*Journal of Infrastructure, Policy and Development* (2023) Volume 7 Issue 1.
DOI: 10.24294/jipd.v7i1.2067

ORIGNIAL ARTICLE

# Visualization analysis of research hotspots and frontiers on factors influencing urban green innovation—Based on CiteSpace knowledge map

***Fanbo Li*[1], *Hongfeng Zhang*[1*], *Xiaoyu Wei*[1,2]**

[1] *Faculty of Humanities and Social Sciences, Macao Polytechnic University, Macao*

[2] *School of Applied Science and Civil Engineering, Beijing Institute of Technology, Zhuhai 519088, China*

## ABSTRACT

With the increasing call for sustainable development, cities' demand for green innovation has also been growing. However, relatively little research summarizes the influencing factors of urban green innovation. In this study, we conducted a visual analysis of 1193 research articles on green innovation in cities from the Web of Science core database using bibliometrics and visualization analysis. By analyzing co-occurrence, co-citation, and high-frequency keywords in the literature, we explored the current research status and development trends of influencing factors of urban green innovation and summarized the research in this field. The study found that collaboration among authors and institutions in this field needs to be strengthened to a certain extent. In addition, the study identified the research hotspots and frontiers in the field of urban green innovation, including "management", "diffusion", "smart city", "indicator", "sustainable city", "governance", and "environmental regulation". Among them, "management", "governance", "indicator", and "internet" are the research frontiers in this field, which are expected to have profound impacts on the future development of urban green innovation. The co-citation analysis results found that China has the highest research output in this field, followed by the United States, England, Australia, and Italy. In conclusion, this study uses CiteSpace software to identify important influencing factors and development trends of urban green innovation. Urban green innovation has gradually become a norm for social and collective behavior in the process of concretization, interdisciplinary development, and technological innovation. These findings have important reference value for promoting research and practice of urban green innovation.

## KEYWORDS

*urban green innovation; influencing factors; CiteSpace; bibliometric analysis*

ARTICLE INFO
Received: April 27, 2022
Accepted: June 2, 2023
Available online: June 29, 2023

*CORRESPONDING AUTHOR
Hongfeng Zhang, Faculty of Humanities and Social Sciences, Macao Polytechnic University, Macao; hfengzhang@mpu.edu.mo

CITATION
Li F, Zhang H and Wei X (2023). "Visualization analysis of research hotspots and frontiers on factors influencing urban green innovation—Based on CiteSpace knowledge map". *Journal of Infrastructure, Policy and Development*, 7(1): 2067. doi: 10.24294/jipd.v7i1.2067

## 1. Introduction

With the continuous advancement of industrialization, countries around the world have achieved remarkable achievements in economic development, but at the same time, it has irreversible impacts on natural processes, resulting in unexpected ecological consequences and social disasters. The problems of resource constraints, environmental pollution, and ecological degradation caused by the extensive economic growth model are becoming increasingly prominent (Hsu et al., 2021). Compared with traditional innovation, green innovation encourages the adoption of clean and renewable energy, promotes circular economy and resource recycling, reduces pollutant emissions, and facilitates environmental restoration. It not only accelerates the industrialization process but also mitigates many adverse impacts on sustainable development while reducing production costs and external environmental costs (Shaheen et al., 2022). Many countries and organizations have identified green innovation as an important strategy for achieving environmental protection and economic growth (Jang et al., 2015). Cities are the most economically dynamic, open, and innovative entities, and objective analysis of urban green innovation is conducive to cities identifying their positioning and further optimizing the development of green innovation (Fan et al., 2021). Given this, countries around the world have begun to focus on urban green innovation and regard it as an important program for coordinating ecological environment and economic development.

In 2011, the OECD Ministerial Conference identified the Green Growth Strategy as the overarching development strategy, the number of institutions and organizations researching urban green innovation has gradually increased, and a large number of research literature on green innovation has emerged. However, so far, the academic community has not provided a definition of green innovation that is understandable and widely accepted by the public. The concept of green innovation is similar to eco-innovation or environmental innovation. In a narrow sense, green innovation generally refers to the use of green technologies by enterprises in their production and development activities, to achieve optimal innovation output with the lowest resource and environmental costs. In a broad sense, green innovation also includes technological innovation, institutional innovation, and cultural innovation that promote economic, ecological, and social sustainable development (S. Wang et al., 2022). This study regards urban green innovation as a process that takes place in urban environments, involving the adoption of novel concepts, technologies, products, and strategies to promote environmental sustainability and ecological balance while achieving economic, social, and environmental benefits. It encompasses interdisciplinary and cross-domain activities. This definition emphasizes the nature of innovation, which involves the use of new ideas and methods to address the challenges faced by urban sustainable development and advance the goals of sustainability. It highlights the multidisciplinary and comprehensive nature of urban green innovation, reflecting its involvement in diverse fields and interdisciplinary characteristics. It is important to note that the definition of urban green innovation is an evolving and changing concept as research and practice continue to drive its further development and deepening. Therefore, conducting an in-depth exploration of the development patterns of urban green innovation is of great significance in promoting sustainable and healthy urban economic development.

Currently, there have been some achievements in the research literature on the influencing

factors of urban green innovation. However, the research results are not consistent, and processing subjective experiential data of individuals is no longer sufficient to meet the needs of practical research. Therefore, it is necessary to systematically review and summarize the existing research results. In this study, 1193 research articles with the theme of influencing factors of urban green innovation in the Web of Science core database are used as research samples. Based on CiteSpace software, visualized analysis is conducted from multiple dimensions such as countries, institutions, authors, keywords, journals, and literature, to explore the research hotspots, trends, and overall characteristics of influencing factors of urban green innovation. Thus, corresponding research conclusions and future research directions are drawn.

This study includes five research questions. 1) What are the research topics and hotspots in the field of influencing factors of urban green innovation? Through visual analysis using CiteSpace software, research topics and hotspots in the field of urban green innovation can be identified, and their changing trends can be analyzed. 2) What are the influencing factors in this field? The path analysis function of CiteSpace software can identify the influential literature and research paths in the field of urban green innovation, providing an in-depth understanding of the influencing factors in this field. 3) What is the collaboration network in this field like? The co-word network analysis function of CiteSpace software can construct the collaboration network in the field of urban green innovation, identify authors, institutions, or countries with close collaborative relationships in this field, and further understand the structure and characteristics of the collaboration network. 4) What are the research trends in this field? The timeline function of CiteSpace software can observe the research trends in the field of urban green innovation during different periods, including changes in keywords and the evolution of research hotspots, thus understanding the research dynamics in this field. 5) How is interdisciplinary research conducted in the field of urban green innovation? The keyword clustering and evolution analysis function of CiteSpace software can identify interdisciplinary research topics and research paths in the field of urban green innovation, providing an in-depth understanding of cross-disciplinary collaboration among different fields.

## 2. Review of literature

The term “green innovation” emerged in the context of environmental sustainability and the need for more environmentally friendly and sustainable practices, and gained prominence in the early 21st century as concerns about climate change, resource depletion, and environmental degradation increased worldwide. Currently, the academic literature on green innovation mainly covers the following three categories: 1) viewing green innovation as reducing adverse environmental impacts and meeting the needs of sustainable development through the introduction of green behaviors, green products, and green processes (Cai and Li, 2018); 2) viewing green innovation as a type of innovation that considers environmental performance (Úbeda-García et al., 2022); and 3) viewing green innovation as an improvement in environmental performance and environmental innovation (Costantini et al., 2017). The academic community has made significant progress in understanding the factors influencing green innovation, primarily from the perspectives of environmental economics, innovation economics, management, and other fields, focusing on the impact of factors such as environmental policies, foreign direct investment (FDI), resource capability, and corporate governance on green innovation. Firstly, in the field of environmental economics, scholars have conducted a significant amount of research on whether environmental policies can promote green

innovation and ecological sustainability. The impact of environmental policies on green innovation is nonlinear, although green innovation can help improve the ecological environment, rebound effects may offset the environmental performance of green innovation (K.J. Li et al., 2020). Borsatto's research results indicate a positive correlation between environmental policies and green innovation, with environmental policies being one of the main driving factors of green innovation (Borsatto and Bazani, 2021). Pan et al. (2021) summarized an inverted U-shaped relationship between environmental policies and green innovation using regional panel data. Secondly, in innovation economics, the innovation theory is used to explain the innovation behavior of agents in dealing with environmental issues in the production process, as well as the impact of innovation policies on innovation activities. The effectiveness of environmental policies can significantly promote the level of green innovation more than the number of policies (Wu et al., 2022). The research of J. Liu et al. (2022) found that technological capabilities such as human capital promote traditional innovation rather than green innovation, while environmental policies are more effective in promoting green innovation. Finally, in the field of management, existing research has focused more on the influence of organizational characteristics on green innovation, the impact of green innovation strategies on innovation performance, and the optimal path for green innovation. Xie and Zhu (2021) found that the nature of a company affects its green innovation behavior, and a green strategic orientation can bring sustainable development performance to the company. Y. Liao et al. (2022) found that the output of green innovation significantly enhances a company's ability for sustainable development, and the relationship between the two is more significant when the company's innovation management or research capabilities are weaker.

