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Evaluation of the Wind Power Industry Policy in China (2010–2021): A Quantitative Analysis Based on the PMC Index Model

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Abstract: Industrial development cannot be separated from policy guidance and support. Scientific evaluation and analysis of wind power industrial policies can promote the sustainable and healthy development of the industry, which has great significance to accelerate the green and low-carbon transformation of energy and achieve the double carbon target. In this paper, based on 66 wind power industrial policies from 2010 to 2021 in China, the policy texts were coded and classified into policy tools. By combining the text mining technology with the Policy Modeling Consistency (PMC) index model, 10 groups of evaluation index systems were established to evaluate the industrial policies quantitatively. The results show that the use of the three types of policy tools is unbalanced. Among them, environmental policy tools are used most frequently while supply and demand policy tools are relatively few. According to the PMC score, the overall situation of wind power industrial policy has certain scientific qualities. However, there are few policy texts for ordinary residents in terms of policy recipients, and there are shortcomings in technical support and talent construction. In addition, the three types of policy tools have certain limitations in different aspects. Based on the existing problems, we put forward suggestions for policy improvement.

Keywords: wind power; industrial policy evaluation; PMC index model; policy tools; text mining

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1. Introduction

Since the Industrial Revolution, the utilization of fossil energy such as coal, oil, and natural gas has improved production efficiency while the carbon dioxide produced by its combustion has also brought about environmental problems such as global warming, threatening the survival and development of human beings. The international community has reached a consensus on reducing carbon emissions and addressing climate change. In recent years, the number of economies that have issued carbon neutral goals has increased rapidly. At the 75th United Nations Summit, General Secretary Xi Jinping proposed achieving carbon peaks by 2030 and carbon emissions neutralization by 2060. To achieve these goals, the most important step is to promote the development of renewable energy and the transformation and upgrading of energy. Since the implementation of the *Renewable Energy Law* in 2006, China has issued a series of policies to promote the development of the renewable energy industry, which is developing rapidly. In 2021, the installed capacity of China's renewable energy power generation will exceed one billion kilowatts, and the installed capacity of wind power has ranked first in the world for 12 consecutive years. The installed capacity of wind power accounts for about 13% of the total installed power supply in the country, and the proportion of power generation accounts for about 7.5%. The role of wind power generation in the national power supply is becoming more and more important.

Wind energy is cheaper to use than other renewable energy sources such as solar [1], and it can develop faster when it receives policy support. Wind power has become one of the most widely used renewable energy sources [2]. Wind power gradually became a leader in the new energy industry. Although the wind energy industry has made great progress,

it still needs the government to adjust policy measures to overcome various challenges [3]. At present, there are a series of problems in the development of the wind power industry, such as an over-reliance on subsidies, the continuous expansion of the subsidy gap for new energy power generation [4], the difficulty in connecting wind power to the grid, and overcapacity [5]. There are serious bottlenecks in wind power technology [6], lacking key core technologies. The comprehensive capacity of wind power development is lower than the global average level [7]. Therefore, it is necessary to have a comprehensive evaluation and analysis of the wind power industry policy system by scientifically analyzing the use of different policy tools. Text mining is used to analyze the key directions of current industrial policies. At the same time, it is necessary to quantitatively evaluate and analyze various dimensions of policies, including policy timeliness, policy receptors, and function levels, and show its strengths and weaknesses at different levels through visual graphics.

Based on the wind power industry policies issued from 2010 to 2021, this paper evaluates the policies and provides theoretical support for the formulation, revision, and implementation of future policies for the wind power industry, intending to promote the healthy development of the wind power industry. The main contributions of this paper are as follows: (I) this study use text mining technology and the Policy Modeling Consistency (PMC) index model in combination, and, therefore, the evaluation method is more objective. Policy texts are divided into three types of policy tools: supply type, demand type, and environmental type. The PMC score is calculated to obtain the PMC index of the three types of policy instruments; (II) it studies the entire wind power industry policy system instead of a single industry policy. Hence, the research results are more accurate and objective and have more practical value; (III) while drawing the PMC surface map of the policy system, it also draws its radar chart, which can more clearly show the concave degree of the indicators of each policy, and it derives the scores of various policy dimensions more clearly; (IV) this research constructs a comprehensive policy evaluation system for the wind power industry. Quantitative analysis is used to evaluate policies, which reduces the subjectivity of the evaluation. The method used in this paper is not only suitable for renewable energy but also can be extended to any field of public policy research.

