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Institutional Logic of Carbon Neutrality Policies in China: What Can We Learn?

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Abstract: Global warming is a critical crisis threatening human survival and development. International organizations and countries worldwide are introducing policies and practices to achieve carbon neutrality. In China, numerous carbon neutrality policies have been established; however, a systematic understanding of the underlying policy logic is lacking. Using the institutional analysis and development (IAD) framework, this paper analyzes selected carbon neutrality policies in China. We conducted a bibliometric visualization analysis of the texts of 20 policies and matched their logic to the elements of the IAD framework. We established 90 keywords with occurrences of no less than 10 times in China's carbon neutrality policies. The network visualization analysis identified six clusters. We discuss implementation challenges of China's carbon neutrality policies, address the policy implementation, and finally outline impacts on China's carbon neutrality governance. This study responds to the global concern over China's carbon neutrality commitments by clarifying the institutional logic of China's policies and actions. This study could provide a reference for countries worldwide that are designing and introducing carbon neutrality policies.

Keywords: carbon neutrality; energy transition; public policy; institutional logic; China

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1. Introduction

Global warming is the most challenging contemporary development crisis in the world. The Intergovernmental Panel on Climate Change (IPCC) issued a "code red for humanity" warning given current and projected climate change [1]. Since the establishment of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, countries around the world have introduced various policies that target carbon dioxide (CO_2) emissions reduction. These involve varied initiatives to regulate carbon emissions (Germany), energy transitions (Japan), zero-carbon technological innovations (United States), and market-based carbon policy instruments (United Kingdom) [2].

As the world's second-largest economy and the most populous country, China is the biggest emitter of CO_2 emissions, accounting for 30 percent of global emissions. Its climate action is critical for global climate governance and has naturally attracted much attention. Over the last two decades, China has introduced a series of national policy priorities on carbon emissions and climate change, including programs of New Industrialization (2002), Circular Economy (2003), Resource-Saving and Environmentally Friendly Society (2005), Low-Carbon Development (2009), and Ecological Civilization Construction (2012) [3]. More recently, China's President, Xi Jinping, has made important speeches at numerous international events—including the General Debate of the 75th Session of the United Nations General Assembly (2020), the United Nations Summit on Biodiversity (2020), the

3rd Paris Peace Forum (2020), the 12th BRICS Summit (2020), and the G20 Leaders' Summit (2021)—solemnly announcing China's growing focus on adopting more vigorous policies, and striving to reach its carbon peak by 2030 and achieve carbon neutrality by 2060. The latter announcement made at COP 26 in 2021 has set a new policy milestone for carbon neutrality governance in China.

A growing body of literature addresses China's carbon neutrality policies. Much of this research has a relatively narrow focus, mostly approaching policy-making from legal [4], taxation [5], finance [6], and science and innovation [7] standpoints. Consideration of the institutional logic is missing across these studies. The latter is necessary to foster the right kind of institutional structures that can, in turn, support robust climate policy implementation [8,9]. To fill this gap, this research applies Elinor Ostrom's institutional analysis and development (IAD) framework. The framework is widely recognized as a leading guide to gain policy insights, clarify institutional elements, and explore various mechanisms of policy action. In doing so, this study achieves multiple objectives: (i) it responds to the global concern over China's carbon neutrality actions, (ii) identifies the institutional logic of China's climate and energy policies, and (iii) presents the elemental structure of China's carbon neutrality governance. A better understanding of these three aspects provides a basis for supporting China's carbon neutrality policy aspirations, as well as offering lessons on climate policy design and governance for other countries.

The rest of the paper is organized as follows. Section 2 offers a literature review on carbon neutrality and related policies in China. Section 3 discusses the conceptual analytical framework used to explore carbon neutrality policies in China. Section 4 describes data sources and methods. Section 5 presents the results of the bibliometric visualization of China's carbon neutrality policies. Section 6 discusses China's carbon neutrality policy implementation and logic. Finally, in Section 7, we conclude the paper with key findings.

2. Understanding Carbon Neutrality

2.1. Carbon Neutrality

As of 2 November 2021, more than 140 countries had committed to carbon neutrality targets, covering 90% of global carbon emissions [10]. Thus far, however, only Suriname and Bhutan have achieved carbon neutrality [11]. Theoretically, carbon neutrality (i.e., net zero CO_2 emissions) can only be achieved when anthropogenic CO_2 emissions are balanced by anthropogenic CO_2 removals [12].

Achieving net zero CO_2 emissions requires systematic changes to how regions plan their economic and social development. This necessitates a profound transformation of the existing industrial structure, energy composition, modes and spatial patterns of production, and lifestyle. Market forces alone are unlikely to help achieve carbon neutrality, thereby signifying the reliance on national policies [13] and public institutions [14]. Anthropogenic CO_2 removal through artificial sequestration or biological absorption [15,16] requires appropriate institutional response [17]. For example, the European Union (EU) member states have incorporated carbon neutrality actions into the European Climate Law [18], which is both a product of their efforts to uphold the UNFCCC and a response to public calls for stronger environmental legislation [19]. The EU has also formulated the European Green Deal, which encompasses key areas of energy, electricity, industry, transportation, construction, agriculture, and automobiles to form a series of specific carbon neutrality institutions and policy systems. Similarly, the US has proposed to enact legislation to implement comprehensive environmental justice by 2025 [20], and introduced the Clean Energy Revolution Plan to achieve a 100% clean energy economy.

2.2. Carbon Neutrality Policies in China

Public policy includes all areas where governments choose to act (or not act) [21]. Moreover, for actions to be considered policy, focus needs to be on commitment, not intent [22]. Scholars of political science, public governance, and sociology have widely studied the analysis of complex public phenomena, policy mechanisms, and what constitutes effective

governance [23]. It has long been recognized that the pursuit of national interests and civic values is not meaningful in the absence of appropriate policy context [24]. The nature and scope of public policies directly affect economic and social development outcomes and the effectiveness of governance [25].

