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Towards Sustainable Drug Supply in China: A Bibliometric Analysis of Drug Reform Policies

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Abstract: As China has undergone a new round of healthcare reforms since 2009, the drug sector has been subjected to a series of reform measures that aim to ensure a sustainable supply of drugs with controlled expenditures. This paper presents a bibliometric analysis of policy documents for the purpose of exploring the approaches within China's drug reform. The analysis reveals that the National Health Commission (NHC) is the leading department of China's drug reform, demonstrating that the core objective of drug reform is to ensure drug supply meets healthcare needs. The reform has evolved from its initial stage to the deepening and adjusting stage, with policy instruments becoming more interactive and involving greater numbers of implementers. Along with supply, drug quality and safety are the top concerns of the drug reform, followed by drug accessibility and affordability. Rational drug use is receiving greater attention in the deepening and adjusting stage. Environmental and demand-side instruments are being used more frequently in policies, while the utilization of supply-side instruments shows the opposite trend. Government departments at all levels play crucial roles in policy instrument implementation, with the significance of this function increasing. The participation of consumers in policy implementation is also rising. While medical institutions and enterprises are important implementers, their role is diminishing.

Keywords: drug reform; policy documents; bibliometric analysis; social network analysis

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1. Introduction

Since 1996, China has long been reforming its healthcare system to achieve equitable and accessible healthcare in the world's most populous country [1]. As drug supply is one of the foundations of medical service, the implementation of measures to enhance the ability to sustainably supply drugs remains a crucial part of healthcare reform that also affects the development of the pharmaceutical industry. In 2009, the Chinese Communist Party (CCP) and the State Council jointly issued the 'Opinions on Deepening the Reform of the Medical and Health Care System', launching a new era of healthcare reform in China [2]. The system of drug supply, along with systems of public health, healthcare service, and medical insurance, constitutes the basic primary healthcare (PHC) system of the new healthcare reform, taking responsibility for providing safe, effective, convenient, and affordable healthcare services to Chinese residents. The new healthcare reform is attempting to control drug prices and resolve the problem of 'difficult and expensive to access healthcare service' for residents through introducing a series of reform policies in the drug sector. Looking into the objectives of these, two challenges lie ahead, namely, the tasks of guaranteeing supply and expenditure reduction. The former is mainly decided by research and development capabilities, production quality, and market motivation of the pharmaceutical industry, while the latter is dependent on drug pricing, markup, and medicine prescription [3]. Through implementing drug reform policies, the drug supply chain of China has been reconstructed, and substantial improvements have been shown in efforts to tackle independent problems. Conversely, the achievements have also been found

to be unsustainable, and new problems have appeared in long-term practice, necessitating continuous policy adjustments and perfections. For example, to ensure sustainable supply and reduce prices [4,5], China has widely implemented centralized procurement at the provincial level since 2009 [6]. Nevertheless, this policy subsequently raised concerns about the quality of Chinese generic drugs and the problem of shortages of procured drugs with low levels of cost or consumption [7,8], which led to the introduction of policies on generic drug consistency evaluation and volume-based centralized procurement [9,10]. In order to tackle the problem of high drug prices, China has gradually abolished markup charging of drugs in public hospitals since 2009, compensating hospitals' income loss from drug sales through government subsidies. The unanticipated increase in expenditures on medical examination and medical consumables offset the reduction in total expenditures, prompting the policies underlying the adoption of the mechanisms in hospital revenues and medical providers' prescriptions and incentives [11–15]. Additionally, to emphasize the basic needs of medication in medical institutions at all levels, China has strengthened the construction of the national essential medicine system, strictly regulated prescription behaviors, and now requires the provision of essential medicines in all public medical institutions around the country [16,17].

Many researchers have studied the policy measures related to drug supply under China's new healthcare reform. Among those working in the field, some researchers have employed quantitative analysis on the implementation effects and emerging problems of policy measures such as zero markup for drugs [11,12,15,18,19], the national essential medicine system [20–23], and volume-based centralized procurement of drugs. Undoubtedly, policies reflect the plans and intentions of policy makers, determine the direction of the healthcare system and pharmaceutical industry, and have a huge impact on them. Yet, policies are considered difficult to interpret in depth, and it is especially difficult to comprehensively interpret multiple policies and compare policies from a range of periods. Compared with academic papers and patents, policy documents are unstructured and without uniform format, an abstract, official tags such as key words, or classification codes to reveal the essential contents of the policies. These characteristics make it difficult to conduct quantitative analysis to discover policy contents, the internal relationship of policy factors, as well as changes and tendencies. Fortunately, the document-based bibliometric analysis of drug reform policies could overcome these difficulties through transforming unstructured policy documents into structured data through transformation paradigms and field-based frameworks, enabling researchers to undertake the quantitative analysis of policy content. Identifying targets, instruments, and implementers in sets on the basis of quantization data and exploring factors' social network characteristics has the potential to reveal the intentions, key contents, and main approaches of policies in an effective and objective manner [24]. Policy instruments are the specific measures and leading approaches that policy makers adopt to achieve policy targets [25]. Under different theoretical frameworks, policy instruments can be classified in a variety of ways, depending on the policy application environment and their applicability [26,27]. Rothwell and Zegveld divided policy instruments into three categories based on their different orientations. They categorized measures that were adopted to support innovation activities and industrial development as supply-side instruments, which assist with financial support and assistance related to other resources; demand-side instruments, which primarily leverage measures from the market side; and environmental instruments, which create a suitable operational environment through enacting policies in related aspects of society [28]. Additionally, this classification method has been widely used in policy document analysis [29].

China has unique characteristics in terms of drug supply. First, there are many factors that affect drug supply in China. These not only include research and development capabilities and production capacity, but also price and usage. Second, there are different types of subjects involved in the supply chain, and their relationships are complicated. Third, under the top-down governance system in China, policy is a major factor affecting the supply of drugs. The government has used plenty of measures from multiple perspectives

to ensure the sustainable supply of drugs, and policy orientation has been modified over time under different circumstances. To this end, our study focuses on the analysis of China's drug reform policies to discover how reform helps policy makers ensure sustainable drug supply, taking the categories quality and safety, availability, affordability, and rational use, proposed by the World Health Organization (WHO) [30], as the major concerns and targets of drug supply. Through identifying policy target–instrument–implementer sets [31], we aim to investigate the primarily approaches and trends of China's drug reform, and seek answers to the following three questions:

- What is the major concern of drug supply during China's drug reform?
- What is the preference of instruments adopted in policies and their tendencies?
- What are the approaches to sustainable drug supply under China's drug reform?

2. Materials and Methods

2.1. Data Collection

The China State Council Policy Database (www.gov.cn, accessed on 3 January 2023) is the most authoritative policy database of the Chinese central government and collects central-level policy documents issued by the State Council and its constituent departments. The Peking University Law Information Database (PKULaw) is a non-official policy database that provides a platform which can be publicly searched for policy and enables users to download the full texts of over 1.2 million policy documents at all levels of the Chinese government [32]. (Figure 1) We searched for policy documents containing both "healthcare reform" and "drug" or related terms such as "consistency evaluation", "dual invoicing", and "zero-markup" between 2009 to 2022 in both databases. We then retrieved and downloaded 644 policy documents related to China's drug reform. In order to ensure the accuracy of the data, retrieved policy documents were reviewed, and documents that could not effectively reflect the policy makers' intention in drug reform under the healthcare reform system were excluded. The following criteria were applied: (1) the title of policies containing "opinion", "scheme", "plan", "measure", "method", and "notice" were included in the analysis, while articles entitled "report", "correspondence" and other types of policies were excluded; (2) policy documents that only mentioned drug reform, which did not contain substantive content, were excluded through joint discussions with the first, third, and corresponding authors; and (3) policy documents that contained only several words describing drug reform and from which we were unable to extract key factors were excluded. Ultimately, 204 policy documents were included in this analysis, including national healthcare policies, healthcare reform policies, and drug reform policies representing macro-, meso-, and microscale policies on drug reform, respectively, reflecting governance intentions at all levels.