The remainder of the paper proceeds as follows. Section 2 is a review and summary of the previous literature. Section 3 is the source of the policy samples and the analysis of policy instruments. Section 4 is data calculation. Section 5 analyzes the results of the experiment. Section 6 is the conclusions and policy recommendations of this paper.

2. Literature Review

Policy evaluation is critical to understanding the goals of policies and the impact of policies on practice [8]. Scientists and policymakers have also recognized the need to evaluate policies [9]. Through policy evaluation, policymakers can find existing problems and draw lessons from experience, driving improvements in future policy formulation [10]. Text mining technology is employed to process unstructured text data into a structured format [11]. In the era of big data, text mining technology provides a new tool for policy evaluation.

With the rapid development of the wind power industry, there are many related research papers on the wind power industry policy, which mainly focus on the following two aspects.

First is the research on the wind power industry policies of developed foreign countries, its inspiration for China, and the research on the development status of the wind power industry policies. Sadur et al. [12] discussed the successful energy policies of several countries and found that tax exemptions, subsidies, and legislation, among others, have a significant effect on the development of the wind energy industry. Hou et al. [13] analyzed the impact of renewable energy product trading by the European Union (EU) countries on exports and pointed out that the EU's experience has positive reference significance for China in formulating support policies. Zheng et al. [14] took policy tools and the industrial chain as the starting point and conducted a comparative study on the promotion policies

of offshore wind power technology in China, the United States, the United Kingdom, and Germany. Yuan and Xi [15] reviewed and analyzed China's wind power industry policies from 1986 to 2017. They summarized the policy objectives, main measures, and trends of the wind power industry policies that discussed existing problems, and they put forward relevant suggestions. Zhang et al. [16] conducted a comparative analysis of the wind abandonment policies in China, India, the US, and Germany from a two-dimensional policy tool-industry chain perspective. They point out that China should strengthen the research and development of grid-connected technology and strengthen the supervision of enterprises.

The second aspect is the analysis and research on the implementation effect and performance of specific policies and measures for wind power. It mainly includes the research on the subsidy policy of the wind power industry, and the research on the feed-in tariff subsidy policy is also prevalent. Huang [17] used the panel data method to empirically analyze the specific performance of the wind power industry subsidy policy and found that the electricity price subsidy policy had a relatively small impact on the wind power industry. Zhang et al. [18] studied the effectiveness of the wind power on-grid tariff policies at the national level and discussed the important factors affecting wind development at the regional level. Li et al. [19] studied the relationship between subsidy policies and the innovation efficiency of the wind power industry, pointing out that the innovation efficiency of the wind power industry is low and that there is a U-shaped relationship between government subsidies and innovation efficiency. Liu et al. [20] studied the impact of the cancellation of subsidy policies on the wind power industry using the method of difference in difference. They pointed out that the government should timely adjust subsidy policies according to the industrial development status. Yue et al. [21] established an evolutionary game model between the government and offshore wind power enterprises and pointed out that the government's cancellation of the subsidy policy is an inevitable choice. Zhao et al. [22] analyzed the regional differences and industrial effects of the wind power on-grid tariff policies.

Research on wind power innovation policy is presented. Wang et al. [23] studied the impact and mechanism of the wind power industry policy on enterprise innovation performance. Jiang et al. [24] explored the impact of innovation policies on the innovative efficiency of the wind power industry, pointing out that innovation policies are an important factor in improving the innovation efficiency. Lin et al. [25] studied the influence of wind power policy on technological innovation and pointed out that demand-pulled policy has a significant promoting effect on technological innovation.

Other aspects of research are presented. Peng et al. [26] pointed out the problems existing in the fiscal and taxation policies of China's wind power industry and put forth relevant suggestions by comparing the fiscal and taxation policies of the United States. Liu et al. [3] empirically analyzed the effectiveness of different wind power policies from different perspectives, such as energy law and market reform. C et al. [27] used a contagion test to study the impact of wind power industrial policies on other industries and found that the financial industry was the most effected.

To summarize, although there are many studies on the wind power industry policy, many of them are qualitative studies that undertake summarization. At present, there is a paucity of research on the comprehensive system of industrial policy. The development of industry cannot rely on a single policy. It needs coordinated development and joint advancement in all aspects [28]. PMC index model improves the rationality and scientific depth of policy evaluation and reduces subjectivity; this method is the need of the hour to combat difficulties in industrial policy evaluation [29]. The model is also robust in that it examines the advantages and disadvantages of policies in multiple dimensions and multiple aspects, and it reduces the subjectivity of the evaluation to the greatest extent [30]. Therefore, this study uses the method of text mining, a policy evaluation model, and a PMC index model. It analyzes the content of policy texts and uses policy tools to quantitatively score three types of policy tools: supply type, demand type, and environmental type.