Institutional logic is an important element in understanding institutional orders and policy choices [26–29]. In the context of carbon neutrality, stringent policy contributes to better climate change mitigation outcomes [30]. A weak policy could be ineffective in climate mitigation, or exacerbate the carbon footprint [31]. Robust policymaking has paved the way for many countries (e.g., Sweden and Finland) to reduce their carbon footprints [32,33].

It is widely believed that effective policymaking is the key factor to help China achieve carbon neutrality [34]. Nationally, several carbon neutrality policies have been recently established to achieve carbon peaking by 2030 and carbon neutrality by 2060. They are often referred to as '1 + N' [35]. Here, '1' refers to the '*Opinions on Complete and Accurate Implementation of the New Development Concept and Carbon Peaking & Carbon Neutrality of the Central Committee of the Communist Party of China (CCCPC) and the State Council of China (SCC)*', while 'N' denotes the '*SCC's Action Plan for Carbon Peaking by 2030*' and a series of other carbon neutrality policies in key areas and industries.

China's carbon neutrality policy is already comparable with that of other major CO_2 emitter countries and regions (for example, the EU, the US, and Japan) (Table 1). However, China's carbon neutrality policy implementation has only just begun, and faces a range of challenges. Until now, there has been little research on China's carbon neutrality policies despite the world's growing scrutiny of China's action on climate change. In particular, there is limited understanding of the institutional logic of China's carbon neutrality policies and practices. This paper aims to shed more light on the logic and institutional fabric of China's carbon policy landscape using the IAD framework.

Table 1. Carbon neutrality policy comparison between China and other major CO_2 emitters.

Country or Region	Climate Legislation	Carbon Emission Regulation	Clean Energy and Technological Innovation	Carbon Market	Circular Economy
China	China has not yet included carbon neutrality in its climate law.	Control of energy consumption intensity and quantity in key industries including coal, steel, infrastructure, architecture, and petrochemicals	To promote clean energy replacement (biomass, hydrogen, wind, geothermal, solar) and technological innovation (e.g., zero-carbon, carbon capture, utilization and storage (CCUS)).	Carbon emission rights trading market (pilot in 2013, full launch in 2021).	Developing circular economy and improving energy efficiency.
EU	Enacting European Green Deal and EU Climate Law (incorporated carbon neutrality actions into the law).	Covering industrial sectors such as energy, electricity, industry, transportation, construction, agriculture, and automobiles.	To promote renewable energy, hydrogen energy, integrated energy systems, energy infrastructure, and CCUS.	European Union Emission Trading Scheme (EU ETS, the world's first and largest market-based climate policy), promoting carbon finance through climate and energy exchanges.	Issued circular economy action plan to reduce carbon emissions.
United States	To enact Environmental Justice by 2025, and the Clean Energy Revolution Plan.	To promote carbon emission reduction at the enterprise level, and drive carbon emission reduction in a 'bottom-up' voluntary reduction model.	Promoting cutting-edge zero-carbon technologies such as small modular reactors, nuclear fusion, and green hydrogen; battery energy storage, next-generation low-carbon buildings, renewable energy, hydrogen energy and advanced nuclear energy, and conducting regional CCUS demonstration R&D projects.	Carbon trading market.	Developing a circular economy (the states are supposed to set up associations and NGOs to promote recycling and utilization).
Japan	Enacting Global Warming Countermeasures Promotion Act and Carbon Neutrality Green Growth Strategy by 2050.	To focus more on carbon reduction through clean energy replacement (renewable energy, hydrogen and ammonia fuel, thermal energy, electric vehicles, energy storage).	Promoting carbon neutrality strategic industry development (offshore wind, solar, geothermal, new generation thermal energy.).	Planning to launch a national model carbon credit trading market in 2022–2023.	Circular economy has been developed for many years; the government is paying increasing attention to further advance its implementation.

Source: Authors' compilation.

3. Conceptual Analytical Framework: Institutional Analysis and Development (IAD) Framework

3.1. What Is the IAD Framework?

Elinor Ostrom's IAD framework has developed into one of the most influential institutional theories. As a metatheoretical language for institutional research, the IAD framework holds great value for institutional and policy analysis [36]. It provides a shared language for discussing the impact of various attributes and rules on the structure of the action arena and the outcomes faced by actors from an institutional and policy perspective. The IAD framework has been applied to analyze underlying complexities across several policy areas, including the management of common pool resources, public crises, and resource allocations. Iterations to the IAD theoretical framework have also been attempted in the past. For example, Araral and Amri [37] proposed a series of specific questions for policy research in conjunction with specific stages of the policy process, which they call IAD 2.0, while others have revised it as the "Institutional Analysis and Reconfiguration Framework" [38]. Drawing on the IAD framework, Ostrom herself developed a socio-ecological system analysis approach that highlighted biophysical properties in the institutional development [39]. Additionally, scholars [40] have tried to integrate other theories or research methods with the IAD framework (such as institutional syntax) to facilitate an in-depth study of the interactive relationship and endogenous logic between institutions and policies. Existing research demonstrates the IAD framework's suitability to examine China's public policies on water resources [41], urbanization governance [42,43], and ecological conservation [44].

3.2. Constituent Elements of the IAD Framework

The central institutional elements of the IAD framework are external variables, action arenas, patterns of interactions, outcomes, and evaluative criteria (Figure 1).

