science and the China University of Mining and Technology published 38 and 35 English-language

articles on resource-based cities, respectively. The China University of Geosciences, the University of the Chinese Academy of Sciences, and Wuhan University each have more than 15 articles published. A comparison of the published institutions in both Chinese and English shows that the research on resource-based cities is mostly conducted by Chinese scientific research institutions, and no foreign scientific research institutions are listed. This shows the scientific research strength of China's institutions and indicates that China attaches great importance to the research on resource-based cities.

3.4 Analysis of highly cited literature

A statistical analysis of highly cited literature helps readers quickly understand the important literature in this field. [Table 3](#) and [Table 4](#) show the top 10 most highly cited Chinese and English articles on the theme of resource-based cities, respectively. In the Chinese literature, as of 9 June 2022, the article "Definition and Classification of Resource-based Cities in My Country" has been cited 520 times total. It defined resource-based cities for the first time, and it established the principles of determining resource-based cities in China and the classification of resource-based cities, which laid the foundation for the study of resource-based cities. The second most cited is "Research on Environmental Regulation, Resource Endowment, and Urban Industrial Transformation: A Comparative Analysis Based on Resource-based Cities and Non-resource-based Cities," published in the *Economic Research Journal* in 2018. This article explains that industrial transformation is the key to the transformation of resource-based cities and analyzes the influence mechanisms of environmental regulation and resource endowment on industrial transformation ([Li and Zou, 2018](#)). In just 4 years, the citation volume of this article climbed to the second place, which indicates its significance for the study of resource-based cities and to be of referenced and studied by scholars in related fields. Until 9 June 2022, "The Impact of Low-Carbon City Construction on Ecological Efficiency: Empirical Evidence from Quasi-Natural Experiments," published in 2020, topped the list with 104 citations in the English literature. The heterogeneity analysis between resource-based cities and non-resource-based cities indicated that cities with high natural resource dependence tend to develop resource-based industries and fall into the "resource curse," which makes the effects of low-carbon city pilot policies not obvious ([Song et al., 2020](#)). The article "Effects of Urbanization on Ecosystem Service Values in a Mineral Resource-based City," published in 2015, also topped the list. Huaibei (a mining resource-based city in China) is taken as an example to illustrate the impact of the urbanization process on resource-based ecological service systems and residents' quality of life ([Wan et al., 2015](#)). A comparison of the citations of Chinese and English literature indicates that the Chinese literature has obvious advantages, that it is more macroscopic and provides a better reference value for research on resource-based cities.

Top 15 Keywords with the Strongest Citation Bursts

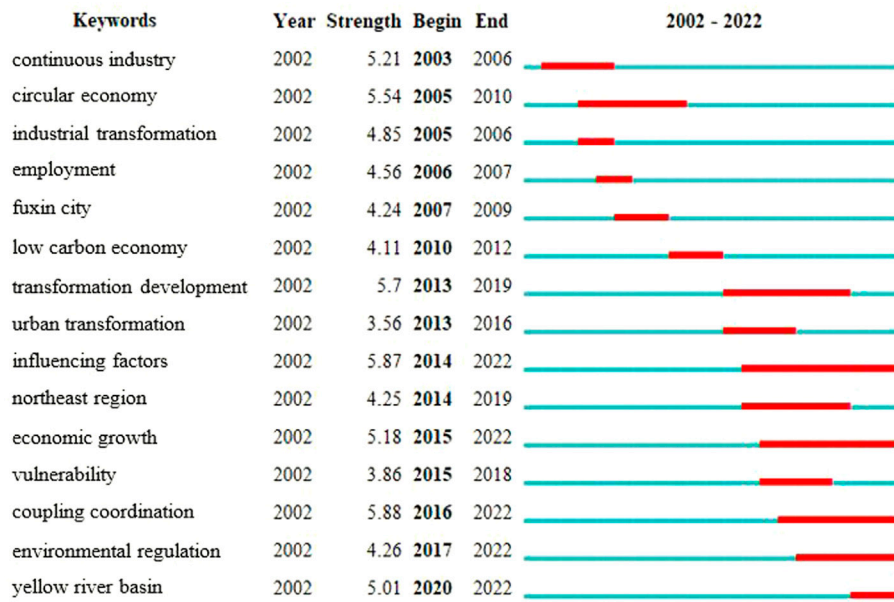


FIGURE 4 Analysis of keyword emergence in the CNKI literature.