The existing research results on green innovation are abundant, and they play an important role in enriching the research content and theoretical system of green innovation. However, compared to the business sector, the academic community has paid less attention to urban green innovation. Existing research on urban green innovation mostly explores the distribution pattern of green innovation from a spatial perspective. For example, Lu et al. (2022) conducted a spatial econometric analysis based on provincial panel data in China and found significant differences in green innovation between eastern, central, and western cities, with greater fluctuations in green innovation in central and western cities compared to the eastern region. Empirical studies by K. Liu et al. (2023) show that the spatial pattern of green innovation in eastern, central, and western China exhibits a decreasing trend, with obvious spatial agglomeration effects and narrowing differences in green innovation among provinces. B. Liao and Li (2022) quantitatively analyzed the spatial correlation strength of green innovation in 284 cities and found that there are significant intra-cluster agglomeration and inter-cluster associations among different green innovation agglomeration clusters, with significant overall spatial polarization effects.

## 3. Data sources and research tools

### 3.1. Data sources

Considering the specific objectives and research questions of this study, as well as the usability of the database, we have chosen to use the Web of Science (WOS) Core Collection as the primary source of literature and analysis tool. The reasons for this choice are as follows. 1) WOS provides rich analysis tools and functionalities, allowing for co-occurrence analysis, citation analysis,

and high-frequency keyword analysis, among others. 2) WOS has undergone rigorous screening and evaluation and includes important academic publications from around the world. In fact, green innovation can also be referred to as ecological innovation, sustainable innovation, and environmental innovation, as they all aim to achieve economic sustainability. Therefore, in the WOS database, this paper searched with keywords such as "Urban Green Innovation Factors, Urban Ecological Innovation Factors, Urban Environmental Innovation Factors, Urban Sustainable Innovation Factors", spanning all years. Considering the timeliness of journal articles and their sensitivity to cutting-edge research compared to books and reports, the document type was refined to "Article OR Review OR Proceeding paper" for screening. In the end, 1193 pieces of literature were retrieved, and the sample data was imported into CiteSpace software, and the data analysis was used to identify the corresponding network nodes and map out the knowledge map of urban green innovation impact factor research.

The research results presented in this paper are mainly based on four analyses. 1) Descriptive analysis aims to provide a comprehensive understanding of the research field. 2) Cooperation network analysis includes three levels: country, institution, and author, to describe the main factors influencing urban green innovation from macro, meso, and micro perspectives. 3) Co-citation analysis includes clustering of co-cited references and identification of key citing authors, aiming to determine the main research topics and classic literature. Journal co-citation analysis includes journal co-citation and citation bursts. 4) Research hotspots are summarized through keyword co-occurrence network analysis and clustering analysis, analyzing the evolution of research topics, and using burst detection analysis to identify potential future research directions. Through the above analysis methods, we can gain a comprehensive and in-depth understanding of the current situation, development trends, and future directions in the field of urban green innovation research, providing useful references and guidance for academic research and practical applications in this field.

### 3.2. Research tools

The knowledge graph is a graphical representation of a knowledge domain, which not only presents the changing process of scientific knowledge but also indicates the structural relationships between knowledge. It is created using bibliometric software by mining information such as keywords, authors, and institutions from literature (Chen, 2006).

CiteSpace is a software developed by Chen (2014) based on Java, which translates unquantifiable scientific literature knowledge into visualized graphs through data analysis. It is widely used in the field of scientific literature metrics. The software analyzes a large number of citations, including co-citations, reference citations, and cluster citations, to present a clear picture of the research status, hot topics, development trends, key authors, and institutions in a specific field. This enables multidimensional, temporal, and dynamic visual analysis of a research field. In this study, the software CiteSpace V6.1.R3 was used for analysis. Keywords, categories, references, and other algorithms were selected to perform multi-dimensional clustering analysis on urban green innovation using pathfinding and network slicing. After visualizing the results, the analysis was further refined by adjusting and optimizing the graph format. Excel was used to analyze and rank the data, including publication volume, disciplinary information, countries, and keywords, as well as to analyze the significant increase in citations. Finally, the research status, hot topics, cutting-edge research, and development trends in the field of urban green innovation were presented and

described through knowledge graphs, visual analysis, and statistical tables.

## 4. Research content

### 4.1. Time distribution characteristics

The changes in the quantity of research literature in a research field to some extent indicate the research trends, stages, and development speed of that field. From **Figure 1**, it can be observed that the literature development trend in this research field can be divided into three stages. The first stage is from 1999 to 2006, during which the number of publications was relatively low, with an average annual publication quantity of only around 3 papers. The research content mainly focused on new perspectives on environmental resources and sustainable cities, and most of them were general theoretical research (Sha et al., 2006; C. Wang et al., 2002). The second stage is from 2007 to 2015, during which the concepts and significance of influencing factors of urban green innovation began to develop in the academic community. The average annual publication quantity increased significantly to around 20 papers compared to the first stage. This may be due to the United Nations Climate Change Conference held in 2007, and the Intergovernmental Panel on Climate Change (IPCC) released the "Fourth Assessment Report on Climate Change" outlining the catastrophic changes that climate warming would cause to humanity, which attracted widespread attention from the international community (Garfin et al., 2013). The third stage is from 2016 to the present, with an average annual publication quantity of over 100 papers, and the highest number of publications in 2022 reached 366 papers. This research field has become a hot topic in the academic community. The reason may be that the United Nations' adoption of the "2030 Agenda for Sustainable Development" and its 17 Sustainable Development Goals (SDGs) in 2015 has influenced the direction of international and national development policies (Lee et al., 2016), making sustainable development a new focus for the academic community and government agencies. Overall, this field continues to receive attention from researchers, and the quantity of research literature is continuously increasing.

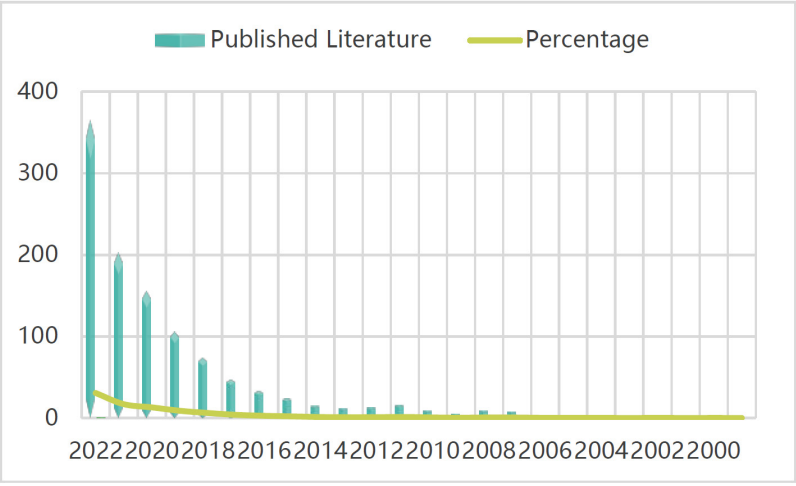


**Figure 1.** Literature development trend chart.

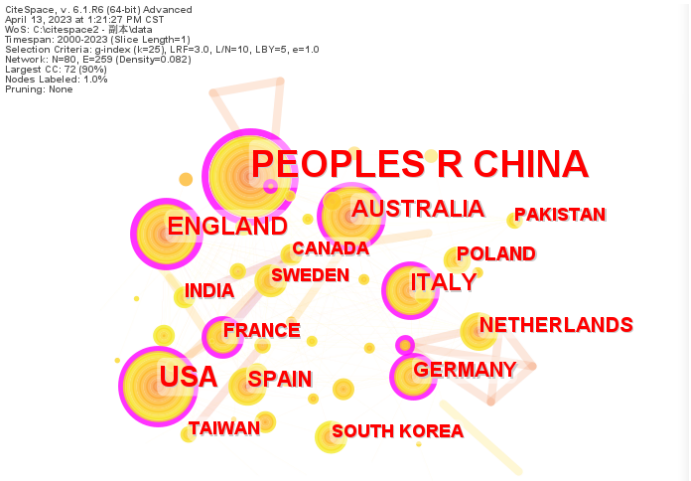


**Figure 2.** Visualization of country cooperation networks.

## 4.2. Spatial distribution characteristics

### *4.2.1. Country distribution*

We set the node type in CiteSpace as "Country" to analyze the cooperation network among countries interested in this field, and obtained a visualized network of cooperation between countries. From **Figure 2**, it can be seen that the cooperation network among countries has 80 nodes and 259 connections, with an overall network density of 0.082. It's common practice to compare the network with a randomly generated network to determine whether its density is high or low, indicating a relatively close cooperation network among countries. Among them, China has the highest research output, followed by the United States, England, and Australia, indicating a higher focus on the influencing factors of urban green innovation.

Centrality is a measure of the extent to which a node plays a role in the entire network. The higher the centrality of a node, the stronger its connections in the network and the greater its influence (Chen, 2006). Generally, a node with a centrality greater than 0.1 is considered a key node. **Table 1** lists the top 10 most productive countries, and it can be seen that China, the United States, England, Australia, Italy, and Germany have significant influence in this research field.