This study evaluates them scientifically and reasonably. Employing various policy tools in the wind power industry policy will help promote policy rationalization and overall sectoral development.

3. Policy Sample and Analysis of Policy Tools

3.1. Policy Sample

The selection of policy texts is driven by the magic weapon database of Peking University, supplemented with various government portal websites. Using "renewable energy," "wind power," and "wind energy" as keywords, the magic weapon database of Peking University was searched, and policies above the ministerial and commission level were retrieved, including notices, opinions, and measures. To accurately reflect the real situation and timeliness of China's policy texts in recent years, the policy texts released between 2010 to 2021 were selected. Simultaneously, due to a large number of collected policy texts and their complicated content, the policy texts were filtered. This also ensured that the policy texts were representative and comprehensive. The selection was undertaken as per the following criteria. (1) Select policies were retrieved at the national level, mainly policy texts issued by the State Council and its ministries, commissions, and bureaus. (2) Representative documents closely related to the wind power industry were gathered. (3) The expired policy text was deleted. A total of 66 industrial policies were selected (see Table 1).

Table 1. Examples of Policy Texts.

Code	Policy Name	Release Date
1	Notice of the Ministry of Finance on printing and distributing regulations on Additional Accounting Treatment of Renewable Energy Price	27 December 2012
2	Notice of the Ministry of Finance, the National Development and Reform Commission on raising the collection standards for renewable Energy Development Funds and other related issues	1 May 2016
...	...	...
65	Notice of the General Office of the Ministry of Housing and Urban-Rural Development on soliciting technical proposals for promotion, application, restriction, and prohibition in building energy conservation, green building, and renewable energy building application fields	27 May 2017
66	Notice of the Comprehensive Department of the National Energy Administration on the demonstration of Wind Power parity	17 May 2017

3.2. Classification of Policy Tools

Policy tools are specific measures to achieve policy goals. The most traditional classification of policy tools was proposed by Rothwell and Zegveld [31], who divided policy tools into three categories—supply-type, environmental-type, and demand-type. This classification method has been favored and generally accepted by scholars. This paper draws on the division method of Zhang et al. [32], in which the supply-oriented policy tools promote the development of the wind power industry from the aspects of financial support, personnel training, and public services, and the demand-oriented policy tools promote the development of the wind power industry from the aspects of government procurement and demonstration project construction. The environmental policy tool involves the government creating an ideal environment for the development of the wind power industry through target planning, institutional norms, and other measures and promotes the development of the wind power industry in an indirect way [33].

Since policies might involve multiple policy tools, this study codes the policy tools using the format "1-G/X/H-1." The first number represents the policy number, the letter represents the policy tool type (i.e., "G" represents supply-type policy tools, "X" represents demand-type policy tools, and "H" represents environment-type policy tools), and the second number represents the code of the policy tools. To ensure the objectivity of coding, the coding was completed by three graduate students and one professor, and the consistency

reached 85%. Table 2 lists details of the text coding of policy tools and the division of policy tools.

Table 2. Examples of policy text coding and policy tool division.

Code	Policy Tool	Policy Sub Tool	Policy Text Analysis Unit
1-H-1	Environmental-type	Legal regulation	Regulations on the accounting treatment of renewable energy electricity price
2-H-1	Environmental-type	Financial support	Raise the fund collection standard of all electricity sold except for household and agricultural production in each province
2-H-2	Environmental-type	Legal regulation	Strengthen the collection and management of funds such as power plants owned by enterprises
		...	
64-X-1	Demand-type	Government procurement	Solicit technical proposals on promotion, application, restriction, and prohibition of renewable energy building applications
65-X-1	Demand-type	Demonstration project construction	Wind power parity online demonstration project
66-X-1	Demand-type	Demonstration project construction	Wind power parity online demonstration project

The statistics on the use of the three policy tools are shown in Table 3. From Table 3, it can be seen that the most widely used of the three policy tools supported by the wind power industry is the environmental policy tool, accounting for 61%, followed by the supply-type policy tool, accounting for 28%, and demand-based policy tools are the least used, accounting for only 11%. On the whole, there is a certain degree of imbalance in the use of the three policy tools, and the differences are more obvious in the specific sub-tools they employ. The top three sub-policy tools in terms of frequency of use are regulations, target planning, and financial support on the supply side.

Table 3. Usage of three policy tools.