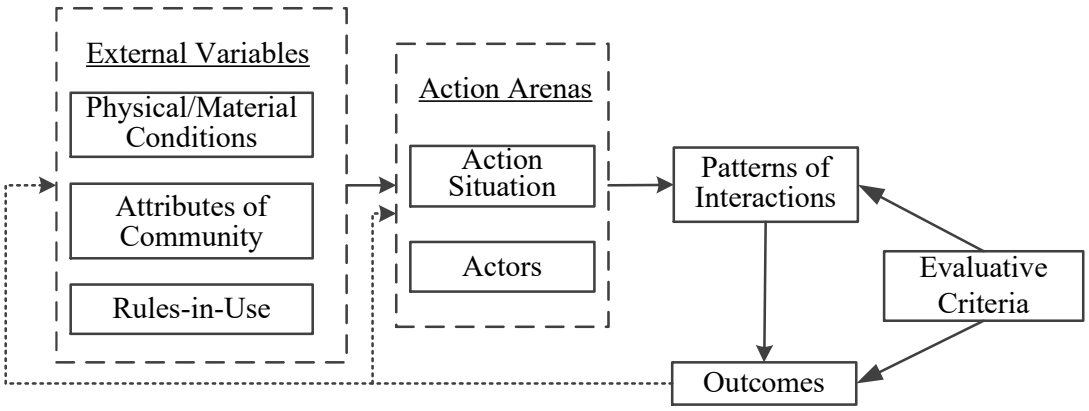

Figure 1. Conceptual analytical framework [45].

The primary institutional element is the action arena, which is used to describe, analyze, predict, and explain the policies. The action arena includes the action situation and actors as the core variables. The former represents the policy internal environment, and includes seven specific variables that influence policy formulation and implementation (Table 2). The latter takes the leading role in policy development and implementation, and the behavior of actors significantly affects the outcome of policy implementation. According to Elinor Ostrom's [45] assumptions about actors, the behavioral outcomes of actors in policy design may vary depending on the nature of resources brought in by decision-makers, the action steps taken, the assessment of actions, and the access to—and use of—information.

Table 2. Environmental variables of the action arena.

No.	Variable	Variable Explanations
1	Participants	Who and how many participants are involved in the policy process?
2	Positions	What are the respective hierarchies and positions of policy actors?
3	Allowable actions	Which types of actions are used by policy actors?
4	Potential outcomes	What factors influence the policy development and implementation, and what are the effects of potential outcomes?
5	Level of control over choice	Do policy appropriators take action on their initiative, or do they confer with others?
6	Available information	How much information do appropriators have about the condition of policies, about other appropriators' cost and benefit functions, and about how their actions may cumulatively result in joint outcomes?
7	Costs and benefits of actions and outcomes	How costly are various actions for each type of appropriator, and what kinds of benefits can be obtained as a result of various outcomes?

Source: Adapted from Ostrom Elinor's IAD [46].

As shown in Figure 1, three elements (physical and material conditions, attributes of community, and rules-in-use) comprise external variables that affect the action arena. In the policy context, physical and material conditions influence decision-making and implementation, while also indicating policy orientation and governance key points. Community attributes serve as a lubricant for the formulation and implementation of policies, showcasing the interface with actors. The rules-in-use form the guaranteed network for effective policy implementation and regulate the action order and requirements of policy actors.

Patterns of interactions are specific pathways that guide policy implementation. These patterns are often reinforced, and the corresponding action outcomes are produced through a series of institutionalized and non-institutionalized action arrangements, as well as the combined effects of external variables and action arenas. In other words, outcomes are the synergistic effects of different elements through a series of policy arrangements. Simultaneously, as an institutional element, the outcome itself will in turn affect external variables and the action arena. Specifically, if the action outcomes are significant (both good and bad) after being measured by evaluative criteria, they may influence other institutional elements (external variables, the action arena and even the patterns of interactions), thereby resulting in an iterative loop that would influence shifts in external variables and action attributes.

4. Data and Methods

4.1. Data

This research analyzed 20 formal documents representing key carbon neutrality policies in China, including the 14th Five Year Plan, national regulations, provincial work plans, guidelines, and opinions. Websites of national and provincial governments covering the period between 2017 and 2022 provided access to these documents. To maintain consistency, search was performed in the documents' original language, Chinese. A combination of the following keywords were used: 'climate change', 'climate governance', 'carbon governance', 'low carbon development', 'green development', 'ecological civilization construction', 'carbon peaking', and 'carbon neutrality'. Only those documents that were closely related to carbon neutrality were selected (Table 3). For some documents, specific sections were used that best aligned with the study's primary focus on carbon neutrality. For example, in *The 14th Five-Year Plan for the National Economic and Social Development of the People's Republic of China* and the *Outline of Long-Term Goals for 2035*, we extracted Section 4 of Chapter 38 titled "Actively Responding to Climate Change". The total length of the documents studied was 140,000 words.

Table 3. Key carbon neutrality policies in China.