As the study included macro- and mesoscale policies, which not only contain content related to drug reform but also to other areas, analysis units based on paragraphs were extracted before text mining and semantic analysis. For healthcare policies and healthcare reform policies, only analysis units related to drugs were included; accordingly, for drug reform policies, all analysis units were included. Finally, 2322 analysis units were included in the policy content analysis of this study.

2.2. Methods

2.2.1. Identify Key Factors

In order to discover the approaches applied to achieve targets among sustainable drug supply, key factors of policy documents should first be identified via text mining, which is the process of extracting information from text automatically by means of a computer and turning text into data, establishing the basis for quantitative analysis [33]. This is followed by sematic analysis, which is the basis of natural language processing, enabling computers to retrieve keywords or concepts from policies and to unify different lexical expressions of the same semantics based on context [24,34]. In order to accomplish this, we constructed a framework of policy instruments, their targets, and their implementers

based on the writing style of Chinese policies and the characteristics of the drug sector. According to the framework, the 3 types of policy factors were standardized into unified terms and phrases from different modes of expression in unstructured policy texts that could be classified into 13 categories under 5 types of targets, instruments (supply-side, demand-side, environmental), and implementers. The framework is shown in Table 1.

Table 1. The framework of targets, instruments, and implementers.

Type	Category	Terms and Phrases in Policy Text
Targets	Accessibility	Accessibility, supply guarantee, capability of supply, meeting need, etc.
	Affordability	Affordability, anti-monopoly, price reduction, burden reduction, expenditure control, etc.
	Rational use	Rational use, standardize medication, etc.
	Quality and safety	Quality, safety, efficacy, etc.
	Other targets	Industrial upgrading, innovation promotion, bribery punishment, structural adjustment, social stability, etc.
Supply side Instrument	Financial support	Financial support, health input, R&D investment, government input, S&T project, industrial upgrading project, etc.
	Talent cultivation	Talent cultivation, talent training, institutional capacity building, education program, etc.
	Infrastructure construction	Infrastructure construction, production base, research facilities, service facilities, etc.
	Information support	Information support, cyberinfrastructure, information platform, information system, etc.
Demand-side Instrument	Procurement	Procurement, procurement catalog, procurement list, stockpile, centralized procurement, joint procurement, pooled procurement, etc.
	Pricing and payment	Pricing, payment, subsidy, price negotiation, free of charge, insurance coverage, settlement, etc.
	Usage	Usage, national essential medicine list, drug provision, drug service, medication guide, priority use, guidelines, etc.
	Contract and cooperation	Contract, cooperation, designated production, entrusted production, cooperative R&D, entrusted delivery, etc.
	Qualification	Qualification authentication, certificate, registration, admittance, etc.
Environmental Instrument	Regulatory system	Formulate/introduce/improve systems/policies/methods/procedures/regulations/schemes/mechanisms/rules, demonstration, pilot program, pilot promotion, etc.
	Supervision	Supervision, investigation, inspection, monitoring, rectification, accountability, punishment, etc.
	Assessment	Assessment, evaluation, consistency evaluation, index, etc.
	Provider incentive	Incentive, income distribution, remuneration, allowance, etc.
	Strategic planning	Plan, goal, etc.
Implementers	Government	Government, State Council, National Health Commission, National Medical Products Administration, Ministry of Industry and Information Technology, National Healthcare Security Administration, governments at all levels, etc.
	Enterprise	Enterprise, manufacturer, trading enterprise, retailer, circulation enterprise, enterprise staff, etc.
	Medical institution	Medical institution, pharmacist, public hospital, primary healthcare institute, medical institution staff, etc.
	Consumer	Patient, resident, children, elderly, etc.
	Other implementers	Media, social organization, etc.

2.2.2. Bibliometric Analysis and Visualization

We conducted bibliometric analysis, combined with descriptive statistics and visualization, to discover both external characteristics and internal content of drug reform policies. First, the number of policies issued each year and the proportion of jointly issued policies were calculated in two stages based on new healthcare reform processes. Meanwhile, milestone policies were marked and explained. Second, the primary departments responsible for issuing drug reform policies were identified. Third, the types and categories

of policy instruments used in policies were counted with their targets and implementers, as were their tendencies and the proportion of instrument types used in each policy in the time span from 2009 to 2022. Finally, the co-word analysis of targets, instruments, and implementers in analysis units in both stages was conducted and visualized, and the social network characteristics of factors were calculated and explained. Excel and Tableau were used for statistical analysis and visualization. Bibexcel was used for constructing the factors co-word matrix. Additionally, Gephi was used for co-word cluster visualization and social network characteristic calculation.

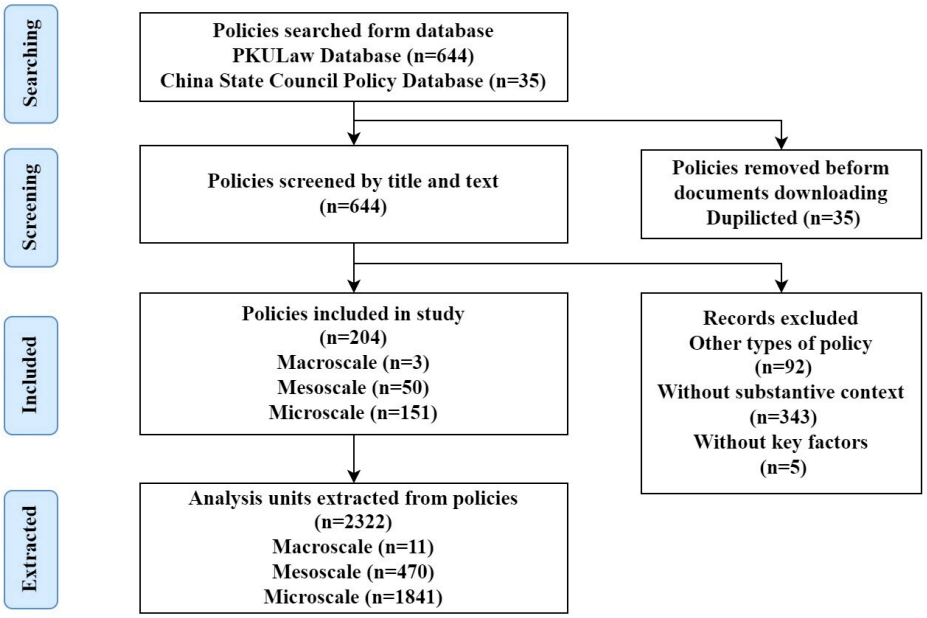


Figure 1. Flow diagram for data collection.

3. Results

3.1. Distributions

Figure 2 shows that the number of China's drug reform policies has fluctuated between 2009 and 2022. The darker blue bars at the top represent the number of jointly issued policies, while the lighter blue bars at the bottom represent the number of policies issued by a single department. The period from 2009 to 2015 could be seen as the initial stage of the new healthcare reform era. In 2009, after 2 years of preparation by the central government, a package of policies was issued in a centralized manner, covering various aspects of drug reform measures. In the following years, the effects of previously issued policies gradually emerged, the number of policies dropped, and a small number of newly issued policies primarily played the role of supplement. During this period, a series of radical drug reform policies were issued, such as centralized procurement at the provincial level, a zero-markup policy on drug sales in public hospitals, and a special path for innovative drug review and approval, laying the foundation of the drug reform system and setting up the root principles. The second stage of drug reform began in 2016, with the upgrade of the healthcare demands of China's 13th Five-Year Plan and the initiatives of the 'Healthy China 2030' plan, which led to another peak in policy issuance. In this stage, the problems of drug supply became more complicated and interdependent, which called for comprehensive and deepening reform with coherent and sustainable measures. Policies issued in this stage were highly coordinated with policies issued in the first stage and aimed to fill the gaps in achieving reform targets and to curb emerging problems in a timely fashion. For example, the policy of "consistency evaluation" of generic drugs was launched to set a quality threshold for centralized procurement, whereas "dual invoicing (only allowing two steps of invoicing which are manufacturers to distributors followed by distributors to medical institutions)" was used to force cuts to processes in drug distribution and the erosion chain

they formed. After 2020, with the initial accomplishment of the drug reform system and the impact of COVID-19, the number of reform policies declined. The proportion of jointly issued policies significantly rose from 32.7% in the first stage to 44.7% in the second stage, indicating a wider involvement of government departments in China's drug reform and reflecting the increasing complexity of the reform.