Policy Tool	Policy Sub Tool	Code	Total
Supply-type	Financial support	3-G-1, 4-G-1, 5-G-1, 9-G-1, 17-G-2, 25-G-1, 32-H-1, 50-G-1, 50-G-2, 55-H-1, 56-G-1, 57-G-1, 58-G-1, 59-G-1	14
	Personnel training	44-G-4	1
	Public service	16-G-1, 19-G-1, 44-G-3, 61-G-1	4
	Infrastructure construction	10-G-1,	1
	Technical support	16-G-2, 17-G-1, 35-G-1, 44-G-1 44-G-2, 51-G-1, 62-G-1	7
Demand-type	Government procurement	8-X-1, 31-H-1, 44-X-1, 50-X-2, 64-X-1	5
	Restraint of trade	——	0
	Construction of demonstration	22-X-1, 50-X-1, 60-X-1, 63-X-1, 65-X-1, 66-X-1	6
Environmental-type	Financial support	2-H-1, 5-H-1, 6-H-1, 16-H-2, 23-H-1, 30-H-1, 50-H-1, 50-H-3	8
	Goal programming	7-H-1, 11-H-1, 12-H-1, 13-H-1, 15-H-1, 17-H-1, 18-H-1, 20-H-1, 24-H-1, 26-H-1, 33-H-1, 40-H-1, 46-H-1, 48-H-1, 51-H-1, 52-H-1, 53-H-1, 54-H-1	18
	Legal regulation	1-H-1, 2-H-2, 2-H-3, 3-H-1, 5-H-2 11-H-2, 12-H-1, 13-H-2, 14-H-1, 16-H-1, 17-H-2, 17-H-3, 17-H-4, 21-H-1, 27-H-1, 28-H-1, 29-H-1, 34-H-1, 36-H-1, 37-H-1, 38-H-1, 39-H-1, 41-H-1, 42-H-1, 43-H-1, 44-H-1, 44-H-2, 44-H-3, 45-H-1, 47-H-1, 49-H-1, 50-H-2, 50-H-4, 51-H-2	34
	Property protection	——	0

Figure 1 is a double-ring diagram of the proportion of policy tools and sub-tools. In comparison, environmental support tools are used most frequently. Regulatory control,

target planning, and financial support are used to indirectly promote the development of the wind power industry. Supply-type support tools are mainly used through financial support and technical support and are used to promote industrial development. Public service infrastructure construction is less used. Demand-based policy tools are used the least, mainly through the construction of demonstration zones and government procurement to stimulate industrial development and trade control is not involved.

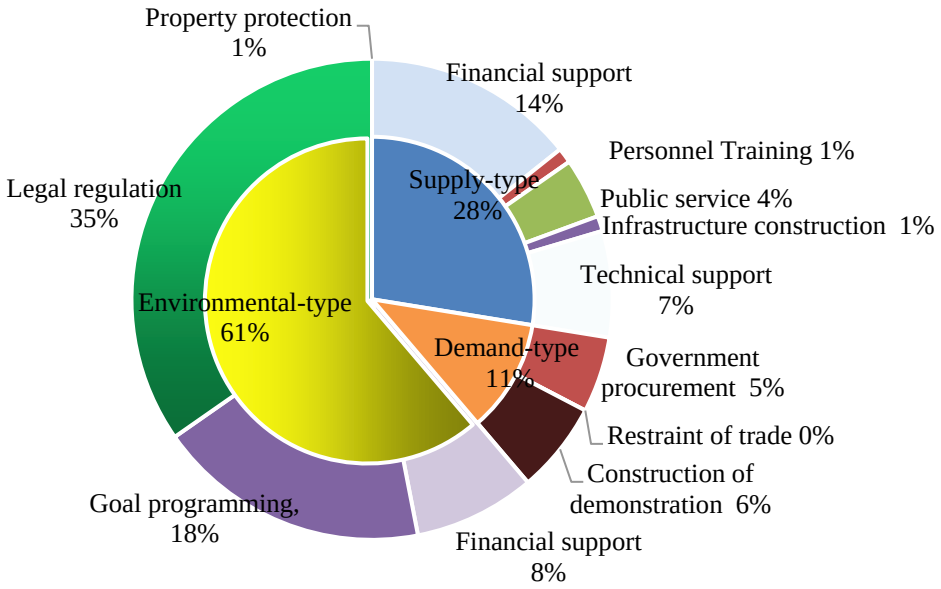


Figure 1. Double-ring diagram of the proportion of policy tools and sub-tools.