No.	Selected Documents	Key Agency Responsible	Date
1	*National Carbon Emission Trading Market Construction Program (Power Generation Industry)*	National Development and Reform Commission (NDRC)	December 2017
2	*Carbon Emissions Trading Management Measures (Trial)*	Ministry of Ecology and Environment (MEE)	December 2020
3	*Guidance on Coordinating and Strengthening the Work related to Climate Change and Ecological Protection*	MEE	January 2021
4	*Guidance on Accelerating the Establishment of a Sound Green Low-Carbon Cycle Development of the Economic System*	State Council of China (SCC)	February 2021
5	*The 14th Five-Year Plan for the National Economic and Social Development of the People's Republic of China and the Outline of Long-Term Goals for 2035 (Excerpt: Actively Responding to Climate Change)*	CCCPC	March 2021
6	*Opinions of on the Implementation of the "Government Work Report" on the Division of Key Tasks (excerpt: Solid Work on Carbon Peaking and Carbon Neutrality)*	SCC	March 2021
7	*The Work Plan to Promote Carbon Peaking and Carbon Neutrality in Jiangsu Province*	Jiangsu Provincial Department of Ecology and Environment	June 2021
8	*The Action Plan for the Science and Technology Innovation of Carbon Peaking and Carbon Neutrality in Zhejiang Province*	Zhejiang Provincial Science and Technology Department	June 2021
9	*The 14th Five-Year Plan for Circular Economic Development*	NDRC	July 2021
10	*The 14th Five-Year Plan for Ecological Protection in Hainan Province*	Hainan Provincial Government	July 2021
11	*Opinions on the Complete and Accurate Implementation of the New Development Concept and Carbon Peaking & Carbon Neutrality*	CCCPC, SCC	September 2021
12	*The Institutional Program to Control Energy Consumption Intensity and Quantity*	NDRC	September 2021
13	*The Promotion Regulations on Carbon Peaking and Carbon Neutrality in Tianjin*	Tianjin Municipal People's Congress	September 2021
14	*Opinions on the Implementation of Accelerating the Building of an International Green Financial Hub in Shanghai to Serve the Goals of Carbon Peaking and Carbon Neutrality*	Shanghai Municipal Government	October 2021
15	*National Standardization Development Outline (excerpt: Establishing Sound Carbon Peaking and Carbon Neutrality Standards)*	SCC	October 2021
16	*Opinions on Promoting the Green Development of Urban and Rural Construction*	General Office of the CCCPC and SCC	October 2021
17	*Action Plan for Carbon Peaking by 2030*	SCC	October 2021
18	*China's Policies and Actions to Address Climate Change*	SCC	October 2021
19	*Opinions on Deepening the Battle of Pollution Prevention and Control (excerpt: Accelerating the Promotion of Green and Low-Carbon Development)*	CCCPC, SCC	November 2021
20	*Integrating Carbon Peaking and Carbon Neutrality into the Overall Layout of Ecological Civilization Construction*	MEE	November 2021

Source: Authors' compilation.

4.2. Methods

All policy texts were preprocessed by ROST CM6.0 (ROST), a large-scale data mining software developed by Professor Shen Yang's team in China [47], to assist researchers in the humanities and social sciences. Both the classification and the test corpus of ROST experiments are in Chinese and well-adapted for Chinese text preprocessing [48]. Then, data cleaning and manual noise reduction were also performed, such as the standardization and unification of synonyms and the removal of words with no real meaning (such as dummy words, prepositions, and ordinal numbers).

Subsequently, we conducted a bibliometric visualization analysis of China's carbon neutrality documents. Bibliometrics is the cross-disciplinary science of quantitative analysis of knowledge carriers using statistical methods [49]. It is a commonly used method to identify the relationship between different keywords [50,51]. Accordingly, the data on the occurrences, links, and total link strength of different terms in the visualization were analyzed by VOSviewer (version 1.6.1) (Table 4).

Based on the conceptual analytical framework, the institutional elements (external variables, action arenas, and patterns of interactions), logical structure, and interactive mechanisms of China's carbon neutrality policies were clarified (see Figure 1). VOSviewer is a free software developed by Van Eck and Waltman [52]. It is a powerful tool that performs co-occurrence analysis and bibliometric visualization [53]. The occurrences suggest the frequency of the keyword. The more frequent the co-occurrence of different keywords, the more likely they will be classified into the same cluster. In other words, a cluster refers to a set of items that are included in a network and are not necessarily exhaustive [54].

Clustering techniques play a prominent role in bibliometric research because the software algorithms can automatically classify a large number of keywords [55].

Table 4. Explanation of analytical elements in the bibliometric method.

No.	Analytical Element in the Bibliometric Method	Explanation
1	Keyword/term	It refers to the result of the separation of the China's carbon neutrality policy by ROST.
2	Co-occurrence	Co-occurrence indicates that different keywords appear together in one sentence or one paragraph.
3	Cluster	A cluster refers to a set of items that are included in a network and are not necessarily exhaustive.
4	Links	Links represent the number of connections an item has with other items.
5	Total link strength	It is the total strength of the links of an item with other items.

Source: Authors' compilation.

5. Results

5.1. Keyword Frequency Analysis

We imported the noise-reduced text data into VOSviewer software; then, the keywords with occurrences of no less than 10 were derived. As Table 5 demonstrates, the occurrences of 'carbon peaking and carbon neutrality' are the highest, appearing 94 times, whereas the links with other words and total link strength are also highly significant, at 206 and 645, respectively. Notably, most of the keywords have clear institutional attributes. At this stage, for example, China must strengthen the protection of the 'ecological environment', actively respond to 'climate change', and fulfill the relevant commitments of the 'Paris Agreement', all of which comprise the physical and material conditions that necessitate China to introduce carbon neutrality policies. Consequently, the Chinese government has launched a series of policy requirements and rules (such as the establishment of the 'standard system', 'regulations', and 'ecological protection red line'). These are aimed to support actors ('municipal cities', 'enterprises', 'key emitter', and 'county government') in promoting carbon reduction and to prioritize carbon governance in key areas and industries (such as 'steel', 'energy', and 'transportation'). These actors are tasked with the overall reduction in greenhouse gas emissions by various patterns of interactions, such as 'eco-environmental protection' and 'comprehensive green transformation'.

Table 5. Keyword occurrence statistics (occurrences $\geq$ 10).