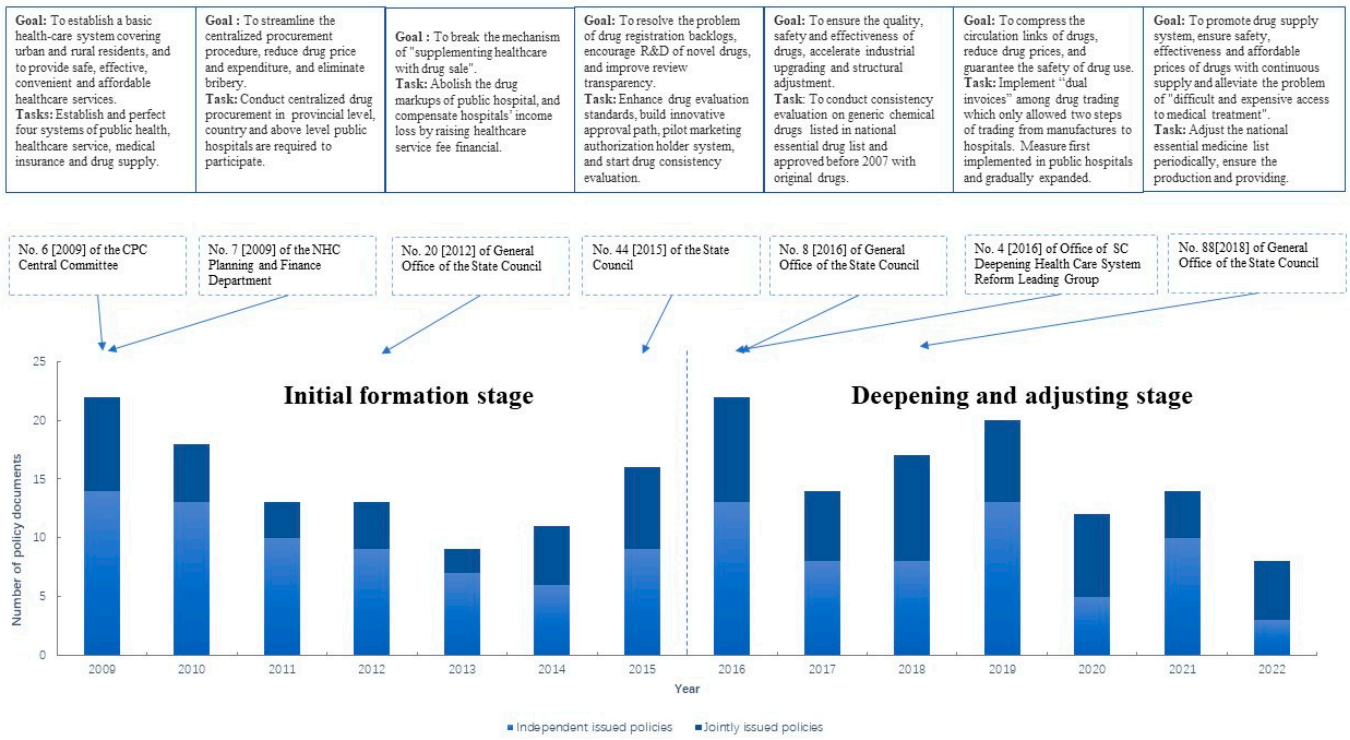


Figure 2. Key policies of drug reform issued in China, 2009–2022.

3.2. Issued Departments

As is shown in Figure 3, the National Health Commission (NHC) is the primary government department leading drug reform, issuing nearly half of the reform policies either independently or jointly. This indicates that China's drug reform is more than a reform of the drug sector, but instead constitutes a supportive and coordinative system under a reform of China's healthcare system for the purpose of establishing and perfecting basic healthcare systems that provide universal healthcare service to all Chinese residents. Subsequently, the National Medical Products Administration (NMPA), along with the State Council (SC) and its affiliated offices, is also responsible for the formulation and issuance of reform policies, with the former focusing on micro-level policies related to drug regulation, and the latter issuing macro-level policies that are directional and embody national top-down design. In 2018, several departments related to drug governance were reorganized, including the cancellation of the State Council Office of the Leading Group for Deepening Medical and Healthcare System Reform, with the functions taken over by the NHC, and the establishment of the National Healthcare Security Administration (NHSA), which integrates functions of medical insurance, healthcare service pricing, and drug procurement. Since its establishment, the NHSA has issued 25 drug reform policies that highly affect the drug sector and has become one of the most influential departments in the area of drug reform. The four government departments mentioned above not only issued a large number of policies but were also dominant in more than 60% of policies they issued jointly, demonstrating their key function in leading drug reform. In addition, several other government departments, including the Ministry of Industry and Information Technology (MIIT), the National Development and Reform Commission (NDRC), and the

Ministry of Finance (MOF), also issued policies to direct different aspects of drug reform, such as industrial development, pricing, and financial support.

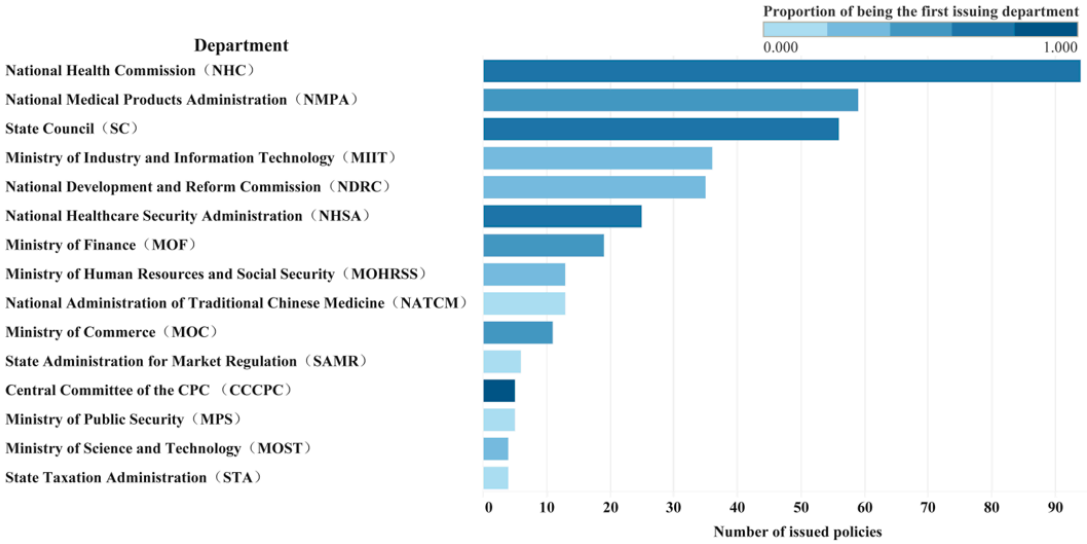


Figure 3. The leading government departments of drug reform in China, 2009–2022.

3.3. Emphasis and Trend of Policy Factors

3.3.1. Proportion of Policy Factors

From Figure 4, it can be seen that the most commonly used policy instruments in drug reform policies are environmental instruments and demand-side instruments, accounting for 42.8% and 41.9% of the total polices implemented, respectively. Supply-side instruments are less used in drug reform policies, accounting for only 15.3% of the total instruments used.

In terms of specific instrument categories, the environmental instruments "regulatory system" is the most commonly used instrument in drug reform policies, which is the primary duty and most important leverage of government departments. After the formulation and improvement of the "regulatory system", the procedure followed by other environmental instruments includes conducting lifetime "supervision", performing corresponding "assessment", and offering appropriate "provider incentives". The frequency of instruments used in this procedure decreases in steps.

"Procurement" and "pricing and payment" are the widely used demand-side instruments in drug reform policies. They are fundamentally related to drug purchases and expenditures, and specifically illustrate how drugs are purchased and paid for and at what price they are sold. In addition, policies also use instruments such as "essential medicine list", "medication guide", and "drug provision" to guide the "usage" of drugs, also harnessing "qualification" and "contract and cooperation" for drug R&D, production, distribution, and other marketing activities.