3.3. Policy Text Mining and Analyzing

The 66 wind power policy texts were imported into Rostcm6 software for text mining. Text segmentation was performed through the software, and word frequency statistics were performed on the segmented documents. The frequency statistics of high-frequency words provided a reference for the setting of variables related to the PMC index.

Data processing includes extracting high-frequency words, filtering meaningless words, extracting characteristic words, constructing co-occurrence matrices, and constructing a semantic network map of the wind power industry policy (see Figure 2). The semantic network map connects the keywords in the wind power industry policy in the form of a network diagram, which is more intuitive and reflects the connection between each keyword. In addition, the UCINET tool is used to analyze the centrality of the wind power industry development policy. Point-degree centrality measures the number of connections between a node and other nodes in the network. The larger the degree, the wider the influence range of the node and the core position in the network [34]. Table 4 shows the points of some nodes in the wind power industry policy.

Through the network map and centrality analysis, three trends can be seen. (1) Keywords such as "wind power," "country," "renewable energy," "project," "construction," "energy," and "development" have the highest centrality, indicating that the country attaches great importance to the development of the renewable energy industry. It also indicates that the wind power industry focuses on the construction of wind power projects, including project competition configuration, power grid transmission project construction, project grid connection, and consumption. (2) Key words such as "grid," "enterprise," "power generation," "energy bureau," and "electricity" have a high degree of centrality, which indicates that the focus of the wind power industry development is on power grids and related enterprises. The National Energy Administration plays an important role in the development of the wind power industry. (3) Words such as "management," "notice," "planning," "development," and "reform" indicate that the current main policy text type for the wind power industry is notification to promote industrial development.

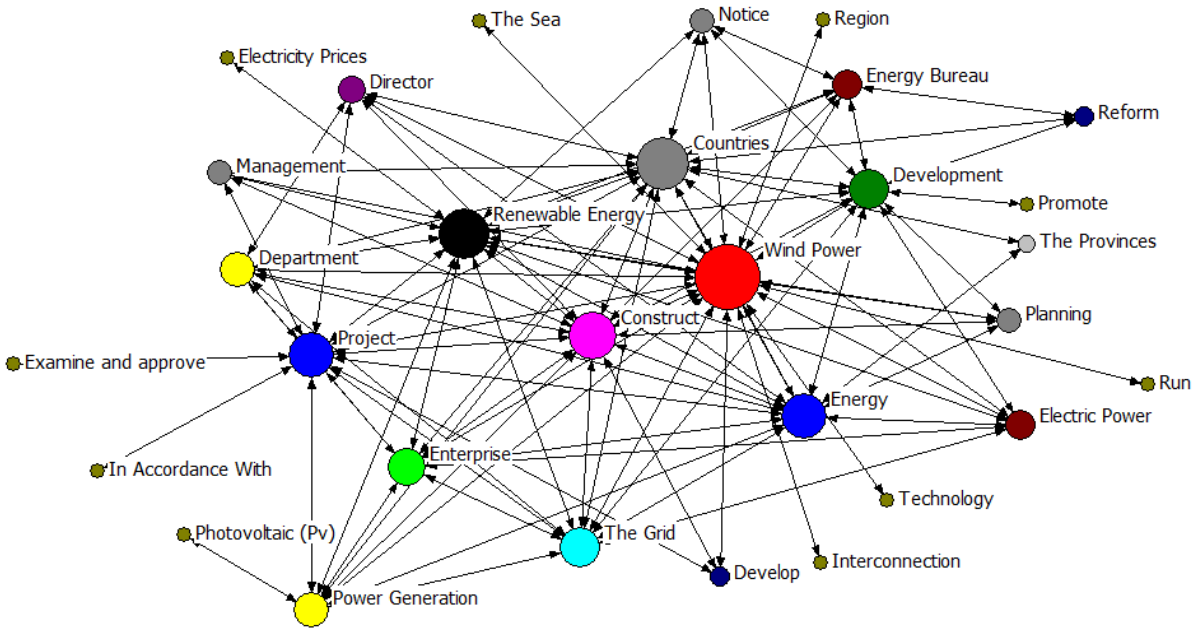


Figure 2. Semantic network diagram of wind power industry policy.

Table 4. The centrality of the key words of the wind power industry policy.