**Table 1.** Cooperating countries

| Countrys | Frequency | Intermediary centrality | Years |
|---|---|---|---|
| China | 622 | 0.45 | 2006 |
| USA | 119 | 0.19 | 2004 |
| England | 58 | 0.35 | 2004 |
| Australia | 51 | 0.13 | 2002 |
| Italy | 46 | 0.18 | 2000 |
| Spain | 38 | 0.06 | 2008 |
| Germany | 31 | 0.11 | 2015 |
| Netherlands | 29 | 0.04 | 2000 |
| Poland | 24 | 0.08 | 2011 |
| France | 23 | 0.10 | 2004 |

Furthermore, these 10 countries include both developed and developing countries, indicating that green innovation has become a global issue. China, with 622 publications, ranks first by a large margin compared to other countries. This may be because China, as an emerging market participant, is implementing sustainable development strategies, and cities in China are placing a strong emphasis on green development as an internal requirement and actively assuming environmental protection responsibilities (Aizawa and Yang, 2010). Moreover, Italy, the Netherlands, and Australia had an early start in research in this field, while other countries started after 2004.

### *4.2.2. Institutional distribution*

The institutional collaboration network can illustrate the distribution of research space in the field, reflect the collaboration among institutions, and provide a reference for evaluating the academic influence of institutions. From **Figure 3**, it can be seen that the institutional collaboration network has a total of 417 nodes and 458 links, with an overall network density of 0.0053, indicating that more institutions are researching the influencing factors of urban green innovation.

In addition, to further analyze the collaborative relationships among institutions, **Table 2** lists the top 10 most productive institutions. It can be seen that the institutions with the most publications are the Chinese Academy of Sciences, Shanghai University of Finance and Economics, Wuhan University, and China University of Geosciences. However, the collaboration among these institutions is not high, indicating that although they are highly productive institutions, their collaboration with other institutions is not close. Therefore, research in this field is mainly carried out independently by various institutions, and there is still significant room for improvement in collaboration among these institutions.

### *4.2.3. Author distribution*

The literature review published in journals to some extent represents the academic status of authors in the field. Therefore, by analyzing the quantity of literature published by authors and their connections, high-productivity and high-impact authors in the field can be identified. The collaborative network among authors is shown in **Figure 4**, which consists of 499 nodes and 378 links. The overall network density is 0.003, indicating weak collaboration among authors in the research field of urban green innovation factors. The most influential authors are Liu Ying and Fu Xuemei. They are not only a highly collaborative group but also the most recent emerging group in


**Figure 3.** Visualization of institutional cooperation network.

**Table 2.** Cooperating institutions

| Institutions | Frequency | Years |
|---|---|---|
| Chinese Acad Sci | 27 | 2007 |
| Shanghai Univ Finace & Econ | 21 | 2020 |
| Wuhan Univ | 18 | 2019 |
| China Unvi Geosci | 17 | 2017 |
| Zhongnan Univ Econ & Law | 16 | 2020 |
| Tongji Univ | 15 | 2011 |
| Tsinghua Univ | 15 | 2015 |
| Ocean Univ China | 12 | 2022 |
| Guangzhou Univ | 12 | 2020 |
| Shandong Normal Univ | 12 | 2019 |


**Figure 4.** Visualization of author collaboration network.

**Table 3.** Cooperating authors

| Authors | Frequency | Years |
|---|---|---|
| Zhou Qian | 6 | 2020 |
| Xue Dan | 5 | 2021 |
| Liu Bei | 4 | 2022 |
| Ahmad Fayyaz | 4 | 2021 |
| Liu Ying | 3 | 2022 |
| Fu Xuemei | 3 | 2022 |
| Gao Da | 3 | 2022 |
| Miao Zhuang | 3 | 2022 |
| Wen Huwei | 3 | 2022 |
| Yang Siying | 3 | 2022 |

this field. Therefore, the research in this field may have a small collaborative network.

As seen from **Table 3**, the number of publications by each author is relatively low. Zhou Qian

ranks first with 6 publications, followed by Xue Dan with 5 publications, and Liu Bei and Ahmad Fayyaz with 4 publications each. Among them, Zhou Qian is the most prolific author, and this author has high collaborations with authors from other countries. However, overall, the distribution of authors in the research on urban green innovation factors is not concentrated, and there is not much interaction among different authors.

## 4.3. Co-citation analysis

### *4.3.1. Literature co-citation*

Bibliographic co-citation analysis refers to the analysis of literature in a specific research field to identify high-quality literature in that field (Chen, 2006). **Figure 5** shows the co-citation relationships of the literature, with a total of 904 nodes and 2665 edges. The overall network density is 0.0065. **Table 4** shows the top 10 most cited literature, with Bin Li and Shusheng Wu having the highest co-citation strength ($N = 34$), followed by Jinhua Cheng ($N = 25$), Malin Song ($N = 23$).

This study utilized the natural logarithm algorithm in CiteSpace for cluster analysis (see **Figure 6**). The results showed that the Modularity Q value was 0.83, which is greater than 0.4, indicating an appropriate level (Chen et al., 2014). **Table 5** lists the clusters with Silhouette values greater than 0.8. The results showed that the largest cluster in this study was "green total factor productivity", which included 119 literature references. The main research directions in this cluster were "in-difference model", "spatiotemporal pattern evolution", and "influencing factors". In this cluster, the literature with the highest co-citation frequency was the one on the impact of environmental regulation on green total factor productivity by Li and Wu (2017), published in *Journal of Cleaner Production*. The second most cited literature was published by Cheng et al. (2019), regarding the promotion of green growth through low-carbon urban construction, also published in *Journal of Cleaner Production*. The second largest cluster was "green total factor energy efficiency", which included 87 literature references. The research focuses in this cluster were "green technology innovation", "industrial structure", and "digital finance". In this cluster, the literature with the highest co-citation frequency was the one on the impact of fiscal decentralization on green total factor productivity by Song et al. (2018), published in International Journal of Production Economics. The second most cited literature was published by Du et al. (2021), regarding urban green technology innovation and

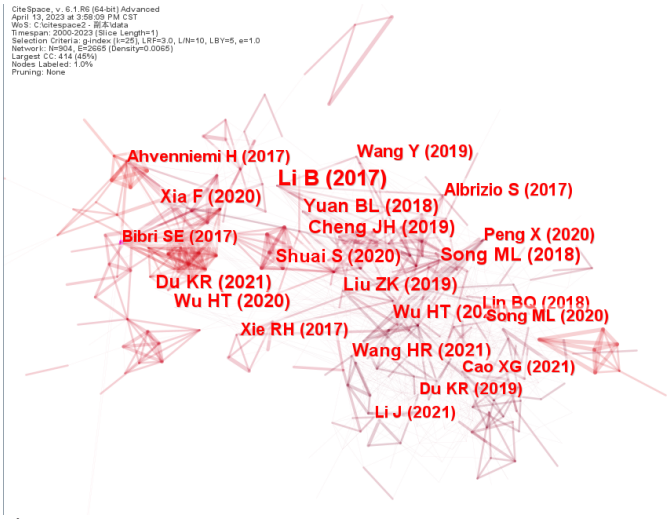


**Figure 5.** Literature co-citations.

**Table 4.** Top 10 most cited articles

| Rank | Journal | Articles | Authors | Co-citation intensity | Years |
|---|---|---|---|---|---|
| 1 | *Journal of Cleaner Production* | Effects of local and civil environmental regulation on green total factor productivity in China: A spatial Durbin econometric analysis | Bin Li and Shusheng Wu | 34 | 2017 |
| 2 | *Journal of Cleaner Production* | Can low-carbon city construction facilitate green growth? Evidence from China's pilot low-carbon city initiative | Jinhua Cheng et al. | 25 | 2019 |
| 3 | *International Journal of Production Economics* | Impact of fiscal decentralization on green total factor productivity | Malin Song et al. | 23 | 2018 |
| 4 | *Journal of Cleaner Production* | Environmental regulation, industrial innovation and green development of Chinese manufacturing: Based on an extended CDM model | Baolong Yuan | 21 | 2018 |
| 5 | *Energy Economics* | Environmental regulation, green technology innovation, and industrial structure upgrading: The road to the green transformation of Chinese cities | Kerui Du et al. | 21 | 2021 |
| 6 | *Energy Policy* | Has China's Belt and Road Initiative promoted its green total factor productivity?—Evidence from primary provinces along the route | Zuankuo Liu | 20 | 2019 |
| 7 | *Energy Policy* | Does internet development improve green total factor energy efficiency? Evidence from China | Haitao Wu | 20 | 2021 |
| 8 | *China Economic Review* | Green total factor productivity: A re-examination of quality of growth for provinces in China | Fan Xia | 20 | 2020 |
| 9 | *Energy Economics* | How do environmental regulation and environmental decentralization affect green total factor energy efficiency: Evidence from China | Haitao Wu | 6 | 2020 |
| 10 | *Journal of Environmental Management* | Modeling the role of environmental regulations in regional green economy efficiency of China: Empirical evidence from super efficiency DEA-Tobit model | Su Shuai | 20 | 2020 |

industrial structure upgrading, published in Energy Economics.