No.	Keywords	Occurrences	No.	Keywords	Occurrences	No.	Keywords	Occurrences
1	Carbon peaking and carbon neutrality	94	31	Green low-carbon technology	17	61	Greenhouse gases	12
2	Response to climate change	72	32	Infrastructure	17	62	High energy consumption	12
3	Municipal cities	63	33	Key areas	17	63	Hydrogen energy	12
4	Carbon emissions	61	34	CCCPC	16	64	Industry	12
5	Green low-carbon	52	35	Comprehensive green transformation	16	65	MEE	12
6	Carbon emission rights	51	36	Energy	16	66	standard system	12
7	Economic and social development	37	37	Green finance	16	67	Technology innovation	12
8	Enterprise	37	38	Measures	16	68	Wetlands	12
9	Carbon peaking	35	39	NDRC	16	69	Building materials	11
10	Trading market	34	40	New energy	16	70	Carbon sequestration capacity	11
11	Greenhouse gas emissions	32	41	Architecture	15	71	Country	11
12	2030	29	42	Eco-environmental protection	15	72	County-level districts	11
13	Key emitter	29	43	Energy consumption	15	73	Departments	11
14	Green low-carbon development	28	44	Energy saving	15	74	Ecological protection red line	11
15	Ecological environment	27	45	Industries	15	75	Energy storage	11
16	Key industries	26	46	Integrated utilization	15	76	Lifestyle	11

Table 5. *Cont.*

No.	Keywords	Occurrences	No.	Keywords	Occurrences	No.	Keywords	Occurrences
17	Renewable energy	25	47	Low-carbon	15	77	Ocean	11
18	All over the country	23	48	New development concept	15	78	Power	11
19	Industry structure	23	49	Objective tasks	15	79	Regulations	11
20	Steel	23	50	People's government	15	80	The 13th Five-Year Plan	11
21	Ecological civilization	21	51	Reducing pollution and carbon emissions	15	81	Total energy consumption	11
22	SCC	21	52	2025	14	82	Transportation	11
23	CCUS	20	53	Action plan	14	83	Wind power	11
24	High-quality development	20	54	Energy structure	14	84	Carbon emission allowance	10
25	Carbon neutrality	19	55	Evaluative criteria	14	85	Carbon market	10
26	Financial agencies	19	56	Paris Agreement	14	86	Carbon reduction	10
27	Key tasks	18	57	Carbon emission intensity	13	87	County-level cities	10
28	Climate change	17	58	Circular economy	13	88	Forest	10
29	Ecosystem	17	59	Petrochemical	13	89	Freight transportation	10
30	Green development	17	60	Chemical	12	90	International cooperation	10

Source: ROST and VOSviewer software.

To conduct a more in-depth analysis, we carried out further classification analysis based on the semantics of the keywords and the context of the policy texts in which they originated. These keywords correspond to the 'institutional elements' of the conceptual analytical framework. The framework provides the opportunity to gain insights into the logic of carbon neutrality policies at the macro-level and the mechanism of interaction between different institutional elements at the micro-level. For example, we find that the actor 'municipal cities' has the highest number of occurrences among all actors (63), while its links and total link strength are 130 and 254, respectively. All three values are relatively high. In practice, the central government often plays the role of general coordinator and allocates tasks to provincial government in the process of China's policy development [56]. Subsequently, each province carries out task outsourcing or target allocation to its subordinate 'municipal cities'. Counties are the ultimate actors of policy implementation, and the effectiveness of their implementation is highly related to the quality of the translation of documents by 'municipal cities'. The latter needs to connect with national strategies and provincial plans, but also accurately translate documents in a detailed manner based on the prevailing context of 'municipal cities'. This, in turn, signifies the emphasis that the Chinese municipal government places on the role of 'municipal cities' in the design of carbon neutrality policies. China has incorporated additional multiple actors (such as enterprises, top emitters, key industries, financial agencies, local governments, and departments) into the decision-making and implementation of carbon neutrality policies. This has been carried out with the aim of establishing a top-down, tightly knit network of actors so that the institutional advantages of China's 'whole nation system' can be fully used and exploited [57].

In the comparison of different actors, the government's role is relatively dominant. This finding may be related to the fact that China is currently in the initial stage of carbon neutrality governance, where government institutions and policies tend to play a greater role than market mechanisms [58]. Moreover, this phase is often a period of intensive policy introduction; thus, the government naturally becomes the most prominent actor in the action arena. In terms of the levels of government, the CCCPC is the highest leadership body responsible for carbon neutrality policies. The National People's Congress (NPC) is accountable for translating policy arrangements into national willingness, while the SCC is responsible for policy implementation. Additionally, there are specialized leadership working groups, such as the National Leading Group on Climate Change, which collaborates with the SCC to guide and supervise policy implementation by national ministries, interprovincial organizations, and provincial governments (Figure 2). This institutionalized arrangement of administrative actors offers a concrete manifestation of China's 'whole nation system'. Undoubtedly, however—in addition to government actors—there are other important actors including enterprises and the Chinese society, which are not only insti-

tutionalized objects but remain key forces that facilitate the implementation of carbon neutrality policies.