Although less popular in drug reform policies, supply-side instruments are still crucial as they represent the workforce, funds, and properties supported by the government to guarantee drug supply and pharmaceutical industry development. "Talent cultivation" is emphasized in policies, specifically through "training" medical providers and funding "education program", etc. Additionally, the instrument known as "information support", represented by "cyberinfrastructure", "information platform", and the "information system" related to the foundation of informatization, is also highlighted. "Financial support" and "infrastructure construction" are paid less attention in drug reform policies, with the percentages of use being 3.0% and 2.2%, respectively, suggesting that, although the government budget in healthcare is increasing year by year, there is no intention to allocate it to the drug sector.

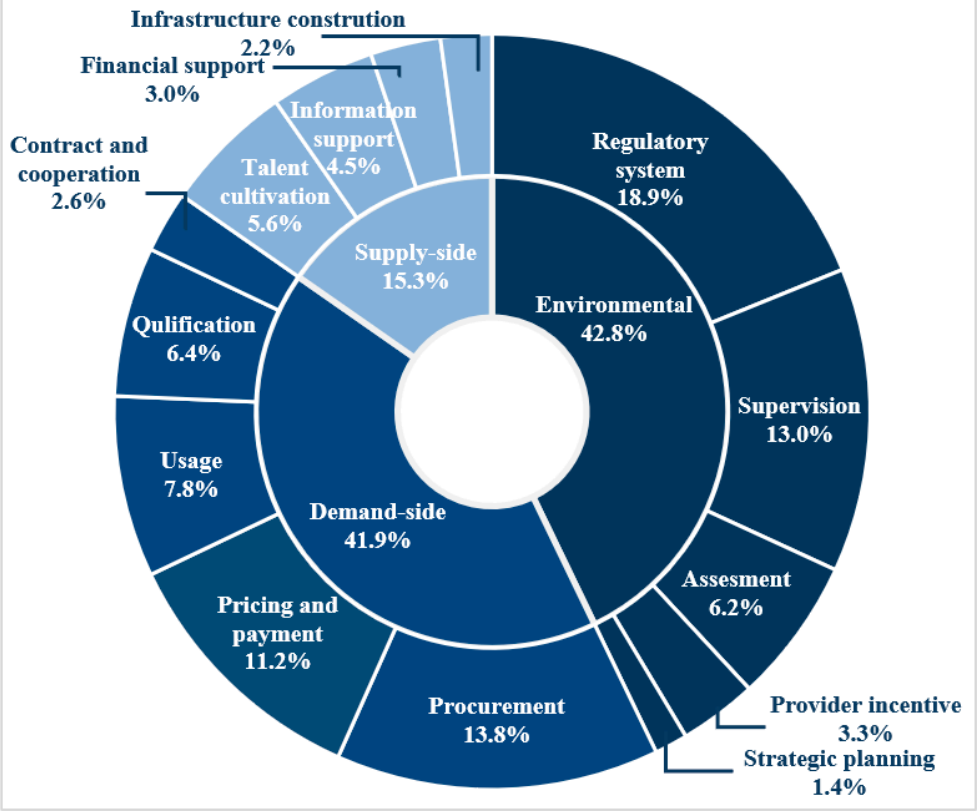


Figure 4. Percentage of used policy instruments in China's drug reform policies, 2009–2022.

For drug reform to serve the core objectives of China's new healthcare reform through providing a sustainable drug supply, it includes several concerns that could be seen as specific policy targets. Figure 5 shows that ensuring the quality and safety of drugs is the primary target of the reform, accounting for 26.4% of the total targets retrieved from policies. This is followed by accessibility, which takes up 23.5% in comparison. It is noteworthy that accessibility not only includes access to drugs that have already been launched in China, but also to those expected to have clinical benefits but which have not been registered or approved in China or globally. Affordability and rational use are less targeted in drug reform policies, taking up 18.5% and 17.3% of total targets, respectively. Similarly, the affordability of drugs not only refers to drug prices afforded by patients, but also the affordability of medical insurance, meaning that the coverage of the drugs in medical insurance is budgetarily feasible and sustainable. Rational use is the target with a higher requirement, and this could generally be seen as the next step in reform after the provision of access to high-quality drugs. In addition, China's drug reform policies also commit to several other targets affecting areas broader than drug supply, such as industrial upgrading, innovation promotion, bribery punishment, social stability, etc.

Implementers are the subjects involved in the implementation of policy instruments, completing the approach to drug reform with the core piece. Figure 5 shows that government departments play the most important role in instrument implementation. This situation prevails primarily due to the environmental instruments used most frequently in drug reform policies as they need to be carried out or participated in by government departments. Medical institutions comprising public hospitals, primary healthcare institutions, community health centers, and other healthcare facilities are also key implementers of policy instruments. Moreover, enterprises including manufacturers, trading enterprises, distribution enterprises, retailers, and other enterprises along the supply chain are the root suppliers of drugs, meaning that their functions in utilizing reform policy instruments are irreplaceable. Several other implementers are involved, such as media, social organizations, research institutions, etc.

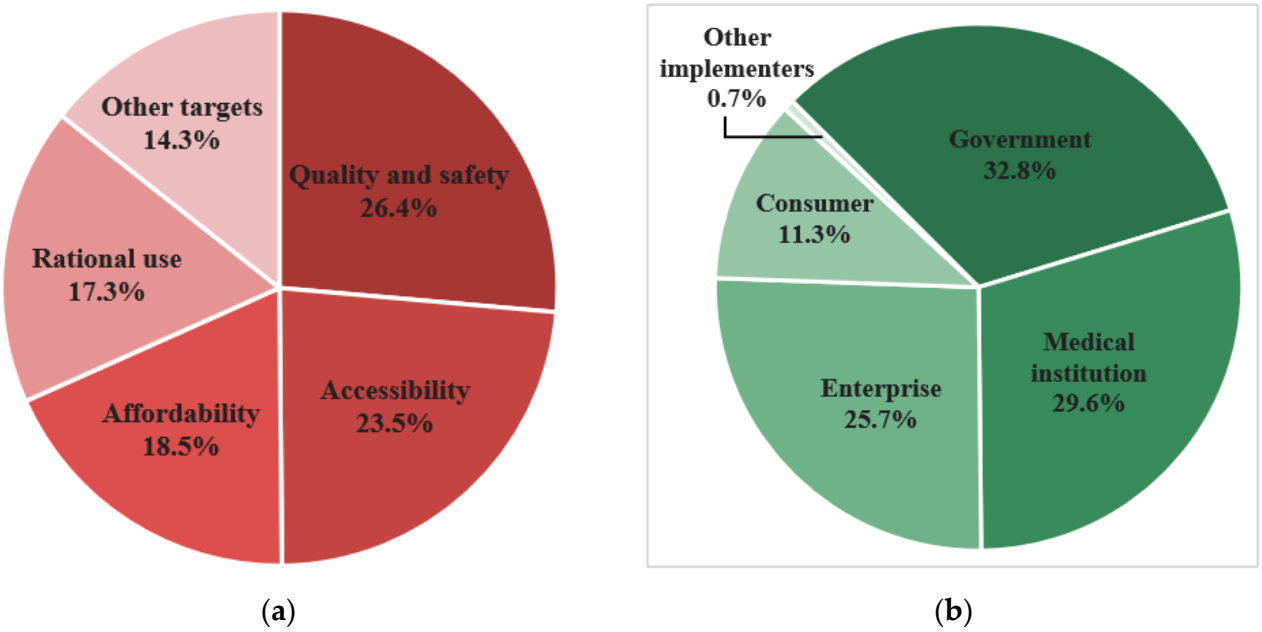
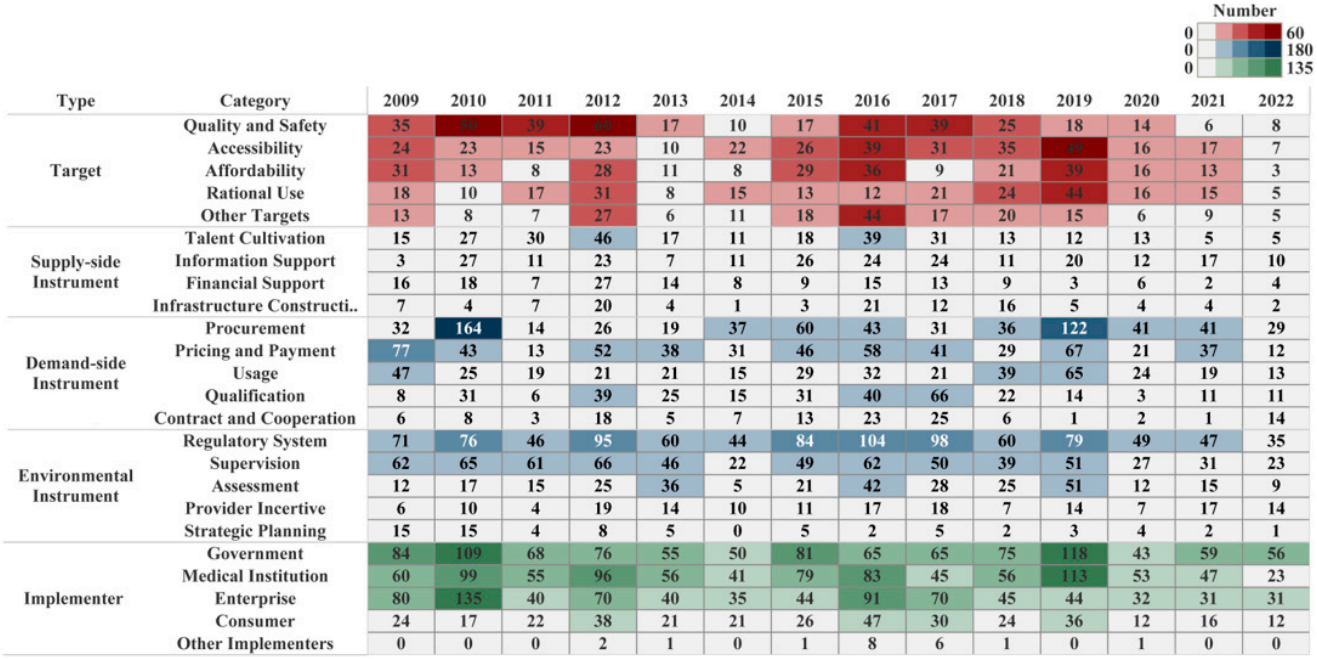