### *4.3.2. Journal co-citation*

Journal co-citation analysis can help researchers identify the most frequently cited journals and their impact. To systematically understand the publication status of the literature, the journal co-citation network is displayed in **Figure 7** and **Table 6**, with a total of 966 nodes and 5401 edges. The overall network density is 0.0116. The journal *Journal of Cleaner Production* received the most citations ($N$ = 641), followed by *Sustainability-Basel* ($N$ = 499) and *Energy Policy* ($N$ = 412). The results indicate that journals in the fields of environment, technology, management, and energy have

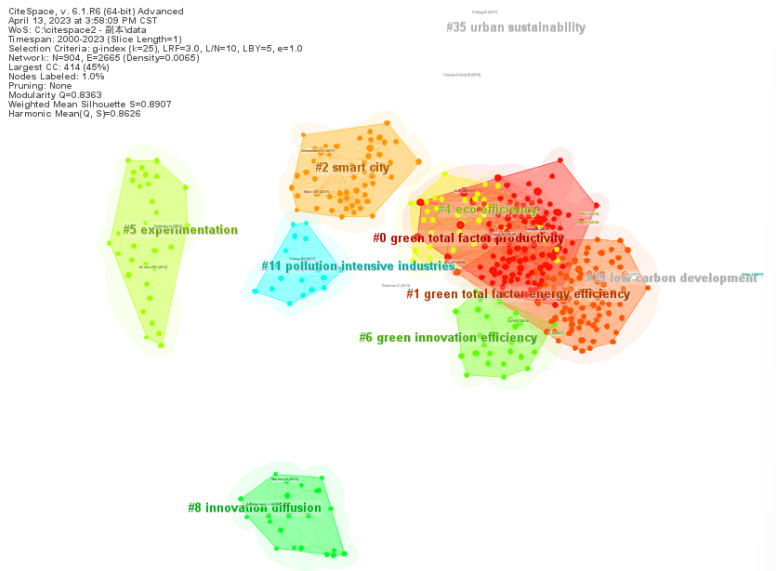


**Figure 6.** Clusters of cited references.

**Table 5.** Details of cited reference clusters

| Rank | Size | Silhouette | Years | Lable (LLR) |
|---|---|---|---|---|
| 1 | 119 | 0.826 | 2019 | green total factor productivity; high-speed rail; in-difference model; spatiotemporal pattern evolution; influencing factors |
| 2 | 87 | 0.832 | 2020 | green total factor energy efficiency; green technology innovation; industrial structure; digital finance; ict development |
| 3 | 56 | 0.972 | 2016 | sustainable development; smart governance; structural equation modeling; business models; innovation ecosystem |
| 4 | 36 | 0.898 | 2017 | environmental regulation; chemical industry; firm competitiveness; Jiangsu province; firm relocation |
| 5 | 32 | 0.965 | 2014 | sustainability transitions; grassroots initiatives; radical niches; transformative social innovations; local food security |
| 6 | 30 | 0.898 | 2020 | influencing factors; green technology innovation; super-efficiency sbm model; spatiotemporal differentiation; construction industry |
| 7 | 24 | 0.996 | 2012 | innovation diffusion; local government; technology acceptance; green infrastructure; transformative capacity |
| 8 | 18 | 0.986 | 2017 | environmental regulation; industrial redistribution; spatial spillover effect; pollution-intensive industries; fog computing |
| 9 | 7 | 0.996 | 2015 | low-carbon development; urban agglomerations; factor-biased technological progress; technical improvement strategy; technological progress |
| 10 | 5 | 0.985 | 2016 | sustainable development; sustainable city; social farming; community garden; social ecological innovation |

published the most literature on the influencing factors of urban green innovation.

Citation bursts indicate that a research field is gaining increasing attention, and citation peaks may appear explosively. Journal bursts are shown prominently in **Figure 8**. The strength of “SCIENCE” and “LOCAL ENVIRON” is 25.67 and 25.32, respectively, in 2019 and 2020,

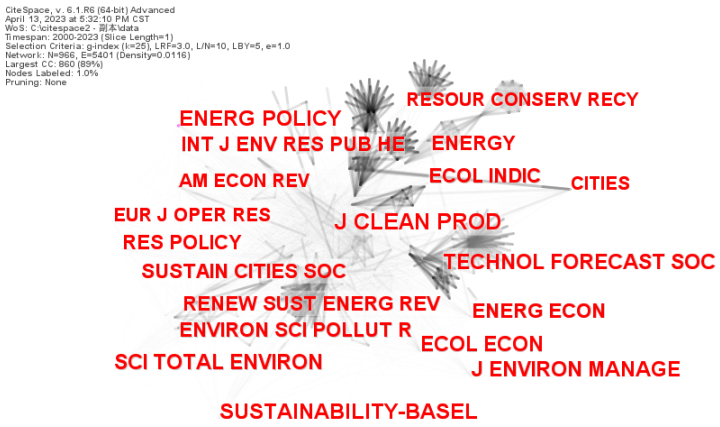


**Figure 7.** Journal co-citations.

**Table 6.** Top 10 most cited Journals

| Rank | Journals | Citation frequency | Years |
|---|---|---|---|
| 1 | *Journal of Cleaner Production* | 641 | 2012 |
| 2 | *Sustainability-Basel* | 499 | 2016 |
| 3 | *Energy Policy* | 412 | 2010 |
| 4 | *Journal of Environmental Management* | 366 | 2014 |
| 5 | *Ecological Economics* | 350 | 2011 |
| 6 | *Technological Forecasting and Social Change* | 339 | 2008 |
| 7 | *Science of the Total Environment* | 315 | 2017 |
| 8 | *Energy Economics* | 270 | 2015 |
| 9 | *Environmental Science and Pollution Research* | 261 | 2018 |
| 10 | *Renewable and Sustainable Energy Reviews* | 250 | 2014 |

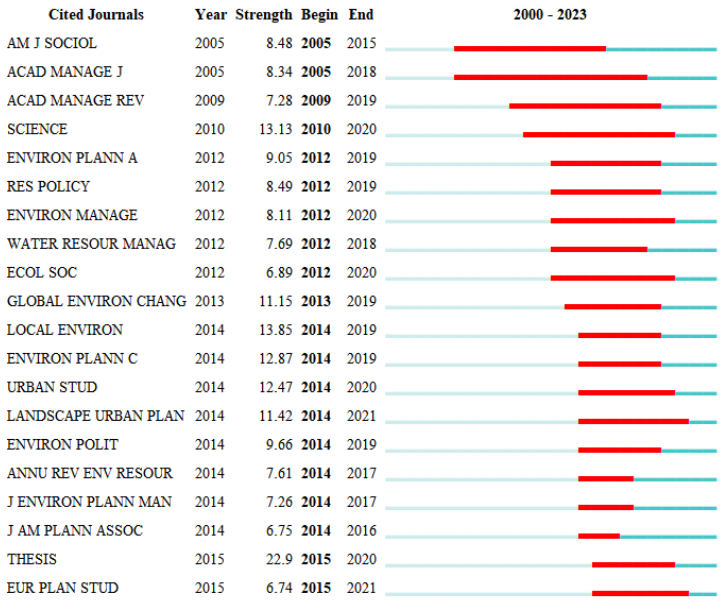


**Figure 8.** Journal citation burst.

which means that the citations to these journals increased significantly during the active period of research in this field, indicating a "citation burst" (Chen et al., 2014). From the emergence and time nodes of the cited journals, research on influencing factors of urban green innovation has shown significant growth after 2014, with a focus on journals related to the environment, management, economics, and sustainability. This indicates that these types of journals have played a key role in the development of this research field.

## 4.4. Research trend analysis

### *4.4.1. Keyword co-occurrence*

Keywords are concise representations of the main content of an article, and the co-occurrence of keywords can explain the trend of a hot research topic over time (Chen, 2006). **Figure 9** shows the co-occurrence network of keywords in this field, which has 568 nodes and 3014 links, with an overall network density of 0.0187. Among them, "innovation" is the most important node, followed by "city" and "management" as secondary important nodes. To a large extent, these keywords may represent the current research trends and hot topics.

Based on the co-occurrence characteristics of keywords, they can be classified into five categories. 1) Policy and management: including keywords such as environmental regulation, policy, management, strategy, and governance. Research trends in this category include exploring the impact of urban environmental regulations and policies on green innovation, the promoting role of urban management models in green innovation, and potential new policies and management strategies in the future (Q. Yang et al., 2021). 2) Economy and development: including keywords such as economic growth, investment, sustainable development, and growth. Research trends in this category include the contribution of urban green innovation to economic growth and sustainable development and the supportive role of urban investment in green innovation (Jin et al., 2019). 3) Technology and energy: including keywords such as technology, energy, big data, and productivity. Research trends in this category include the fields and trends of urban green technological innovation and the promoting role of urban energy transformation in green innovation (Rutherford and Coutard, 2014). 4) Social and behavioral: including keywords such as behavior, city, transition, system, urbanization, and perspective. Research trends in this category include the attitudes and behaviors of urban residents and enterprises towards green innovation and their participation


**Figure 9.** Keyword co-occurrence network map.

and influence in green innovation (Sharma et al., 2022). 5) Climate and environment: including keywords such as climate change, $CO_2$ emissions, pollution, emissions, and barrier. Research trends in this category include the mitigation effect of urban green innovation on climate change and environmental pollution and the impact of urban emissions and emission reduction technologies on green innovation (C. Li et al., 2022).

The top 20 high-frequency keywords are shown in **Table 7**. The results indicate that the frequency of the keyword "innovation" reaches 245 times, followed by "impact" ($N = 184$) and "city" ($N = 156$), indicating that these keywords are strongly correlated with other popular terms, and research on the influencing factors of urban green innovation is centered around these keywords.

Keyword clustering analysis can visualize the research hotspots in the field. **Figure 10** shows the keyword clustering of research on the influencing factors of urban green innovation. The results show that the Modularity Q value is 0.5719, which is greater than 0.4, indicating an appropriate level of Q value. The mean Silhouette value is 0.7464, indicating a high similarity within the clusters and reliable results (Chen, 2006).