Serial Number	Keyword	Degree Centrality	Serial Number	Keywords	Degree Centrality
1	Wind power	4074	16	Notice	693
2	Countries	3299	17	Planning	664
3	Project	2873	18	Develop	588
4	Renewable energy	2739	19	Reform	504
5	Construction	2649	20	The provinces	248
6	Energy	2427	21	Run	162
7	Development	2174	22	Technology	149
8	Grid	1765	23	Interconnection	143
9	Enterprise	1717	24	Photovoltaic (pv)	137
10	Department	1573	25	Examine and approve	137
11	Power generation	1457	26	The sea	136
12	Energy bureau	1289	27	Region	134
13	Director	1076	28	Electricity prices	133
14	Electricity	1030	29	According to	122
15	Management	856	30	Promote	122

3.4. Variable Classification and Parameter Identification

Combined with the relevant high-frequency word statistics and keyword centrality analysis of the wind power industry policy text mining, the relevant indicators of the PMC index model of the wind power industry policy are set up. The ten first-level policy evaluation indicators and the parameter identification table are shown in Table 5 [33,35,36]. Simultaneously, the parameters are identified with binary standards for each variable according to the PMC model.

3.5. Create a Multi-Input–Output Table

The multi-input–output table quantifies a single variable from multiple dimensions and establishes a data analysis framework. In the multi-input–output table, we assign values to 42 secondary variables under 10 primary variables, and each variable occupies the same weight. This paper establishes a multi-input–output table based on the specific conditions of each variable of the wind power industry policy (see Table 6).

Table 5. Policy indicators for the wind power industry.

Primary Variable		Secondary Variable		Primary Variable		Secondary Variable	
X1	Policy Nature	X11	Prediction	X6	Policy measures	X61	Investment subsidies
		X12	Supervision			X62	Tax incentives
		X13	Suggestion			X63	Legal norms
		X14	Description			X64	Goal programming
		X15	Guidance			X65	Technical support
X2	Policy timeliness	X21	Long-term			X66	Cultivation of talents
		X22	Mid-term			X67	Other
		X23	Short-term	X7	Policy field	X71	Economic
X3	Publishing department	X31	National Development and Reform Commission			X72	Technology
		X32	The Ministry of Finance			X73	The Environment
		X33	Ministry of Housing and Urban-Rural Development			X74	Social
		X34	National Energy Administration			X75	Political
		X35	Other			X76	Other
X4	Policy receptor	X41	Enterprise	X8	Role level	X81	Function level
		X42	Government agencies			X82	Country
		X43	Residents			X83	Area
X5	Content	X51	Grid connected power generation			X84	Enterprise innovation
		X52	Liability for consumption	X9	Policy Perspective	X91	Macro
		X53	Feed in tariff/grid charge				
		X54	Construction of demonstration area			X92	Micro
		X55	Development fund				
		X56	Technical standard	X10	Policy Disclosure	–	
		X57	Other				

Table 6. Multiple inputs and outputs.

X1	X2
X11, X12, 1, X14, X15	X21, X22, X23
X3	**X4**
X31, X32, X33, X34, X35	X41, X42, X43
X5	**X6**
X51, X52, X53, X54, X55, X56, X57	X61, X62, X63, X64, X65, X66, X67
X7	**X8**
X71, X72, X73, X74, X75, X76	X81, X82, X83, X84
X9	**X10**
X91, X92	X10

4. Data Calculation and Analysis

4.1. Calculation of PMC Index

The PMC Index model was proposed by Ruiz Estrada et al. [37] based on the Omnia Mobilis hypothesis. The PMC model highlights that the policy model should consider a wide range of factors. Researchers can study the level of policy coherence and the strengths and weaknesses of policies across dimensions. The PMC model can accurately calculate the results of the policy evaluation and can visualize the scoring status of the policy in each index system through the combination of surface charts, radar charts, and other graphs [38]. The PMC index model has three advantages. (I) The variable parameters are considered comprehensively, enhancing overall policy effectiveness and consistency. (II) Combined with text mining technology, the subjectivity of evaluation is significantly reduced, and the scientific nature of the evaluation is improved greatly [30]. (III) The policy is examined from multiple angles and aspects, reflecting the advantages and disadvantages of the policy. The PMC index model is widely used in science and technology, innovation, medicine, and other fields. Related scholars have conducted detailed research, providing new methods for the evaluation and analysis of national policies in various fields, and they have made significant progress in policy research.