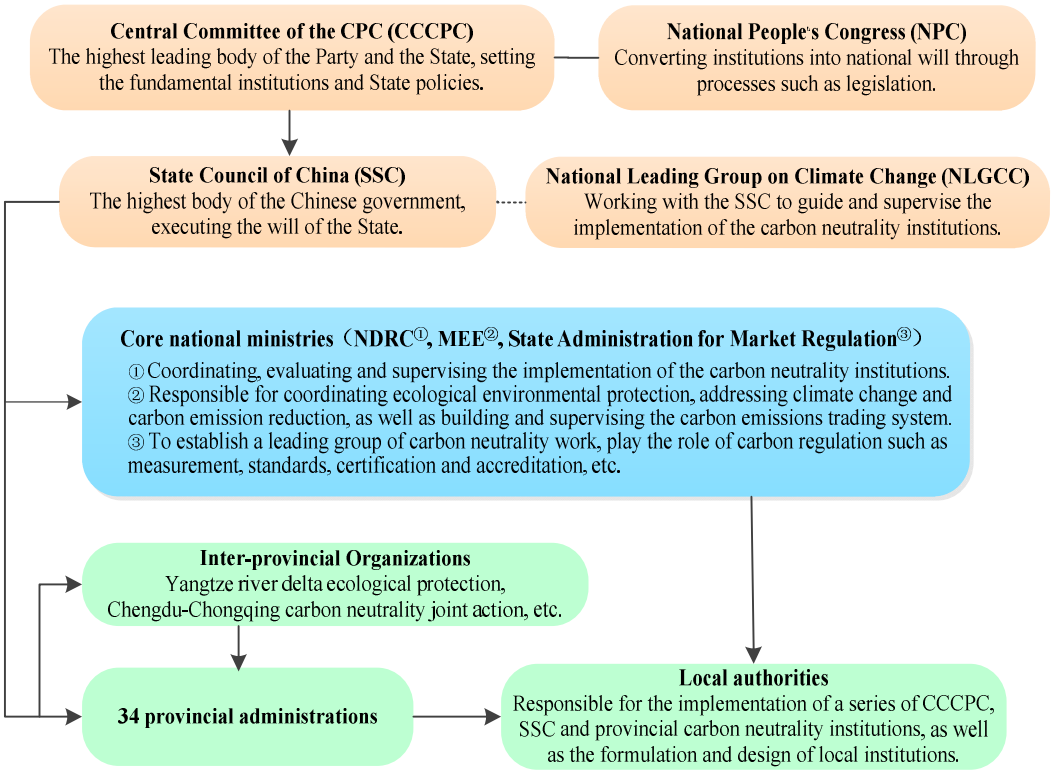

Figure 2. Structure of carbon neutrality government actors in China. Source: Authors' compilation.

5.2. Co-Occurrence Network and Visualization

In the network visualization analysis, a total of 317 keywords (represented by nodes) appeared when the minimum number of keyword occurrences was set to five (Figure 3). The size of each node represents keyword occurrences, with larger nodes representing higher word occurrences. The lines connecting two nodes depict the co-occurrence of two keywords in one sentence or one paragraph. The network graph is color-coded based on clustering. In total, six clusters were identified.

Among all the keywords, the values of links and total link strength reached 8403 and 13,764, respectively. The terms of 'carbon peaking and carbon neutrality' are particularly striking, with three values of occurrence, link, and total link strength reaching 94, 206, and 645 respectively, thus accounting for the highest counts among all keywords. The three keywords with the most frequent links to 'carbon peaking and carbon neutrality' are 'municipal cities', 'green low-carbon', and 'economic and social development', with counts of 19, 19, and 15, respectively. These links support the carbon neutrality policy logic in China. Firstly, 'municipal cities' is the most important level of government directly accountable for local carbon neutrality (as discussed in the previous section). Secondly, the links with 'green low-carbon' and 'economic and social development' further substantiate China's carbon neutrality as an essential driver of green low-carbon development which, in turn, underpins contemporary national planning for economic and social development.

At the same time, the keywords 'carbon peaking' and 'carbon neutrality' are also found separately in the network visualization because the semantics and contexts of 'carbon peaking' and 'carbon neutrality' are not identical across different policy texts. In some cases, policy makers may emphasize the importance of both, while in other cases, they may highlight only 'carbon peaking' or 'carbon neutrality' in specific contexts and situations. We note the occurrences, links, and total link strength of the keywords 'carbon peaking' (35, 156, and 354, respectively) and 'carbon neutrality' (19, 100, and 159, respectively).