**Table 8** shows the years and the number of keywords for the top 10 clusters. The years for the top 10 clusters range from 2008 to 2020, indicating that the influencing factors of urban green innovation have been a hotspot for a considerable period. Among them, the largest cluster appeared

**Table 7.** High frequency keywords

| Rank | Keywords | Frequency | Years |
|---|---|---|---|
| 1 | innovation | 245 | 2002 |
| 2 | impact | 184 | 2011 |
| 3 | city | 156 | 2011 |
| 4 | growth | 116 | 2015 |
| 5 | environmental regulation | 110 | 2017 |
| 6 | performance | 100 | 2017 |
| 7 | efficiency | 88 | 2006 |
| 8 | policy | 87 | 2006 |
| 9 | management | 78 | 2004 |
| 10 | China | 78 | 2014 |
| 11 | economic growth | 71 | 2018 |
| 12 | sustainable development | 70 | 2010 |
| 13 | model | 65 | 2010 |
| 14 | system | 64 | 2009 |
| 15 | energy | 59 | 2006 |
| 16 | $CO_2$ emission | 55 | 2015 |
| 17 | urbanization | 53 | 2019 |
| 18 | productivity | 50 | 2019 |
| 19 | emission | 50 | 2004 |
| 20 | technology | 44 | 2010 |

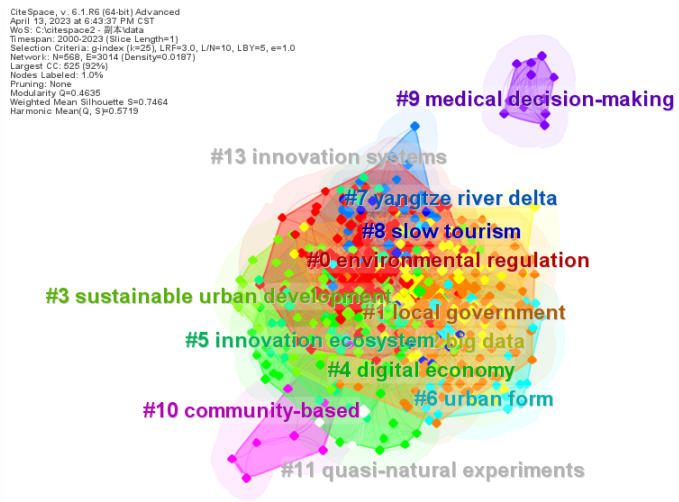


**Figure 10.** Keyword clusters.

**Table 8.** Details of keyword clusters

| Rank | Size | Silhouette | Years | Lable (LLR) |
|---|---|---|---|---|
| 1 | 118 | 0.572 | 2020 | environmental regulation; green innovation; civilized city construction; green innovation efficiency; sbm-dea model |
| 2 | 97 | 0.711 | 2015 | sustainable development; sustainable city; social ecological innovation; community garden; social farming |
| 3 | 69 | 0.675 | 2017 | smart cities; urban planning; social sustainability; happy cities; multiple pathways |
| 4 | 68 | 0.779 | 2015 | sustainable urban development; transportation management; water quality; public health; solar water heater |
| 5 | 39 | 0.894 | 2012 | technological innovation; sustainable urban mobility; $SO_2$ pollution; mcm v3; green finance |
| 6 | 32 | 0.878 | 2013 | impact; environmental innovation; determinant; spillover; insight |
| 7 | 28 | 0.853 | 2013 | delphi method; impact factors; intensive land use; evaluation index system; Shanghai pilot |
| 8 | 24 | 0.856 | 2020 | ecological efficiency; Yangtze River delta; spatial distribution; spatial durbin model; ebm model |
| 9 | 15 | 0.948 | 2008 | sustainable development; geographical marginality; slow tourism; alternative tourism; agricultural intensification |
| 10 | 11 | 0.954 | 2012 | industrial upgrading effect; quasi-natural experiments; green total factor productivity; trading system; carbon emissions |

in 2020 and is labeled as “environmental regulation”, containing 10 keywords. The main keywords in this cluster are “environmental regulation”, “green innovation”, “civilized city construction”, “green innovation efficiency”, “sbm-dea model”, and “green total factor productivity”. Therefore, it can be concluded that research on the influencing factors of urban green innovation mainly focuses on environmental regulation, city construction, green total factor productivity, and the application of structural equation models and data envelopment analysis methods to measure the efficiency of urban green innovation.

Keyword burst analysis can clearly display the start time, burst strength, and burst duration. **Figure 11** shows the results of the keyword burst analysis, in terms of the years of keyword bursts, "management" and "diffusion" appeared earlier, while keywords such as "smart city", "indicator", and "sustainable city" appeared later but have continued until 2021. In terms of the strength of keyword bursts, keywords such as "management" ($N$ = 7.5), "framework" ($N$ = 6.01), "smart city" ($N$ = 5.36), and "governance" ($N$ = 5.13) have very high burst strength, indicating that the frequency of appearance of these keywords has changed significantly (Chen, 2006). In terms of the duration of keyword bursts, "management" and "diffusion" have the longest duration, followed by "governance", "climate change", and "barrier", indicating that these keywords are research hotspots in this field. Overall, "management" and "governance" are considered the latest research hotspots in the field of influencing factors of urban green innovation due to their high burst strength and long duration of appearance.

In **Figure 12**, we can see a visual representation of keyword clusters arranged along a horizontal timeline. The clusters are organized vertically based on their size, with the largest ones at the top.

| Keywords | Year | Strength | Begin | End | 2000 - 2023 |
|---|---|---|---|---|---|
| management | 2004 | 7.5 | **2011** | 2018 | |
| diffusion | 2011 | 4.18 | **2011** | 2018 | |
| governance | 2014 | 5.13 | **2014** | 2020 | |
| city | 2011 | 4.2 | **2014** | 2017 | |
| barrier | 2014 | 3.41 | **2014** | 2019 | |
| climate change | 2014 | 3.32 | **2014** | 2020 | |
| innovation | 2002 | 3.58 | **2016** | 2017 | |
| acceptance | 2016 | 3.34 | **2016** | 2019 | |
| transition | 2016 | 3.25 | **2016** | 2019 | |
| framework | 2017 | 6.01 | **2017** | 2020 | |
| system | 2009 | 3.3 | **2017** | 2020 | |
| land use | 2017 | 3.27 | **2017** | 2019 | |
| smart city | 2018 | 5.36 | **2018** | 2021 | |
| indicator | 2018 | 4.01 | **2018** | 2021 | |
| urban | 2018 | 3.91 | **2018** | 2019 | |
| sustainable city | 2018 | 3.87 | **2020** | 2021 | |

**Figure 11.** Keyword burst.

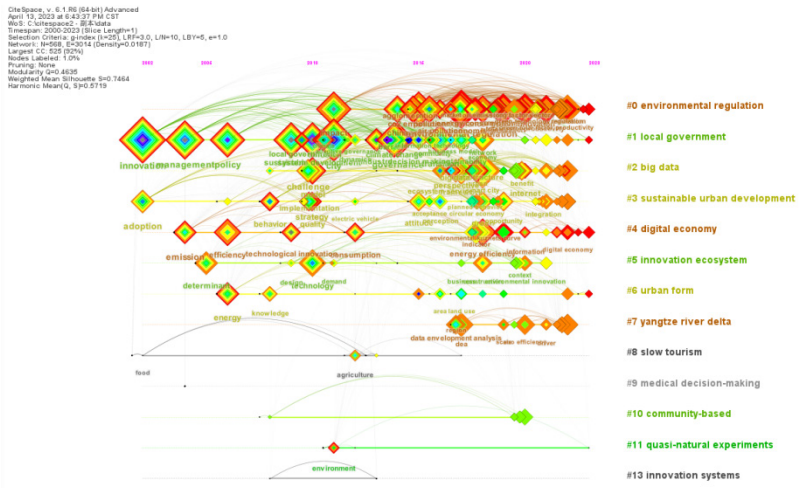


**Figure 12.** Keyword timeline.

The curves connecting the clusters indicate the relevance and connections between them. The visualization network of keywords has generated a total of 13 clusters.

From Figure 12, it can be seen that the duration of research hotspots in the field varies among clusters, which also represents the evolutionary process of the field. The largest cluster is "environmental regulation", which includes keywords such as green innovation, civilized city construction, and green innovation efficiency, with burst years ranging from 2015 to the present. The second largest cluster is "local government", which includes keywords such as sustainability, innovation, and governance, and has continued from 2002 to the present.

The temporal zone map uses time as the horizontal axis and displays the updated status of literature and the relationships between literature in chronological order (Chen, 2014). The analysis results of the keyword temporal zone map are shown in **Figure 13**.

For the study of influencing factors on urban green innovation, the most significant node is "environmental regulation", with keywords such as innovation, efficiency, energy, and policy. Meanwhile, high-frequency keywords are concentrated in the years 2006–2018, indicating a high research intensity on influencing factors of urban green innovation during that period. After 2018, concepts such as investment, decomposition, and the Internet emerged in this field, which may become new research directions for influencing factors of urban green innovation in the future.