The calculation of the PMC index requires four steps as shown in Figure 3.

$$X \sim N[0,1] \quad (1)$$

$$X = \{XR[0 \sim 1]\} \tag{2}$$

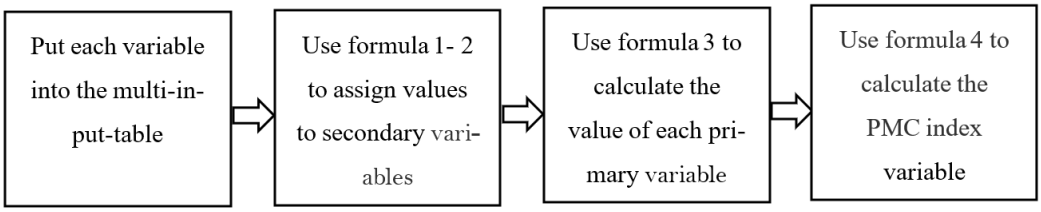


Figure 3. PMC index calculation process.

X obeys (0, 1) distribution. When each sample policy conforms to the secondary variable under each primary variable, it is represented by 1; when it does not conform to the secondary variable under each primary variable, it is represented by 0.

$$Xt\left(\sum_{j=1}^{n}\frac{Xtj}{T(Xtj)}\right) \tag{3}$$

t = 1, 2, 3, 4, 5, 6, 7, 8, 9 . . . where t is the primary variable and j is the secondary variable.

$$PMC = \begin{bmatrix} X1\left(\sum_{j=1}^{5}\frac{X1j}{5}\right) + X2\left(\sum_{j=1}^{3}\frac{X2j}{3}\right) + X3\left(\sum_{j=1}^{5}\frac{X3j}{5}\right) + \\ X4\left(\sum_{j=1}^{3}\frac{X4j}{3}\right) + X5\left(\sum_{j=1}^{7}\frac{X5j}{7}\right) + X6\left(\sum_{j=1}^{7}\frac{X6j}{7}\right) + \\ X7\left(\sum_{j=1}^{6}\frac{X7j}{6}\right) + X8\left(\sum_{j=1}^{4}\frac{X8j}{4}\right) + X9\left(\sum_{j=1}^{2}\frac{X9j}{2}\right) \end{bmatrix} \tag{4}$$

According to Formula (4), the PMC index of the three types of policy tools is calculated, and the grades of the three types of policy tools are obtained according to the policy grading table. The rating standards are shown in Table 7. To ensure the objectivity of the scoring, 20 experts on wind power industry policy were invited to form a scoring group. The PMC scores and ranking results of the three types of policy tools are shown in Table 8.

Table 7. PMC Index Policy Grading.

PMC Score	0–4.99	5–6.99	7–8.99	9–10
Evaluation level	Accepted	Good	Excellent	Perfect

Table 8. PMC index and grade division table of policy system.

Primary Variable	Supply-Type (G)	Demand-Type (X)	Environmental-Type (H)	Mean
X1 Policy Nature	0.80	0.40	1.00	0.73
X2 Policy timeliness	0.67	0.67	1.00	0.78
X3 Publishing department	0.80	0.60	0.80	0.73
X4 Policy receptor	0.67	0.67	0.67	0.67
X5 Content	0.71	0.57	0.86	0.71
X6 Policy measures	0.71	0.43	0.71	0.62
X7 Policy field	0.50	0.50	1.00	0.67
X8 role level	1.00	0.75	0.75	0.83
X9 Policy perspective	1.00	1.00	1.00	1.00
PMC score	6.86	5.59	7.79	6.75
Rank	2	3	1	–
Grade	Good	Good	Excellent	–

4.2. PMC Surface Construction

The PMC surface is constructed by the PMC index obtained above, and the PMC surface can visualize the evaluation results of the policy tools in various dimensions. There are ten primary variables in this study, but the primary variable X10 has no secondary variables, and each policy system has a score of 1 in X10. Therefore, considering the balance and symmetry of the PMC surface, 1 is removed when constructing the PMC surface level variable X10. The PMC surface is composed of a 3×3 matrix, and the construction method is as follows:

$$PMC\ surface = \begin{pmatrix} X1 & X2 & X3 \\ X4 & X5 & X6 \\ X7 & X8 & X9 \end{pmatrix} \quad (5)$$

Substituting the PMC index scores of various policies into the above matrix, the PMC matrix (Formula (5) is obtained. According to the PMC matrix (5), the PMC surface map is drawn (see Figure 4). The supply-type represents supply-oriented policy tools, demand-type represents demand-oriented policy tools, and environment-type represents environment-oriented policy tools.