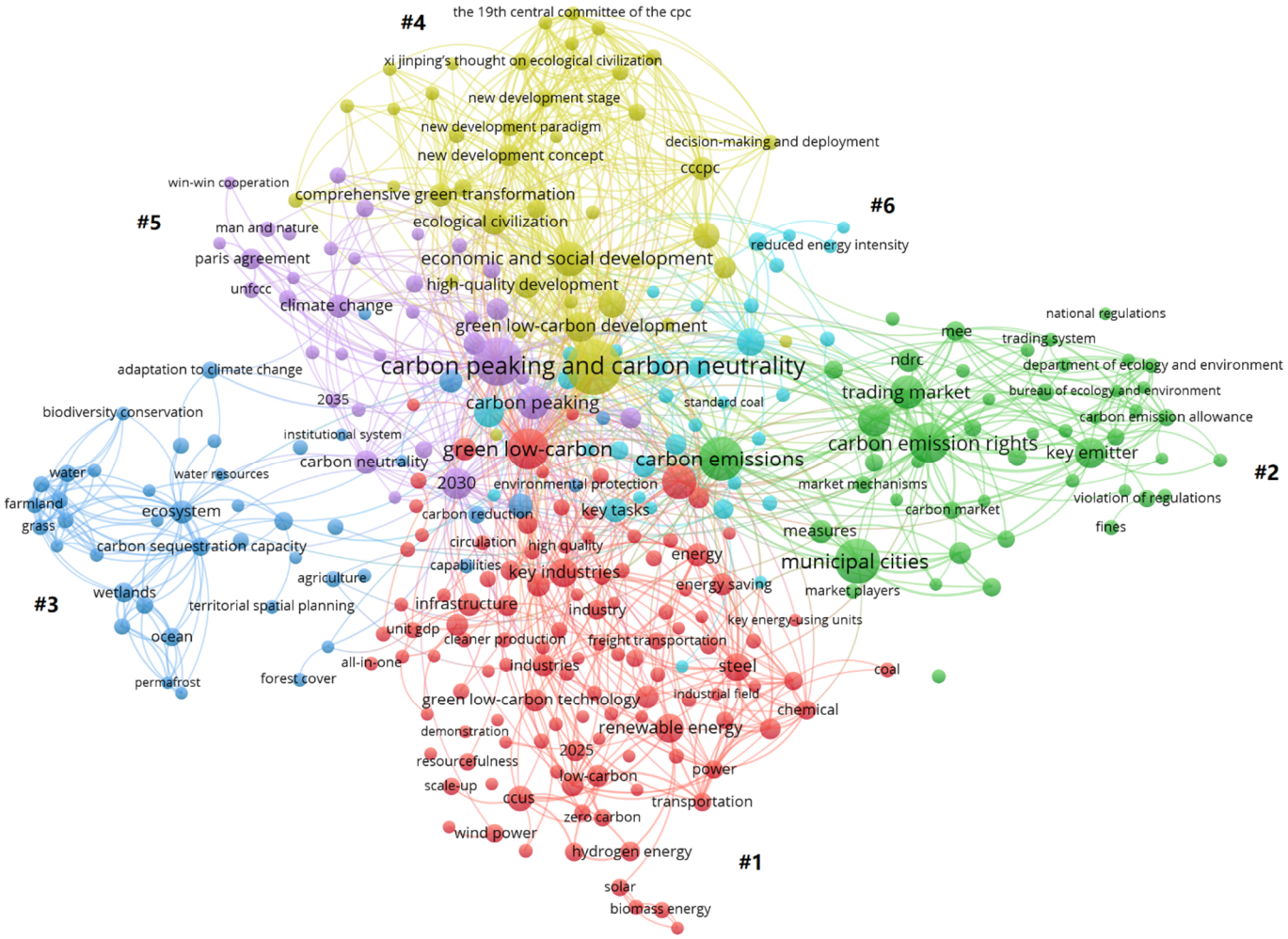

Figure 3. Network visualization of China's carbon neutrality policies. Source: Generated by the authors.

Among the six clusters in the network visualization of China's carbon neutrality policies, Cluster 1 (#1 red) is very complex among all clusters with 114 nodes. From a content standpoint, the range of keywords in Cluster 1 is relatively broad, covering various institutional elements of the conceptual analytical framework, including external variables (e.g., carbon neutrality, ecological environment, response to climate change, and Paris Agreement), action arenas (e.g., key industries namely coal, steel, infrastructure, architecture, petrochemicals, and energy transitions—including biomass, hydrogen, wind, and geothermal), and patterns of interactions (e.g., green transformation, energy saving and storage, standardization, resourcefulness, and integrated utilization).

Cluster 2 (#2 green) contains 50 keywords/nodes, most of which are actors with specific roles in the decision-making and implementation of China's carbon neutrality policies, such as 'municipal cities', 'NDRC', 'MEE', 'People's Government', and 'key emitter'. Additionally, there are many keywords (such as 'carbon market', 'carbon emission rights & allowance', 'trading market', 'Chinese certified emission reduction', and 'fines') whose attributes demonstrate patterns of interactions, indicating the policy logic behind China's carbon neutrality. By retracing the context and semantics of the original policy texts in which these keywords are found, we find that China is trying to develop different patterns of interactions as the logical starting point for implementing carbon neutrality policies.

Cluster 3 (#3 blue) highlights the action situation and ecological objects for the implementation of China's carbon neutrality policies, such as 'wetlands', 'ocean', 'grassland', 'forest', and 'water' (with 44 keywords/nodes in total).

Cluster 4 (#4 yellow) has 41 keywords/nodes, mainly describing community attributes as a significant external variable. It is emphasized that China and other countries in the world are a community with a shared future for humankind [59] that should strive to achieve 'carbon peaking and carbon neutrality' as soon as possible. In brief, the community needs to focus on the synergy between 'economic and social development' and 'green and low-carbon development', to implement China's 'new development concept' and the 'new development paradigm'.

Next, Cluster 5 (#5 purple) has 34 keywords/nodes that primarily describe external variables (such as 'UNFCCC', 'global climate governance', 'global response to climate change', and 'Paris Agreement') and carbon neutrality policies (such as '1 + N policy system' and 'policy measures'). It shows that China considers international conventions as important sources of rules-in-use and policy references.

Finally, Cluster 6 (#6 azure blue) has 34 keywords/nodes. It primarily presents patterns of interactions whose central theme is the control of energy consumption intensity and quantity (main keywords include 'carbon emission intensity', 'control goals of energy consumption intensity and quantity', 'energy consumption', and 'high/total energy consumption'). At the same time, evaluative criteria emerge in this cluster, suggesting that the most important evaluative object is energy consumption.

6. Discussions and Implications

6.1. Challenges in China's Carbon Neutrality Policy Implementation

As the largest carbon emitter in the world, China has a much stronger relationship between economic growth and carbon emissions, particularly when considered against comparable OECD countries. Its large population having been on an upward economic mobility pathway for many decades has continued to generate a strong demand for materials and resources. This poses a significant challenge for China in implementing its carbon neutrality policies [60].

China's industrial structure is dominated by traditional fossil fuels with its energy structure primarily based on coal, thereby contributing to its large CO_2 footprint [61,62]. China's carbon-intensive development path may be a significant bottleneck in the implementation of its carbon neutrality policies. First, information inequality and uncertainties between the goals of carbon neutrality policies and the nature of socio-economic development affect the achievement of carbon neutrality goals [63–66]. It is not quite possible to measure the contribution of each pattern of interaction to the carbon neutrality goals under the current policy. This makes it difficult to monitor the degree of carbon neutrality goal achievement, gaps, and impact on economic and social development nationally. Second, given the rapid expansion of residential consumption and infrastructure investments, reducing emissions from the demand side (or consumption side) remains essential to achieving both the goal of carbon neutrality and the goal of economic growth [64]. Third, current efforts to reduce emissions are mainly responses to top-down policies by the central government. Measures that can incentivize bottom-up efforts more widely are called for, such as setting local mitigation targets for emission caps, perfecting the carbon trade scheme, promoting a just transition towards carbon neutrality, and mobilizing communities and society [67].