### *4.4.2. Disciplinary co-occurrence*

In addition to keyword analysis, co-occurrence analysis of disciplines is also an important tool for determining the main content of literature. Analysis of discipline categories can help researchers understand the development patterns of research topics. The co-occurrence network map of disciplines is shown in **Figure 14**, and **Table 9** lists the top 5 discipline categories, which are ENVIRONMENTAL SCIENCES, ENVIRONMENTAL STUDIES, GREEN & SUSTAINABLE SCIENCE & TECHNOLOGY, ENGINEERING, ENVIRONMENTAL, and PUBLIC, ENVIRONMENTAL & OCCUPATIONAL HEALTH. The results indicate that disciplines in the environmental field, science and technology field, and management field are more actively involved

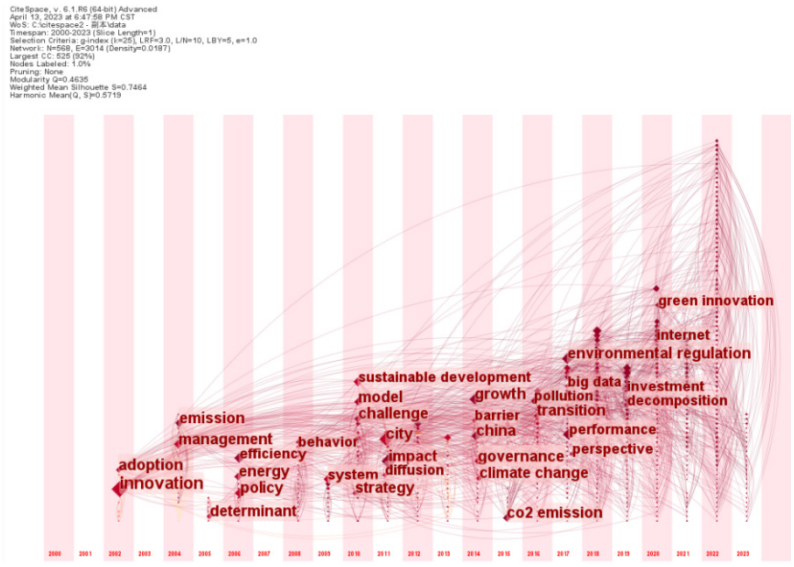


**Figure 13.** Keyword time zone map.

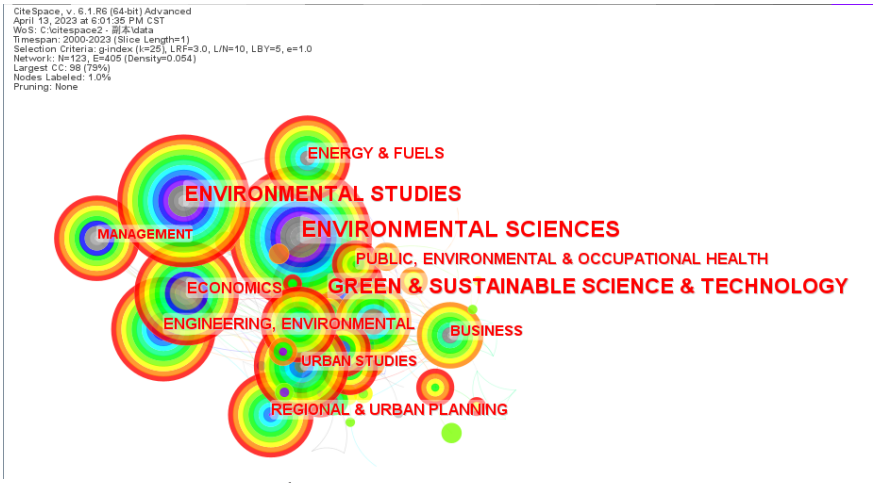


**Figure 14.** Disciplinary co-occurrence networks map.

**Table 9.** High frequency disciplines

| Rank | Categories | Frequency | Years |
|---|---|---|---|
| 1 | ENVIRONMENTAL SCIENCES | 533 | 2004 |
| 2 | ENVIRONMENTAL STUDIES | 306 | 2006 |
| 3 | GREEN & SUSTAINABLE SCIENCE & TECHNOLOGY | 295 | 2008 |
| 4 | ENGINEERING, ENVIRONMENTAL | 76 | 2007 |
| 5 | PUBLIC, ENVIRONMENTAL & OCCUPATIONAL HEALTH | 75 | 2004 |

in the study of influencing factors of urban green innovation.

## 5. Conclusion and discussion

This study provides a systematic and objective overview of the research on influencing factors of urban green innovation. Based on a collection of 1193 articles from the Web of Science (WOS), CiteSpace software was used for bibliometric analysis, including descriptive analysis, co-authorship network analysis, co-citation analysis, and research hotspot analysis, to describe the current research on influencing factors of urban green innovation. A comprehensive knowledge map of this research field was generated to analyze popular topics with development trends.

### 5.1. Research conclusions and research significance

Based on the research knowledge graph, this study summarizes six key findings:

(1) The literature on the influencing factors of urban green innovation first appeared in 1999 but did not receive much attention. Since 2015, the number of publications in this field has increased significantly, reaching 366 articles in 2022. This may be due to the adoption of the 2030 Agenda for Sustainable Development by the United Nations at the Sustainable Development Summit in 2015, which has guided policy-making and research directions on green innovation development in countries around the world, indicating that this research field is gaining increasing attention from the academic community (Lee et al., 2016).

(2) According to co-authorship network analysis, China, the USA, England, Australia, and Italy are in a leading position in research on influencing factors of urban green innovation. This indicates that the attention to influencing factors of urban green innovation has become a common concern for developed and developing countries. China has taken a leading position in research in this field, and the reasons for this may be as follows. Firstly, China faces severe environmental challenges and pressures for sustainable development. The government has put forward a series of initiatives at the policy level, which have motivated scholars to engage in research in this field. Secondly, Chinese cities are experiencing rapid urbanization and industrialization processes, resulting in urgent demands for urban environmental sustainability. Lastly, China has a large population and a vast urban network, providing abundant empirical cases and research samples for the practice of urban green innovation. The findings of the institutional collaborative network suggest that in future collaborative research, institutions should further establish deep collaborative relationships across disciplines and regions.

(3) Based on the analysis of the displayed results from the co-occurrence analysis of keywords, the current research trends may include the following. 1) Comparative study of green innovation policies and management models in different cities. Through comparative research on green innovation policies and management approaches in various cities, this research aims to identify the similarities and differences in promoting green innovation in different regions, thus providing policy recommendations. 2) Analysis of the relationship between urban economic growth and green innovation, exploring the contribution of green innovation to the sustainable development of urban economies. 3) Evaluation of the effectiveness of green technologies and energy in urban innovation, aiming to understand the actual impact of the adoption and utilization of these technologies and energy sources on urban green innovation. 4) Study on the behaviors and influencing factors of urban residents and businesses participating in green innovation, as well as strategies to enhance their active involvement. 5) Exploration of the correlation between urban green innovation and climate change, environmental pollution, as well as the role of green innovation in mitigating climate change and improving environmental quality. In summary, the current research trends demonstrate a comprehensive, multi-perspective, and diverse approach to studying the influencing factors of urban green innovation from different dimensions. These studies provide valuable guidance and decision-making foundations for achieving sustainable urban development.

(4) The research hotspots on influencing factors of urban green innovation include the following. 1) New policies and management models for urban green innovation. This mainly involves how to promote urban green innovation through policy and management measures, and how to enhance the flexibility and adaptability of policies and management to meet the needs of different cities (H. Zhang et al., 2023). 2) Urban green innovation and digital transformation. The impact of digital transformation on urban green innovation may become a future research hotspot, including how to leverage technologies such as big data and artificial intelligence to promote urban green innovation (J. Li et al., 2022). 3) Research on innovation adoption and social behavior. The behavior of urban residents and enterprises plays a crucial role in the adoption and application of green innovation, including social acceptance of green innovation (Yeh, 2017), motivators for residents and enterprises to participate in green innovation, and social impacts of innovation adoption. 4) Investment and business models for green innovation. Green innovation requires financial support and supportive business models, including how to attract and guide investment into urban green innovation, and

how to promote the commercialization and sustainable operation of green innovation (Owen et al., 2018).

(5) Based on the keyword time zone map and timeline analysis, environmental regulation, management, performance, and governance are eternal themes and important influencing factors of urban green innovation. 1) Environmental regulation includes the government's legal, regulatory, and policy provisions for urban green innovation activities, which promote cities to take action in environmental protection and sustainable development. 2) Effective management and performance are reflected in the organization, planning, implementation, and monitoring of urban green innovation activities, and are closely related to the sustainable development and sustainability of urban green innovation. 3) Governance plays a regulatory, guiding, and promoting role in urban green innovation. The government can promote the development of urban green innovation through policies, regulations, and funding support. The role of government in urban green innovation may also change with social and economic changes, and its role in urban planning, resource allocation, and public participation may be continuously adjusted.

Investment, decomposition, and Internet are shifting from macro to specific, from management and monitoring to multi-disciplinary research, and from traditional to technological innovation. 1) According to the main body of literature summarized in the previous section, previous investment research may have focused more on macroeconomic factors such as national economic policies and market trends, but now more research is focusing on specific investment projects such as technological innovation, emerging industries, and urban economic development. For example, some literature has studied investment decision-making in green innovation city construction (R. Li et al., 2022), including specific investment strategies for infrastructure construction, digital technology application, and intelligent transportation. 2) Previous research on decomposition may have focused more on macro-level issues in cities (Peng et al., 2021), such as overall economic growth and resource allocation brought about by innovation, but now research is going deeper into detailed levels. For example, urban transportation, energy management, and environmental protection. 3) Previous research on the Internet may have focused more on its macro impacts, such as information dissemination and social interaction, but now Internet research is increasingly focusing on specific field applications. For example, some literature has studied the application of Internet technologies in green innovation cities, such as the Internet of Things (IoT), and cloud computing, to improve the efficiency of urban management and residents' lives (Harmon et al., 2015).