Figure 5. Percentage of factors in China's drug reform policies, 2009–2022: (**a**) policy targets; (**b**) instrument implementers.

3.3.2. Tendencies of Policy Factors

Figure 6 shows the frequencies of using the three types of instruments varied between years from 2009 to 2022. Environmental instruments and demand-side instruments were used more frequently in the second stage than in the first, while the use of supply-side instruments showed the opposite trend. "Regulatory system" was the most frequently used policy instrument from 2012 to 2022, except in the year 2019, reflecting that regulation construction was the priority of drug reform from the perspectives of policy makers. Since institutional construction and policy optimization were always regarded as the fundamental means of promoting reform, especially after the adjustment of superior regulations such as health policies or healthcare reform policies, they should be adjusted accordingly to continuously adapt to the new needs of healthcare services and address emerging problems. Similarly, "supervision" also attached great significance to policies, which could be seen as a necessary step in implementing the "regulatory system", and the two are complementary to each other. Compared with "regulatory system" and "supervision", the terms "assessment" and "provider incentive" were used less frequently, but the frequencies increased significantly in the second stage.

As the primary demand-side instrument, "procurement" exhibited significant changes in the frequency of use between years. In 2010 and 2019, policies related to drug procurement were issued intensively. The former occurrence was due to a substantial adjustment in China's centralized drug procurement policy in 2009, while the latter development was due to the full implementation of national drug centralized procurement led by the NHSA after its establishment. "Pricing and payment" were also major concerns in policies. In both stages of drug reform, the government controlled drug prices and payment methods through measures such as limiting drug markup, revising the medical insurance catalog, and conducting drug price negotiations. Guiding the "usage" of drugs through the national essential medicine list and medication guidelines, drug provision was also an important means of drug reform that encouraged demand-driven pharmaceutical development, and its frequency of use gradually increased. In addition, "contract and cooperation" received more attention in the second stage, which was attributed to the implementation of the drug marketing authorization holder system (MAH) in 2016. MAH untied the bundling of drug registration and production to accelerate drug innovation through cooperation and contracts between enterprises or institutions.



Type	Category	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Target	Quality and Safety	35	50	39	60	17	10	17	41	39	25	18	14	6	8
	Accessibility	24	23	15	23	10	22	26	39	31	35	49	16	17	7
	Affordability	31	13	8	28	11	8	29	36	9	21	39	16	13	3
	Rational Use	18	10	17	31	8	15	13	12	21	24	44	16	15	5
	Other Targets	13	8	7	27	6	11	18	44	17	20	15	6	9	5
Supply-side Instrument	Talent Cultivation	15	27	30	46	17	11	18	39	31	13	12	13	5	5
	Information Support	3	27	11	23	7	11	26	24	24	11	20	12	17	10
	Financial Support	16	18	7	27	14	8	9	15	13	9	3	6	2	4
	Infrastructure Constructi..	7	4	7	20	4	1	3	21	12	16	5	4	4	2
Demand-side Instrument	Procurement	32	164	14	26	19	37	60	43	31	36	122	41	41	29
	Pricing and Payment	77	43	13	52	38	31	46	58	41	29	67	21	37	12
	Usage	47	25	19	21	21	15	29	32	21	39	65	24	19	13
	Qualification	8	31	6	39	25	15	31	40	66	22	14	3	11	11
	Contract and Cooperation	6	8	3	18	5	7	13	23	25	6	1	2	1	14
Environmental Instrument	Regulatory System	71	76	46	95	60	44	84	104	98	60	79	49	47	35
	Supervision	62	65	61	66	46	22	49	62	50	39	51	27	31	23
	Assessment	12	17	15	25	36	5	21	42	28	25	51	12	15	9
	Provider Incertive	6	10	4	19	14	10	11	17	18	7	14	7	17	14
	Strategic Planning	15	15	4	8	5	0	5	2	5	2	3	4	2	1
Implementer	Government	84	109	68	76	55	50	81	65	65	75	118	43	59	56
	Medical Institution	60	99	55	96	56	41	79	83	45	56	113	53	47	23
	Enterprise	80	135	40	70	40	35	44	91	70	45	44	32	31	31
	Consumer	24	17	22	38	21	21	26	47	30	24	36	12	16	12
	Other Implementers	0	0	0	2	1	0	1	8	6	1	0	1	0	0

Figure 6. Frequencies of use of different instruments in China's drug reform policies, 2009–2022.

"Financial support" for drug research and healthcare service subsidies and "talent cultivation" for drug services are crucial in efforts to support drug reform and develop the pharmaceutical industry from the supply side. However, these two instruments were seldom used in China's drug reform policies in the first stage, and the average percentages even decreased in the second stage by 54.1% and 34.7%, respectively, after standardization by total instruments used each year. In contrast, "infrastructure construction" in drug services and "information support" for drug administration, procurement, and supply surveillance were paid more attention in the second stage, and the percentages rose by 36.6% and 16.4%.

Among the four main targets of drug reform, ensuring the quality and safety of drugs was the priority in the first stage, which was from 2010 to 2012. However, the average percentage being targeted decreased by 33.7% in the second stage. On the contrary, availability was given more emphasis in the second stage, with the average percentage increasing from 21.5% to 26.2%. Policies' attention to affordability varied drastically in both stages. This focus was relatively high in 2009, 2015, 2019, 2020, and 2021, whereas quite the opposite situation prevailed in 2011 and 2017. As the last target of drug reform, rational use exhibited an obvious upward trend in importance during the second stage, with the average targeted rate increasing by 21.0%.