Top 15 Keywords with the Strongest Citation Bursts

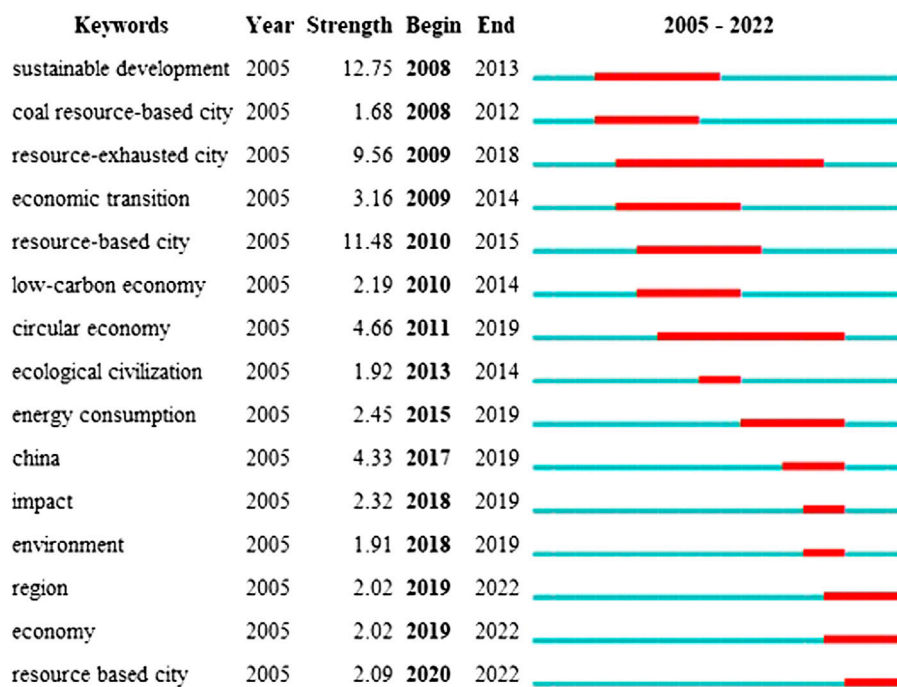


FIGURE 5 Analysis of keyword emergence in the WOS literature.

4 Analysis of research hotspots

Keywords summarize the whole study, and their frequency provides an important basis for judging whether a research direction is a research hotspot in the field, which is one of the means to analyze the research focus of a field. To show the frequency, centrality, and evolution trend of keywords in studies on resource-based cities, this study uses CiteSpace software to analyze keyword co-occurrence and keyword emergence.

4.1 Keyword co-occurrence analysis

Keyword co-occurrence analysis visually shows the research hotspots in a research field through the frequency of keywords. We conducted keyword co-occurrence analysis on the Chinese literature on resource-based cities in the CNKI database and the English literature in the WOS database and drew the keyword co-occurrence network, as shown in [Figure 2](#) and [Figure 3](#) (we translated the Chinese display results in [Figure 2](#) into English). The larger the circle of the node in the figure, the larger the word frequency of the keyword, which indicates a research topic hotspot. The thicker the connection between nodes, the greater they appear in the same article together. A different color in each layer of the circle represents a different year, with darker colors representing earlier years and lighter colors representing later years.

[Figure 2](#) shows that words such as industrial transformation, economic transformation, urban transformation, and industrial structure are at the core of the whole network. It is an important network node and has been the focus of ongoing research since 2002. Although the theme of industrial structure is not dominant in terms of keyword frequency, it can be seen from the color analysis of the outer circle that it has been the focus of scholars in recent years and has very strong characteristics. Because northeast China is rich in natural resources, including coal, minerals, and forest resources, and the old industrial base of northeast China is a very typical resource-dependent region, the northeast area is also a keyword that often appears in the research on resource-based cities. In addition, the circular economy, continuous industries, countermeasures, and resource depletion are important nodes in the network, which readers can learn about.

[Figure 3](#) is a keyword co-occurrence network diagram of relevant literature in the WOS database. Resource-based cities occupy the core position in the network, followed by cities, sustainable development, China, impact, carbon dioxide emissions, and other words. This shows that foreign journals pay more attention to sustainable development and carbon emissions in the transformation process of resource-based cities. By comparing the network diagram of co-occurrence of keywords in China and internationally, it can be seen that the connection between nodes in [Figure 3](#) is more significant. English journals are more systematic in the co-occurrence of keywords and content focus. However, except for a few core nodes of

Chinese journals, the connection between the other nodes is not significant, indicating scattered research content.

4.2 Keyword emergence analysis

The keyword frequency spike is a phenomenon worthy of attention in the field of research, which reflects an interest by researchers and a general academic concern with a specific period of time. CiteSpace generates a keyword emergence network map by extracting the uprush of keywords in a particular timeframe, which becomes keyword emergence analysis. [Figure 4](#) and [Figure 5](#) are plotted to show the temporal changes in keyword emergence in both Chinese and English literature, respectively (we translated the Chinese analysis results in [Figure 4](#) into English). The red lines in the figure represent the temporal regions with significant changes.