The research significance of this article is mainly reflected in the following five aspects.

Firstly, a time trend analysis of the research field of urban green innovation impact factors was conducted, analyzing how this research field has developed and identifying the most focused themes in this field. This contributes to the academic value of the literature in this field through bibliometric analysis, which comprehensively and scientifically evaluates the relationships. This study is the first comprehensive and overall bibliometric analysis on the topic of urban green innovation impact factors.

Secondly, this research also contributes to the methodological application in this research field. Previous literature in this field generally adopts systematic methods. In contrast, this study used CiteSpace software for bibliometric analysis, which directly visualizes the relevant information in

this field. Visualized networks help researchers have a clearer and more transparent understanding of this field, enabling them to quickly identify classic literature in their respective fields, saving literature retrieval time and improving research efficiency.

Thirdly, based on keyword co-occurrence analysis, the research hotspots and future research trends of urban green innovation impact factors were identified, which will guide the research direction of future researchers.

Fourthly, through author co-occurrence analysis, the most significant contributors, most prolific institutions, and countries in the research field of urban green innovation impact factors were identified, which can help future researchers to pay attention to and track their research progress, further understanding the research trends in this field.

Fifthly, this study provides the most popular topics, main keywords of clusters, and focal areas in this field, which not only helps researchers in the fields of engineering technology, management, natural sciences, and social sciences to understand the latest progress of urban green innovation impact factors, but also assists collaborators, managers, and government agencies in other industries in improving urban green innovation development and policy-making by providing necessary foundations.

### 5.2. Future research directions

Given the limitation of purely quantitative analysis in providing comprehensive insights into the forefront of urban green innovation research in the context of specific research backgrounds, this study adopts a bibliometric analysis approach to prospect the research hotspots of green innovation. Based on this analysis, the study suggests that future research in this area should focus on the following aspects.

Focusing on multi-disciplinary and systematic research on hot areas based on strategic orientation and government policies. 1) From the perspective of influencing factors of urban green innovation, the relationship between environmental policy regulation and urban green innovation has received much attention and has yielded fruitful research results (Tian and Feng, 2021; J. Zhang et al., 2020). However, there is a lack of comprehensive consideration of the integrated impacts of technology, market, urban context, and external environment on green innovation, and research on driving factors of green innovation in different types of cities is scarce, necessitating further in-depth research. 2) In terms of the relationship between urban green innovation and innovation performance, most scholars believe that green innovation has a positive impact on urban economic and environmental performance, but the conclusions on this impact are not unified. Some scholars argue that green innovation plays an intermediary role in indirectly influencing innovation performance, while others have found that green innovation acts as an intermediary in the relationship between environmental regulation and green innovation performance (S. Yang et al., 2022). Some scholars also suggest that implementing green innovation strategies can enhance urban economic and environmental performance (L. Li et al., 2022). 3) In terms of the research field of urban green innovation, current research is mainly focused on areas such as environmental studies and management, while research in fields such as tourism and agriculture is relatively scarce.

In terms of research methods, structural equation modeling, DEA analysis, regression analysis, and other methods are commonly used, but there may be more tools and methods emerging in

the future, such as digital technology, data analysis, and artificial intelligence, which may be widely applied in this field. In terms of data sources, urban green innovation is different from corporate green innovation, and panel data is more commonly used, but there is a lack of in-depth investigation of the urban environment, and further research is needed in the future.

The Internet is a new concept that has emerged in this field, and its widespread application has become an important engine for promoting urban innovation and green transformation. 1) The Internet, directly and indirectly, promotes the development of urban green innovation through mechanisms such as promoting producer aggregation, driving financial development, and reducing resource dependency (Ma and Zhu, 2022). 2) There is a non-linear relationship between internet development and urban green innovation under different circumstances (Fang et al., 2022). 3) Policymakers should pay attention to the development in this direction, as Internet development can promote urban green innovation.

The adoption of innovation and social behavior as important influencing factors in urban green innovation have received widespread attention. Future research trends may focus more on the relationship between innovation adoption and social behavior, and explore their mechanisms of action in the process of urban green innovation.

Green innovation investment and business models have always been hot topics in research, and future research trends may focus more on the relationship between green innovation investment and business models, and delve into their mechanisms of action in the process of urban green innovation. On one hand, research can explore the effects of different types of green innovation investment methods, such as government investment, corporate investment, and social capital investment, on urban green innovation. On the other hand, research can delve into the interactive relationship between green innovation investment and business models, such as how investors choose different business models to support green innovation, and how business models influence investors' investment decisions on green innovation (Aldieri et al., 2021).

In addition, interdisciplinary research will also become a future trend (Irvine et al., 2009; Jin et al., 2019. Firstly, interdisciplinary research can integrate research findings from different disciplines, such as economics, sociology, environmental science, and management, at the theoretical level to comprehensively understand the influencing factors of urban green innovation. By integrating theories from different disciplines, in-depth research can be conducted on the multi-level and multi-dimensional influencing factors of urban green innovation, such as the interaction between technology, policy, economy, society, and environment. Secondly, interdisciplinary research can draw on research methods from different disciplines, such as quantitative research, qualitative research, and case studies, to enrich the methodological tools of research. Finally, interdisciplinary research can promote communication and collaboration among disciplines, forming a collaborative research pattern for innovation, collectively addressing the complex issues in urban green innovation, and generating integrated research outcomes that provide more comprehensive and effective support for urban green innovation policies and practices.

### 5.3. Research limitations

Like other research, this study also has its limitations. Firstly, the sample of this study only includes papers retrieved from the WOS database. Future research should incorporate other

databases, such as Scopus and/or emerging journal databases in WOS, as there is a possibility that more studies on the factors influencing urban green innovation have been published in other databases. Secondly, the sample of this study only includes journal articles and review publications, as bibliometric analysis can be applied to any unit of literature measurement. Therefore, future research may include other units of literature measurement such as books, conference proceedings, and policies, to create a more comprehensive knowledge map in the field of influencing factors of urban green innovation. Lastly, due to the significant differences in content and definition of green innovation in academia, other terminologies related to this research field may have been overlooked during the literature search process. Future research should fully consider the comprehensiveness and integrity of the concept of green innovation.

## Author contributions

Conceptualization, HZ and FL; formal analysis, FL and HZ; investigation, FL and HZ; methodology, FL and HZ; project administration, HZ; resources, FL and HZ; writing—original draft, FL; writing—review and editing, FL, XW and HZ.

## Acknowledgments

This work was supported by Macao Polytechnic University (RP/FCHS-02/2022) and The National Social Science Foundation of China's Thirteenth Five-Year Plan 2020 Key Project on Education: "Research on the Integrated Development of Education in the Guangdong-Hong Kong-Macao Greater Bay Area and Institutional Innovation" (AGA200016).

## Conflict of interest

The authors declare no conflict of interest.

## References

Aizawa M and Yang C (2010). "Green credit, green stimulus, green revolution? China's mobilization of banks for environmental cleanup". *The Journal of Environment & Development*, 19(2): 119–144. https://doi.org/10.1177/1070496510371192

Aldieri L, Brahmi M, Bruno B, et al. (2021). "Circular economy business models: The complementarities with sharing economy and eco-innovations investments". *Sustainability*, 13(22): 12438. https://www.mdpi.com/2071-1050/13/22/12438

Borsatto JMLS and Bazani CL (2021). "Green innovation and environmental regulations: A systematic review of international academic works". *Environmental Science and Pollution Research*, 28: 63751–63768. https://doi.org/10.1007/s11356-020-11379-7

Cai W and Li G (2018). "The drivers of eco-innovation and its impact on performance: Evidence from China". *Journal of Cleaner Production*, 176: 110–118. https://doi.org/10.1016/j.jclepro.2017.12.109

Chen C (2006). "CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature". *Journal of the American Society for Information Science and Technology*, 57(3): 359–377. https://doi.org/10.1002/asi.20317

Chen C (2014). *The CiteSpace Manual*. http://cluster.ischool.drexel.edu/~cchen/citespace/CiteSpaceManual.pdf

Chen C, Dubin R and Kim MC (2014). "Emerging trends and new developments in regenerative medicine: A

scientometric update (2000–2014)". *Expert Opinion on Biological Therapy*, 14(9): 1295–1317.

Cheng J, Yi J, Dai S, et al. (2019). "Can low-carbon city construction facilitate green growth? Evidence from China's pilot low-carbon city initiative". *Journal of Cleaner Production*, 231: 1158–1170. https://doi.org/10.1016/j.jclepro.2019.05.327

Costantini V, Crespi F, Marin G, et al. (2017). "Eco-innovation, sustainable supply chains and environmental performance in European industries". *Journal of Cleaner Production*, 155: 141–154. https://doi.org/10.1016/j.jclepro.2016.09.038

Du K, Cheng Y and Yao X (2021). "Environmental regulation, green technology innovation, and industrial structure upgrading: The road to the green transformation of Chinese cities". *Energy Economics*, 98: 105247. https://doi.org/10.1016/j.eneco.2021.105247

Fan F, Lian H, Liu X, et al. (2021). "Can environmental regulation promote urban green innovation Efficiency? An empirical study based on Chinese cities". *Journal of Cleaner Production*, 287: 125060. https://doi.org/10.1016/j.jclepro.2020.125060

Fang Z, Razzaq A, Mohsin M, et al. (2022). "Spatial spillovers and threshold effects of internet development and entrepreneurship on green innovation efficiency in China". *Technology in Society*, 68: 101844. https://doi.org/10.1016/j.techsoc.2021.101844

Garfin G, Jardine A, Merideth R, et al. (Eds.) (2013). *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*. Island Press.