Government departments at all levels were the primary implementers of policy instruments, with three years being the top implementers in the first stage and four years in the second. Declined functions in implementing policy instruments were observed in both medical instruments and enterprises, with the proportion decreasing by 4.5% and 7.6%, respectively. Nevertheless, consumers exhibited a 6.1% growth in instrument implementation, which suggests demand-driven tools and patient participation are the trends in drug reform.

3.3.3. Tendency of Policy Instruments Composition

Analysis of the types of policy instruments used in an individual policy document could reveal the preference for instruments used in China's drug reform (Table 2). Among the drug reform policies issued between 2009 and 2022, the proportion of policies using environmental instruments was the highest, averaging 96.1%. This is higher than the proportion of policies using demand-side instruments at 94.3% and supply-side instruments

at 78.4%. The proportion of policies using all three types of policy instruments was 69.9%. The proportion of policies using supply-side policy instruments increased in the early years and gradually decreased after 2015, while the others showed no significant changes, suggesting that investment of workforce, funds, and properties in the drug sector was less preferred in comparison.

Table 2. Proportions of drug reform policies using the three types of instruments, 2009–2022.

Year	Supply-Side Instruments	Demand-Side Instruments	Environmental Instruments	All Three Types of Instrument
2009	57.1%	90.5%	100.0%	52.4%
2010	83.3%	77.8%	94.4%	77.8%
2011	84.6%	76.9%	92.3%	69.2%
2012	92.3%	100.0%	100.0%	92.3%
2013	88.9%	100.0%	100.0%	88.9%
2014	81.8%	100.0%	100.0%	81.8%
2015	81.3%	93.8%	100.0%	75.0%
2016	71.4%	100.0%	95.2%	71.4%
2017	84.6%	100.0%	92.3%	84.6%
2018	70.6%	88.2%	88.2%	64.7%
2019	78.9%	100.0%	89.5%	73.7%
2020	77.8%	100.0%	100.0%	77.8%
2021	66.7%	93.3%	93.3%	66.7%
2022	77.8%	100.0%	100.0%	77.8%

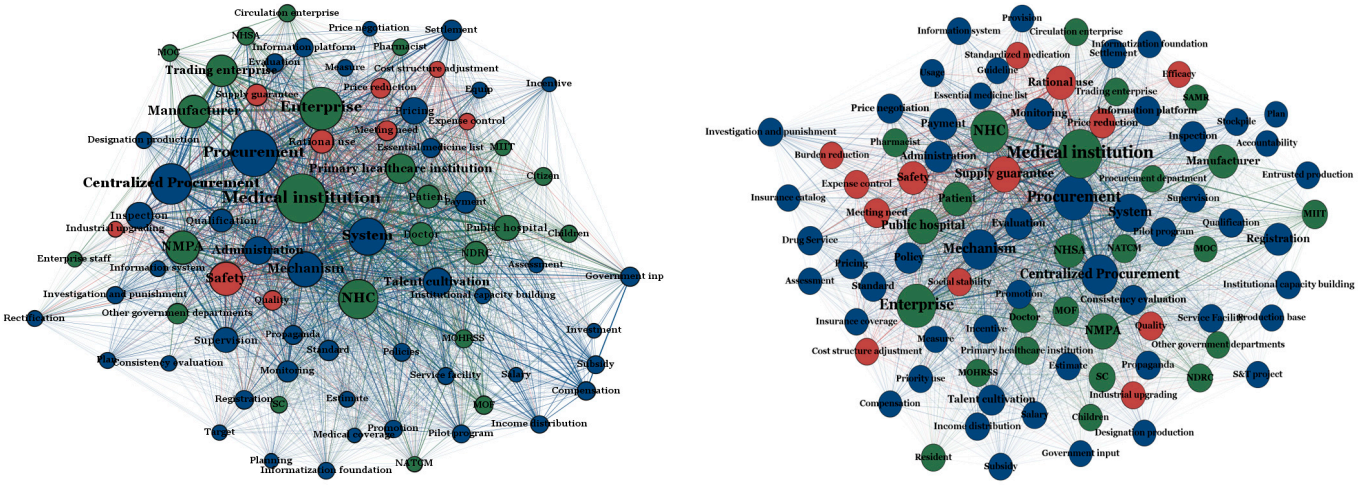
3.4. Relationship of Policy Factors

Based on the co-word analysis theory, when more than one of the key policy factors identified appears in the same analysis units, they have essential relationships [35]. Additionally, the more frequently two factors co-occur, the closer their relationship is. To this end, co-word analysis of targets, instruments, and implementers is conducted on both the initial formation stage and the deepening and adjusting stage to discover the relationship between key factors and illustrate reform approaches to achieve sustainable drug supply. In Figure 7, nodes represent key factors identified from drug reform policies, and red, blue, and green nodes denote targets, instruments, and implementers, respectively. A linkage between two nodes exists when both accord in the same analysis unit, which indicates correlation. For example, an instrument is linked with its targets, its implementers, and other instruments used together. Furthermore, values of social network analysis are counted in order to identify key roles in different stages. In the network, cluster graph density and average path length are two significant indexes that assess the interconnectedness of nodes within the entire cluster. Graph density quantifies the actual number of links in relation to the maximum possible links, while the average path length represents the average number of steps along the shortest paths for all connected nodes. Moreover, centralities provide measures for evaluating the importance of individual nodes. Degree centrality evaluates importance based on the number of links each node possesses, while betweenness centrality calculates the frequency with which a node lies on the shortest path between other nodes. For this study, a policy factor with a high degree of centrality is directly linked with many other factors, while a factor with high betweenness centrality is the shortcut junction of many independent factors.

3.4.1. Initial Formation Stage (2009–2015)

In the initial formation stage of the new healthcare reform, the Chinese state planned to achieve the four main targets of drug reform via four relatively independent paths: (1) Improving the accessibility of drugs was mainly achieved through the use of the demand-side instrument "procurement", which involved medical institutions and enterprises as the main implementers, with the upgrading of the concentration, scale, and scope of centralized drug procurement in 2009. (2) Enhancing the affordability of drugs

largely relied on drug "pricing", which was a demand-side instrument with measures of controlling the markup and sale prices of drugs in medical institutions. (3) Ensuring the quality and safety of drugs was mostly achieved through environmental instrument "supervision", implemented by the drug administration departments at both national and provincial levels to conduct supervision, monitoring, and inspection of manufacturers and trading enterprises, as well as to strengthen registration standards. (4) Promoting the rational use of drugs highly depended on medical institutions and consumers, with primary healthcare institutions as the primary focus. Supply-side and demand-side instruments were leveraged to achieve this target, including "talent cultivation", "national essential medicine list", "propaganda", etc.



(**a**) (**b**)

Figure 7. The co-word cluster graph of target–instrument–implementer in China's drug reform policies during (**a**) the initial formation stage (2009–2015) and (**b**) the deepening and adjusting stage (2016–2022).

In the first stage, the co-word cluster graph density was 0.495, and the average path length was 1.512, indicating a relatively singular means of achieving policy targets, with independent approaches and fewer implementers. From the social network characteristic values shown in Table 3, we can assert that medical institutions represented by primary healthcare institutions and enterprises were the key implementers in the achievement of reform targets. The demand-side instrument "procurement", specifically "centralized procurement", was the first concerned policy instrument of drug reform that had both a high use frequency and social network value. Furthermore, the degree of centrality, closeness centrality, and betweenness centrality of the node "system" were higher than those of other instruments' nodes, indicating system development to be the core means of achieving targets, the prerequisite for the implementation of other instruments, and the key connecting point of other policy factors in this stage. Although NHC and NMPA had high degree centrality, their betweenness centrality values were less prominent, indicating that they were the primary government departments of drug reform in policy implementation, but that their functions were quite independent as they were not located at the intersection of multiple approaches.

Table 3. Top 30 nodes with the largest used number in China's drug reform target–instrument–implementer social network analysis, 2009–2022.