6.2. Lessons Learned from Institutional Logic in China's Carbon Neutrality Policy

The conceptual analytical framework makes clear that policy implementation as a process inevitably affects various institutional elements, which, in turn, impacts pre-existing endogenous and exogenous factors. Consequently, the implementation of carbon neutrality policies is conducive to the evolution and development of various institutional elements and their interaction mechanisms. Government authorities will optimize and redesign policies based on the effectiveness of implementation. The following question also arises: How can we judge when and under what circumstances the policies need to be optimized or redesigned?

From China's carbon neutrality policy analysis, we can learn that: (1) the achievement of carbon neutrality needs strong support from national government; (2) China pays particular attention to external variables such as environmental issues and international climate conventions; and (3) governments, organizations, civil society, and markets need to engage with each other to balance decision-making structures.

Actors take the leading role in policy development and implementation, and the behavior of actors significantly affects the outcome of policy implementation. From our findings, we can tell that the NDRC, MEE, and municipal governments are the core actors in carbon neutrality policy design and implementation. The NDRC is a leading role in developing policy. The MEE is responsible for carbon trading system while municipal governments are primarily in charge of the practical implementation of carbon neutrality policies. The external variables are the natural environment (huge carbon emissions and environmental pollution) and a series of international carbon agreements (such as the *Paris Agreement* and the *Glasgow Climate Pact*). It reveals the constraints on the decision-making and implementation of China's carbon neutrality policy. At the same time, it also indicates the institutional orientation and governance key points under the climate warming in China. Patterns of interactions are the specific paths of China's carbon neutrality policy implementation. They directly contribute to the achievement of carbon neutrality goals. The main current interactions in China include the regulation of carbon emissions, the innovation of zero-carbon technology, and the carbon-trading market.

6.3. China's Carbon Neutrality Governance

In this section, we outline China's carbon neutrality governance structure, specifically, the different stages in policy design and implementation (Figure 4).

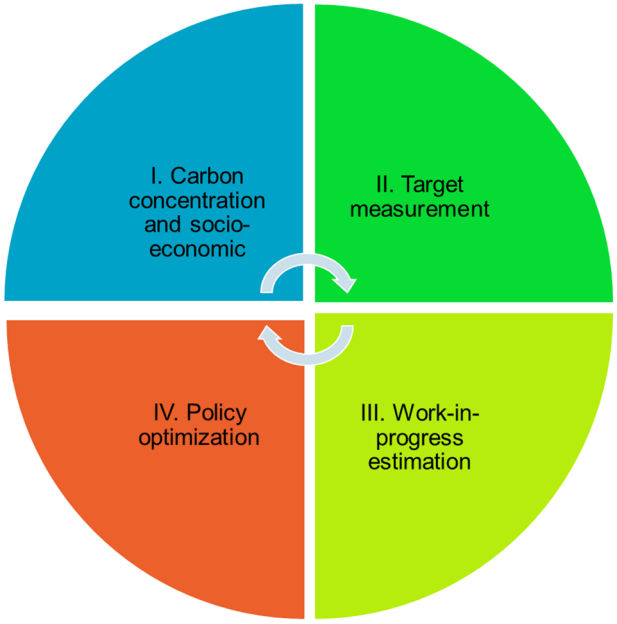

Figure 4. China's carbon neutrality governance. Source: Designed by the authors.

Firstly, it features the relationship between the current carbon concentration and socio-economic development. Understanding of this relationship can significantly lower social, economic, and environmental impacts of carbon neutrality. It is essential not only to monitor carbon concentration, but to also consider socio-economic development needs in present-day China. Carbon concentration and socio-economic consideration highlights sustainable development goals for China.

The second process involves target measurement. The target measurement is to design carbon emission indicators and socioeconomic development needs. We believe that there

is an approach to provide opportunities to measure and calculate the objective levels of carbon neutrality policies in different spatial and temporal domains under different policy scenarios and governance conditions. Moreover, it is possible to optimally measure the daily and weekly frequency of dynamic carbon neutrality targets based on the socio-economic development of different regions with support of national, provincial, and municipal government. Dynamic equilibrium can be achieved between carbon neutrality goals (identifying what actors may be wanted or needed) and socio-economic development aspirations with specific target measurement setting.

The third step is work-in-progress estimation. On the basis of calculating the carbon neutrality goals of a specific city or region, monitoring can help with the dynamic measurement of the changes in the whole life cycle of carbon dioxide. Here, the aim is to perform trend analysis of carbon emissions of different energy consumption entities in the context of geographical and ecological environmental changes. In this way, it is possible to simulate and predict the evolution of carbon neutrality policies, which can considerably improve policy actors' perception of the dynamic evolution of carbon emissions. This can, in turn, accurately forecast the process of achieving carbon neutrality goals.

The last phase is policy optimization. Actors can analyze the problems, gaps, and shortcomings in the formulation and implementation of policies. Determined by the first three steps, it is possible to optimize carbon neutrality policy, which will mitigate social, economic, and environmental impacts.

7. Conclusions

This paper empirically analyzes China's carbon neutrality policies using the IAD framework and adopts a bibliometric visualization approach. We identify China's climate and energy policy logic, the complexity of achieving carbon neutrality, and the challenges of policy design implementation. This research not only responds to global concerns over China's carbon reduction commitments and gaps in concrete actions, but also clarifies and presents the logic, elements, structure, and mechanisms of China's carbon neutrality policies. In doing so, it offers a policy reference for carbon neutrality governance in other countries.

This study has two limitations. Firstly, given that the top-down policy design of China's carbon neutrality system was first introduced in September 2021, several policy texts remain in the process of further refinement. These were therefore excluded from our search. Secondly, given the scope of this paper, we have not conducted a complete and in-depth verification and analysis of the policy implementation results. As such, an understanding of the evaluative criteria necessary to gauge the effectiveness of China's carbon neutrality policies is lacking. These two limitations offer important directions for further research.

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