As shown in [Figure 4](#), scholars paid more attention to the transformation and development of resource-based cities before 2013, including industrial transformation focusing on the economy and the successor industry in terms of employment. Since 2014, “influencing factors” have become an important topic, with the mutation intensity reaching 5.87, which also indicates that the research focus on resource-based cities has changed from how to develop to how to evaluate. In recent years, an increasing number of environment-related keywords have emerged, such as “vulnerability” in 2015, “coupling coordination” in 2016, and “environmental regulation” in 2017. The emergence of these keywords indicates that scholars paid attention to the impact of urban transformation on the environment in their research on resource-based cities.

Since the English literature on resource-based cities started in 2005, the starting year in [Figure 5](#) was changed to 2005. In [Figure 5](#), from the analysis of mutation intensity, sustainable development, resource-based cities, and resource-exhausted cities exhibit intensities of 12.75, 11.48, and 9.56, respectively, indicating that these three keywords occupy a core position in the research field and that sustainable development is the core content of English journals. Resource-exhausted city and circular economy are two keywords that have persisted over time. From 2009 to 2018, resource-exhausted cities were the focus of attention, which coincided with the period when China began to identify resource-depleted cities in 2007. The popularity of the circular economy lasted from 2011 to 2019, becoming a popular research hotspot. The mutation intensity of the circular economy also reached 4.66.

5 Conclusion

First, this study introduces the basic concept of resource-based cities and expounds the domestic and international research on the development of resource-based cities, including the influencing factors of urban transformation, the

path of urban transformation, and the evaluation index of urban transformation. Through data analysis and visual analysis of 1,732 Chinese articles included in CNKI Peking University Core and CSSCI journals and 450 English articles in WOS from 2002 to 2022, the important indicators in the field of resource-based city research are visually displayed. The key topics of Chinese literature mainly focus on urban transformation, including economic, industrial, and environmental dimensions. The evolution of research can be divided into three stages: rapid rise, high fluctuation, and mature development. Future research will focus more on the coupling between low-carbon development and urban transformation. The main theme of the English-language literature is sustainability, supplemented by a circular economy and a low-carbon economy, and the number of articles has increased rapidly since 2017, indicating that research on resource-based cities has received increasing attention from English journals in recent years. In terms of publications, Chinese institutions are the absolute leaders of both Chinese- and English-language journals, indicating that China attaches great importance to the issue of resource-based cities.

However, China's research on resource-based cities still has the following problems. 1) The research scope is uneven. According to the keyword co-occurrence network diagram of CNKI and WOS, it can be seen that, except for a few core nodes, most nodes are small, indicating that the research has focused on the main core points in the past 20 years and has not undergone more extensive development. 2) The focus of the research is scattered. Although the frequency of core keywords in Chinese journals is high, the co-occurrence among keywords is weak, and most keywords have no relation to each other. Meanwhile, in the analysis of keyword emergence, the intensity of the top 15 keywords in Chinese journals is between 4 and 5. In contrast, the intensity of keyword emergence in English journals is obviously differentiated, which indicates that the current research published in domestic journals has not formed a clear system, each topic is popular for a short period of time, and the research content is not thorough enough. 3) Quantitative research is lacking. Among the top 10 most highly cited Chinese and English studies, few have studied the efficiency and policy effects in the transformation process of resource-based cities through quantitative research. This shows that the research on resource-based cities still lacks the support of mathematical models, and the results obtained are mostly based on qualitative analysis and historical information. 4) The evaluation indicators are not unified. In many articles evaluating the transformation effects of resource-based cities, scholars have proposed a variety of indicators and evaluation methods, and the evaluation effects obtained are quite different. Multiple indicators are

not helpful to government analysts; it will be difficult and inefficient for the government to carry out work in this field.

Nevertheless, we provide corresponding prospects for future research work. Researchers can further deepen the existing research conclusions in terms of topic selection and conduct a more thorough analysis and discussion on the existing topics. Qualitative content can be quantified by establishing mathematical models or data-driven methods to make the conclusions more robust. To increase the co-occurrence of keywords in the knowledge network, it is necessary to explore the connections between existing topics and the internal relations between each topic instead of making each topic independent. The existing relevant indicators should be sorted out to form a more systematic evaluation system, and the theoretical content should be implemented to help governments at all levels effectively improve the problems encountered in the transformation process of resource-based cities.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding authors.

Author contributions

DX conceived the idea and outlined in brief. DX and QG collected the data used in the study. ZW participated in the whole discussion and produced all the figures and tables in the study. QG put forward targeted improvement suggestions based on the results. QG and ZW assisted in polishing the manuscript. All authors contributed to study revision and have both read and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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