Rank	Category–Factor	Total Number	Initial Formation Stage			Deepening and Adjusting Stage		
			Number	Degree Centrality	Betweenness Centrality	Number	Degree Centrality	Betweenness Centrality
1	IM–Medical institution	662	326	0.887	0.017	336	0.94	0.024
2	IS–Procurement	577	303	0.845	0.015	274	0.893	0.015
3	IM–Enterprise	532	269	0.852	0.022	263	0.873	0.015
4	IM–Health department/NHC	478	238	0.88	0.014	240	0.913	0.017
5	IS–Centralized procurement	469	251	0.866	0.018	218	0.84	0.011
6	IS–Mechanism	415	200	0.852	0.01	215	0.907	0.013
7	IS–System	406	220	0.909	0.018	186	0.907	0.017
8	IM–NMPA	338	185	0.796	0.011	153	0.82	0.009
9	T–Safety	305	187	0.838	0.022	118	0.807	0.009
10	IM–Manufacturer	301	177	0.796	0.013	124	0.747	0.008
11	IM–Public hospital	262	114	0.817	0.011	148	0.84	0.01
12	T–Supply guarantee	241	82	0.754	0.008	159	0.853	0.01
13	IS–Administration	235	140	0.831	0.009	95	0.813	0.01
14	T–Rational use	226	99	0.796	0.008	127	0.82	0.012
15	IM–Patient	223	96	0.838	0.011	127	0.767	0.007
16	IS–Talent cultivation	223	142	0.803	0.007	81	0.82	0.011
17	IM–Trading enterprise	215	170	0.782	0.011	45	0.767	0.008
18	IS–Inspection	202	126	0.739	0.011	76	0.667	0.004
19	IM–Primary healthcare institution	196	154	0.796	0.008	42	0.76	0.006
20	IS–Pricing	195	129	0.754	0.006	66	0.673	0.003
21	IS–Payment	186	85	0.739	0.004	101	0.727	0.004
22	IS–Monitoring	176	80	0.761	0.008	96	0.847	0.009
23	IM–Medical insurance department/NHSA	175	50	0.57	0.003	125	0.793	0.007
24	IM–Doctor	174	100	0.803	0.007	74	0.76	0.005
25	IS–Registration	168	59	0.641	0.004	109	0.693	0.003
26	IS–Supervision	164	114	0.803	0.011	50	0.667	0.005
27	IS–Qualification	149	95	0.775	0.011	54	0.66	0.006
28	IM–NDRC	146	97	0.789	0.009	49	0.78	0.007
29	IS–Policy	141	53	0.718	0.004	88	0.807	0.005
30	IS–Evaluation	141	55	0.669	0.004	86	0.813	0.008

T = policy target, IS = policy instrument, IM = instrument implementer.

3.4.2. Deepening and Adjusting Stage (2016–2022)

During the deepening and adjusting stage of the new healthcare reform, the four main targets of drug reform intersected in their implementation approaches. In other words, one target should be achieved through the synergy of multiple instruments, and one instrument may take effect upon achieving several targets simultaneously. The implementers of policy instruments also increased, and the reform approaches became more complex and com-

prehensive. (1) The guarantee of drug accessibility was still mainly through "centralized procurement", with the construction and use of the "information platform". The drug procurement threshold was raised through linking it with qualified quality and safety through the use of "consistency evaluation". In this stage, new drug R&D and shortage drug production was emphasized. The supply capacity of urgently needed drugs was enhanced through accelerated review and approval, designated production, entrusted production, and stockpiling. Enterprises and medical institutions were still the key implementers of policy instruments; however, public hospitals had replaced primary healthcare institutions to become the core implementers, and multiple government departments worked together to implement policy instruments, including NHC, NHSA, NMPA, and MIIT. (2) The affordability of drugs not only focused on reducing price but also committed to controlling the overall cost and reducing consumers' burden, which introduced a new target of cost structural adjustment. In terms of measures, the control of "pricing" gradually shifted to manage the "payment". The environmental instruments "pilot program" and "evaluation", as well as the periodically modified demand-side instrument "medical insurance catalog", were used to expand the insurance coverage of needed drugs step by step, while the demand-side instruments "procurement" and "price negotiation" were used to control the total expenditure on medical insurance. These instruments were mainly conducted by government departments represented by the NHSA and NHC. In the second stage, the targets of affordability and accessibility were complementary to each other, and the instruments "procurement" and "payment" were integrated. (3) The target of ensuring that drug quality and safety further advance towards industrial upgrading, in addition to government administration such as "supervision", "inspection" and "accountability", was achieved through enterprise "capacity building", improved industrial "standards", and strengthened "evaluation". (4) The rational use of drugs was underlined more in this stage, which was closely related to other targets such as quality and safety, meeting needs, and social stability. Demand-side instrument "usage" was still the dominant approach, with more diverse instruments arising, including the introduction of "guidelines", improving the "national essential medicine catalog", ensuring the "provision" of essential medicines, and providing professional "drug services". For the purpose of applying the demand-side instruments more efficiently, the supply-side instruments "talent cultivation" and "information support" were used simultaneously. The key implementers of this target were medical institutions, while the importance of consumers had also increased, working jointly with doctors and pharmacists to achieve this target.

In the second stage, the density of the co-word cluster of the target–instrument–implementer network increased to 0.524, and the average path length shortened to 1.479. Higher density and shorter length between nodes indicate an increase in the relationship and interaction between the targets, instruments, and implementers. The centrality of medical institutions further increased, which occupied the core position in the social network graph and became the key to achieving the majority of drug reform targets. The demand-side instrument "procurement" remained as the most commonly used policy instrument in this stage, just as the leading factors of other instruments such as "payment", "pricing" and "settlement". The environmental instrument "system" kept its leading role in achieving targets. Nevertheless, after the gradually improved construction of the "system", the formulation of the "mechanism" received more attention in the second stage. The policy makers paid more attention to the intrinsic connection between reform instruments and were inclined to make them operate sustainably through optimizing the "mechanism". In the second stage, the social network values of the NHC improved, especially the value of betweenness centricity, reflecting that the NHC played an increasingly crucial role in implementing policy instruments and coordinating the implementers involved.

As Table 3 shows, in general, there were three types of nodes in the drug reform target–instrument–implementer co-word social network. (1) The large number of nodes used with high social network values indicated that the factor was highly emphasized in drug reform policies and closely related to other factors, such as "medical institution", "procurement",

"enterprise", "health department/NHC", and "system" in both stages. (2) The large number of nodes used with moderate social network values reflated that the factor was important, but worked relatively independently in the area of drug reform, such as "primary healthcare institute", "pricing" in the first stage, and "manufacturer", "patient", "payment", "medical insurance department/NHSA" and "registration" in the second stage. (3) The number of nodes used was not that large but enjoyed quite high social network values, meaning that factors were not used that much but were necessary in implementing many other instruments or interacted a lot with other factors in achieving multiple targets, such as "patient" and "qualification" in the first stage and "administration", "talent cultivation", "monitoring", and "evaluation" in the second stage.

4. Discussion

Between 2009 and 2022, China's drug reform experienced two stages, namely, the initial formation stage, in which policy makers implemented bold reform measures to reconstruct drug supply chains, and the deepening and adjusting stage, in which the reform focused on internal factor coordination and comprehensive healthcare development. The factors in policies have become more closely intertwined, with instruments and implementers growing ever more diverse [36].

At the early stage, the reform measures were formulated and implemented in a way that aimed at solving the problem of 'difficult and expensive to access healthcare service' for Chinese residents [37]. In terms of drugs, there are generally two problems lying ahead in terms of to ensure drug supply with the consideration of access, quality, price, and rational use. The first is limited capability to provide drugs to those in need of medication, and the second is that consumers could not afford the expense of drugs after reimbursement by medical insurance. The causes for these two problems are varied, including historical issues that formed the structure of China's healthcare expenditures, the level of pharmaceutical industry development, and the regulatory capacity of the drug sector [38,39]. Since 1978, China has gradually reduced government subsidies to medical institutions, allowing hospitals to make profits from drug sales to compensate for their operating costs, forming a mechanism of 'funding medical practice through over-priced drugs'. Although this mechanism enabled hospitals to operate independently without a high proportion of government financial subsidies, commercialized healthcare services undoubtedly led to a series of problems, including the high price of drugs, overmedication, and commercial bribery, all of which impeded the rational use of drugs [39,40]. On the other hand, China's production capacity for innovative drugs is still developing, and original drugs are monopolized by multinational pharmaceutical companies with excessive import prices. Additionally, due to some historical reasons before 2007, the quality of domestically produced generic drugs was uncertain, and some generic drugs had gaps in quality and efficacy compared to the original drugs [41]. In response to these problems, the first stage of drug reform mainly focused on institutional reconstruction. The reform policies were commonly piloted on a small scale at first, gradually expanded, and then fully implemented nationwide after targeted results were observed [42]. At this stage, the reform was revolutionary, and measures were intense, highly targeted, and relatively independent. The major reform measures included upgrading centralized procurement to the provincial level, leveraging a transparent official procurement platform, gradually abolishing the drug markup in public hospitals, preparing the consistency evaluation on generic drugs, and setting up an accelerated review and approval path for innovative drugs [43]. The main approach of drug reform in this stage was to reduce drug expenditures and guarantee qualified drug supply through regulating circulation, limiting sales markup, providing low-cost domestic drug substitution over high-cost imports, and strengthening drug supervision in the whole supply chain with the deep involvement of medical institutions, enterprises, and government departments of the NHC and NMPA [44–46].