Harmon RR, Castro-Leon EG and Bhide S (2015). *Smart Cities and the Internet of Things*. 2015 Portland International Conference on Management of Engineering and Technology (PICMET), pp. 485–494. https://doi.org/10.1109/PICMET.2015.7273174

Hsu CC, Quang-Thanh N, Chien F, et al. (2021). "Evaluating green innovation and performance of financial development: Mediating concerns of environmental regulation". *Environmental Science and Pollution Research*, 28(40): 57386–57397. https://doi.org/10.1007/s11356-021-14499-w

Irvine KN, Devine-Wright P, Payne SR, et al. (2009). "Green space, soundscape and urban sustainability: An interdisciplinary, empirical study". *Local Environment*, 14(2): 155–172. https://doi.org/10.1080/13549830802522061

Jang EK, Park MS, Roh TW, et al. (2015). "Policy instruments for eco-innovation in Asian countries". *Sustainability*, 7(9): 12586–12614. https://doi.org/10.3390/su70912586

Jin P, Peng C and Song M (2019). "Macroeconomic uncertainty, high-level innovation, and urban green development performance in China". *China Economic Review*, 55: 1–18. https://doi.org/10.1016/j.chieco.2019.02.008

Lee BX, Kjaerulf F, Turner S, et al. (2016). "Transforming our world: Implementing the 2030 agenda through sustainable development goal indicators". *Journal of Public Health Policy*, 37: 13–31. https://doi.org/10.1057/s41271-016-0002-7

Li B and Wu S (2017). "Effects of local and civil environmental regulation on green total factor productivity in China: A spatial Durbin econometric analysis". *Journal of Cleaner Production*, 153: 342–353. https://doi.org/10.1016/j.jclepro.2016.10.042

Li C, Li X, Song D, et al. (2022). "Does a carbon emissions trading scheme spur urban green innovation? Evidence from a quasi-natural experiment in China". *Energy & Environment*, 33(4): 640–662. https://doi.org/10.1177/0958305X211015327

Li J, Chen L, Chen Y, et al. (2022). "Digital economy, technological innovation, and green economic efficiency—Empirical evidence from 277 cities in China". *Managerial and Decision Economics*, 43(3): 616–629. https://doi.org/10.1002/mde.3406

Li KJ, Dong DD and Han YF (2020). "The analysis on the environmental performance of green innovation: An examination based on spatial spillover effect and rebound effect". *China Soft Science*, 20: 112–121. https://doi.org/10.3969/j.issn.1002-9753.2020.07.009

Li L, Li M, Ma S, et al. (2022). "Does the construction of innovative cities promote urban green innovation?".

*Journal of Environmental Management*, 318: 115605. https://doi.org/10.1016/j.jenvman.2022.115605

Li R, Xu G and Ramanathan R (2022). "The impact of environmental investments on green innovation: An integration of factors that increase or decrease uncertainty". *Business Strategy and the Environment*, 31(7): 3388–3405. https://doi.org/10.1002/bse.3090

Liao B and Li L (2022). "Urban green innovation efficiency and its influential factors: The Chinese evidence". *Environment, Development and Sustainability*, 25: 6551–6573. https://doi.org/10.1007/s10668-022-02316-4

Liao Y, Qiu X, Wu A, et al. (2022). "Assessing the impact of green innovation on corporate sustainable development". *Frontiers in Energy Research*, 9: 1005. https://doi.org/10.3389/fenrg.2021.800848

Liu J, Jiang Y, Gan S, et al. (2022). "Can digital finance promote corporate green innovation?". *Environmental Science and Pollution Research*, 29(24): 35828–35840. https://doi.org/10.1007/s11356-022-18667-4

Liu K, Xue Y, Chen Z, et al. (2023). "The spatiotemporal evolution and influencing factors of urban green innovation in China". *Science of the Total Environment*, 857: 159426. https://doi.org/10.1016/j.scitotenv.2022.159426

Lu C, Chen M and Tian G (2022). "Spatial-temporal evolution and influencing factors of urban green innovation efficiency in China". *Journal of Environmental and Public Health*, 9: 800848. https://doi.org/10.3389/fenrg.2021.800848

Ma D and Zhu Q (2022). "Innovation in emerging economies: Research on the digital economy driving high-quality green development". *Journal of Business Research*, 145: 801–813. https://doi.org/10.1016/j.jbusres.2022.03.041

Owen R, Brennan G and Lyon F (2018). "Enabling investment for the transition to a low carbon economy: Government policy to finance early stage green innovation". *Current Opinion in Environmental Sustainability*, 31: 137–145. https://doi.org/10.1016/j.cosust.2018.03.004

Pan X, Cheng W, Gao Y, et al. (2021). "Is environmental regulation effective in promoting the quantity and quality of green innovation?". *Environmental Science and Pollution Research*, 28: 6232–6241. https://doi.org/10.1007/s11356-020-10984-w

Peng W, Yin Y, Kuang C, et al. (2021). "Spatial spillover effect of green innovation on economic development quality in China: Evidence from a panel data of 270 prefecture-level and above cities". *Sustainable Cities and Society*, 69: 102863. https://doi.org/10.1016/j.scs.2021.102863

Rutherford J and Coutard O (2014). "Urban energy transitions: Places, processes and politics of socio-technical change". *Urban Studies*, 51(7): 1353–1377. https://doi.org/10.1177/0042098013500090

Sha K, Song T, Qi X, et al. (2006). "Rethinking China's urbanization: An institutional innovation perspective". *Building Research & Information*, 34(6): 573–583. https://doi.org/10.1080/09613210600852730

Shaheen F, Lodhi MS, Rosak-Szyrocka J, et al. (2022). "Cleaner technology and natural resource management: An environmental sustainability perspective from China". *Clean Technologies*, 4(3): 584–606. https://doi.org/10.3390/cleantechnol4030036

Sharma N, Paço A and Kautish P (2022). "The impact of eco-innovation on green buying behaviour: The moderating effect of emotional loyalty and generation". *Management of Environmental Quality: An International Journal*, 33(4): 1026–1045. https://doi.org/10.1108/MEQ-11-2021-0267

Song M, Du J and Tan KH (2018). "Impact of fiscal decentralization on green total factor productivity". *International Journal of Production Economics*, 205: 359–367. https://doi.org/10.1016/j.ijpe.2018.09.019

Tian Y and Feng C (2021). "The heterogeneous impact of environmental regulation on urban green scale economy: An empirical analysis based on city-level panel data in China". *Environmental Science and Pollution Research*, 28(35): 48392–48407. https://doi.org/10.1007/s11356-021-14031-0

Úbeda-García M, Marco-Lajara B, Zaragoza-Sáez PC, et al. (2022). "Green ambidexterity and environmental performance: The role of green human resources". *Corporate Social Responsibility and Environmental Management*, 29(1): 32–45. https://doi.org/10.1002/csr.2171

Wang C, You F and Xue D (2002). "The causes and alleviating countermeasures of the problems of water

resources utilization in areas along Yellow River in Inner Mongolia". *Journal of Natural Resources*, 17(5): 579–589.

Wang S, Abbas J, Sial MS, et al. (2022). "Achieving green innovation and sustainable development goals through green knowledge management: Moderating role of organizational green culture". *Journal of Innovation & Knowledge*, 7(4): 100272. https://doi.org/10.1016/j.jik.2022.100272

Wu G, Xu Q, Niu, X, et al. (2022). "How does government policy improve green technology innovation: An empirical study in China". *Frontiers in Environmental Science*, 9: 723. https://doi.org/10.3389/fenvs.2021.799794

Xie X and Zhu Q (2021). "Qiye lvse chuangxin shijian ruhe pojie "hexie gongsheng" nanti? [How can green innovation solve the dilemmas of 'Harmonious Coexistence']". *Guanli Shijie*, 37(9): 128–149.

Yang Q, Gao D, Song D, et al. (2021). "Environmental regulation, pollution reduction and green innovation: The case of the Chinese Water Ecological Civilization City Pilot policy". *Economic Systems*, 45(4): 100911. https://doi.org/10.1016/j.ecosys.2021.100911

Yang S, Wang W, Feng D, et al. (2022). "Impact of pilot environmental policy on urban eco-innovation". *Journal of Cleaner Production*, 341: 130858. https://doi.org/10.1016/j.jclepro.2022.130858

Yeh H (2017). "The effects of successful ICT-based smart city services: From citizens' perspectives". *Government Information Quarterly*, 34(3): 556–565. https://doi.org/10.1016/j.giq.2017.05.001

Zhang H, Wang Y, Li R, et al. (2023). "Can green finance promote urban green development? Evidence from green finance reform and innovation pilot zone in China". *Environmental Science and Pollution Research*, 30(5): 12041–12058. https://doi.org/10.1007/s11356-022-22886-0

Zhang J, Kang L, Li H, et al. (2020). "The impact of environmental regulations on urban Green innovation efficiency: The case of Xi'an". *Sustainable Cities and Society*, 57: 102123. https://doi.org/10.1016/j.scs.2020.102123