Through implementing reform measures, targets in reducing drug expenditures, lowering procurement price, and controlling overmedication were partially achieved [47,48],

while new problems emerged unexpectedly, such as increased expenditures on examination and medical consumables [14,49] and shortfalls in the capacity to procure low-cost or low-consumption procurement drugs [50,51], issues that compromised the availability, affordability, and rational use of drugs [39]. Therefore, in the second stage of drug reform, in addition to introducing supplementary reform policies, the government paid more attention to internal coordination in the system. The concept of the 'integration of healthcare service, medical insurance, and pharmaceuticals' was officially proposed, and this developed synergic mechanisms between healthcare providers, payers, pharmaceutical enterprises, and the other government departments involved [36]. Policy instruments and targets were closely interconnected as some instruments were committed to more than one target, and most targets need to be achieved through a package of instruments. The most influential instruments were from the demand side, which determined the prices and payment methods of drugs based on centralized procurements moved upward to the national level on the basis of a dynamically modified medical insurance catalog, generic drug consistency evaluation, and drug price negotiation. This optimal combination of policy instruments targeted the affordability, accessibility, quality, and safety of drugs simultaneously. Most of the instruments in this package were led by the NHSA. This department, established in 2018, integrates the insurance, pricing, and procurement functions that were previously scattered across the Ministry of Human Resources and Social Security (MOHRSS), the NDRC, and the NHC to concentrate the government's pricing and payment power [37]. Up to the end of 2022, the NHSA had conducted seven rounds of volume-based centralized procurement and five rounds of drug price negotiations toward high-value original drugs. Additionally, the department adjusted the medical insurance catalog periodically, and had successively put 294 drugs into national-level procurement and 618 drugs into insurance coverage cumulatively [52], which effectively reduced patients' out-of-pocket expenditures [53–55] and government expenditures on drugs [56], in contrast to the rapid growth of government healthcare expenditures. Meanwhile, "dual invoicing" was introduced in 2016 to compress the circulation links of drugs and curb erosion in the trading activities of a large proportion of drugs not yet included in centralized procurement [57]. Additionally, another instrument package was implemented with guide usage as the core. This package primarily aimed to improve rational use and accessibility in the meantime on the basis of providing essential medicines widely in primary healthcare institutes, conducting prescription assessments, and adjusting the wage distribution of healthcare providers to disconnect providers' income from medication [58]. Most of the instruments in this package were led by the NHC, involving medical institutions as the main implementers, becoming the key junction of drugs and the other two healthcare reform systems, healthcare service and medical insurance [36]. Moreover, in order to further accomplish the target of accessibility, measures to encourage drug R&D were advanced in the second stage [59]. The MAH was used to untie the bundling of drug registration and production. Two more accelerated review and approval paths for emergency need and clinical urgent drugs were launched: conditional approval in 2017 and breakthrough therapy in 2020 [44,60]. Content related to intellectual property right (IPR) protection in the policies also increased. To continuously adjust the structure of medical expenditures and optimize payment methods, Diagnosis Related Groups (DRG) and Diagnosis Intervention Packet (DIP) pilot programs were widely started to further explore innovative payment methods, which are separate from payments with prescriptive behavior [61].

The pharmaceutical industry was substantially impacted by China's drug reform since 2009 [62] in each link of the supply chain. The accelerating paths of drug review and approval for innovative drugs and urgently needed drugs effectively encouraged and supported the R&D of enterprises [63,64], while decreased revenue caused by drug price competition in procurement necessitated an increased investment in R&D activities [65–67]. Additionally, generic drug consistency evaluation as the stepping-stone of centralized procurement accelerated the reshuffling of the pharmaceutical industry as several manufacturers with old registration certificates were wiped out, either because

of their dissatisfactory production capability or their reluctance to take input in terms of evaluation after comparing the profit they may bring in. Furthermore, many trading enterprises in the middle of the supply chain were eliminated through implementing "dual invoicing" and government procurement directly from manufacturers. In addition, the role of the drug department in medical institutions transformed from the profitable department to the spending department due to the zero-markup policy, which was considered to be divested in some way.

5. Conclusions

Through clarifying the relationships between three core factors of policies, the approaches and tendencies of China's drug reform towards sustainable drug supply have been generated, and the aforementioned questions can be properly answered. The core aims of drug reform were to effectively support the whole picture of China's healthcare reform and ensure the sustainable supply and rational use of drugs needed in healthcare services, with quality, safety, and affordable prices guaranteed to both government and patients. In the initial stage, massive measures effectively supported the supply of drugs and reduced the price. However, mandatory policies against market rules may compromise the sustainability of drugs supply and lead to new problems. To this end, more comprehensive instruments were adopted with more implementers involved, and the internal synergy between instruments and implementers was emphasized after China's healthcare reform entered the deep-water zone in the second stage. Firstly, the top concerns were quality and safety, as well as accessibility and affordability. With the enhanced capacity of China's pharmaceutical industry and regulatory system, the priority moved forward to rational use in the second stage. Environmental and demand-side instruments were preferred in drug reform policies with a slightly increased tendency, while supply-side instruments were less preferred. "Regulatory system", "supervision", "procurement", and "pricing and payment" were the four instruments with the highest frequency of use in both stages, whereas "supervision" and "pricing and payment" showed a decline in use in the second stage. Additionally, the major content of the "regulatory system" moved from "system" to "mechanism" in the second stage, suggesting that the coordination between policy factors was highlighted to enhance the sustainability of achievements. Regardless of the instrument type, China's drug reform was a government-dominated reform planned from the macroscopic perspective. Additionally, most instruments were led by government departments represented by the NHC, NMPA, and NHSA, with medical institutes, enterprises, and consumers participating.

Quantitative research on policy documents is an important part of bibliometric research, which is currently in the stage of exploration and development. Theoretically, this study simultaneously explores three key factors, namely, policy instruments, their targets, and their implementers, and clarifies the relationship between them through co-word analysis and social network analysis.

Practically, this study makes pioneering use of the bibliometric method in policy study of China's drug reform. Overall, this research exploratorily identifies key targets, instruments, and implementers of reform policies as well as the reform approach within complicated policy texts; explains the intentions, measures, and tendencies of drug reform under China's new generation of healthcare reform launched in 2009; and clearly and objectively answers the "why" and "how" questions of China's reform of its sustainable drug supply.

This study chooses China's drug reform, which is unique and rich in content, as an object of study. Additionally, it introduces the experience of reform and the process of policy evolution. It also elaborates the complexity of the drug sustainable supply and the necessity of comprehensive reform policies. This research has the potential to provide a reference for researchers in healthcare systems and drug management, and for policy makers globally.

However, this study also has its limitations. Firstly, Chinese policy documents tend to use imperative sentences with omitted subjects, which causes difficulties in implementer recognition, resulting in some omissions. Secondly, this study only includes policy documents produced at the central level, so it is unable to explain the characteristics and differences in drug supply measures at the provincial or municipal level. We suggest that, in future, researchers use a language model to fill the missing subjects of policies, and further study policy diffusion and evaluation of China's drug reform.

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