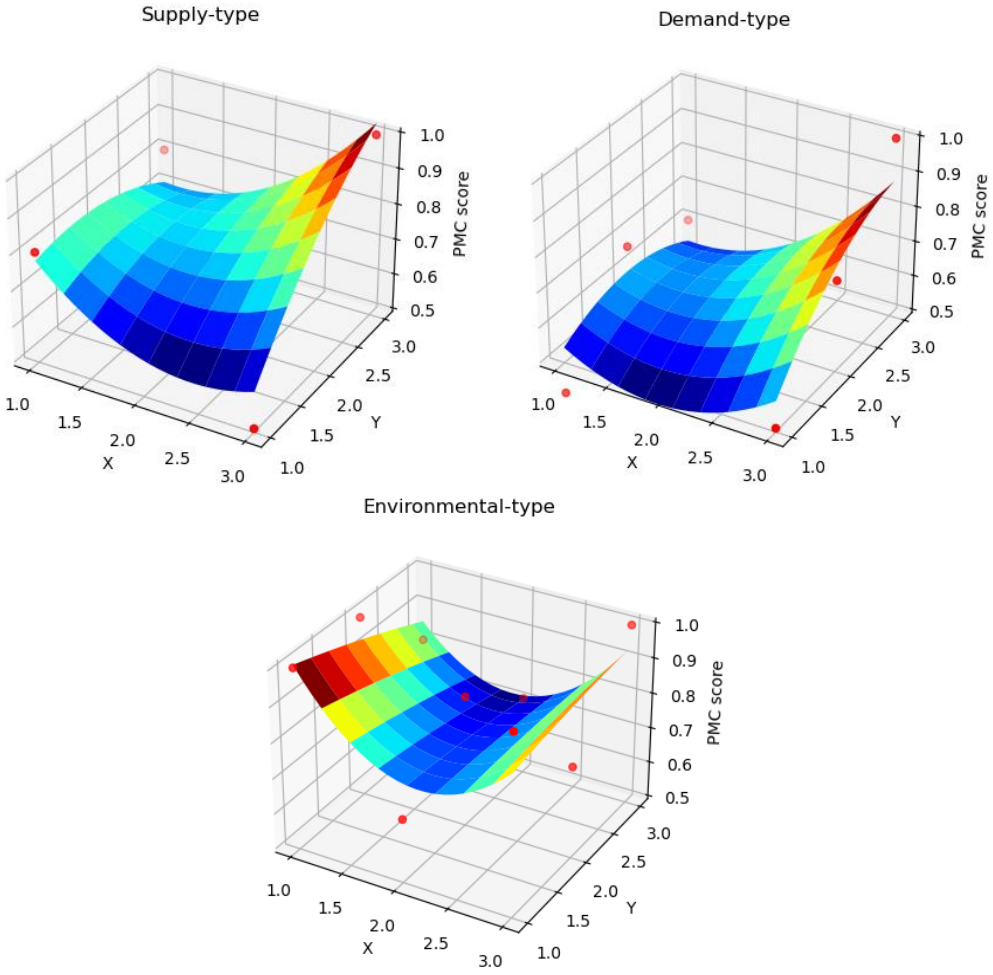


Figure 4. PMC surface map of three types of policy tools for the wind power industry.

5. Result Analysis

From the results of the above PMC index quantification, it can be seen that the evaluation results of the three types of policy tools are all robust, indicating that the current overall development trend of wind power policy is positive, and China's wind power industry policy has certain scientific, rational, and feasible characteristics.

The mean value of the policy nature (X1) of the three types of policy tools is 0.73, indicating that the wind power industry policy plays a more comprehensive role in advice, supervision, and guidance; the mean value of the policy timeliness (X2) is 0.78, indicating that various policy tools in the wind power industry are being used. When considering the combination of long-term, medium-term, and short-term goals, it is conducive to the realization of long-term goals; the average value of the publishing department (X3) is 0.73, indicating that the wind power industry policy departments work together to formulate relevant policies and promote the overall development of the industry policy. The mean value of the receptor (X4) is 0.67, indicating that there are certain limitations in the policy receptor. The mean value of the involved content (X5) is 0.71, indicating that the wind power industry policy can implement industrial policies from multiple angles and in an all-around way. The mean value of policy measures (X6) is 0.62, indicating that the wind power industry policy has defects in policy measures and the use of measures is relatively simple. The average value of the policy field (X7) is 0.67, indicating that wind power industry policy is not comprehensive enough and needs to be further improved. The average value of the role level (X8) is 0.83; it shows that the development of the wind power industry policy considers the development of different levels such as countries, regions, and enterprises. The policy perspective (X9) shows that the wind power industry policy grasps the macro and micro levels more accurately.

The PMC index of the supply-oriented policy tools has a score of 6.86, which is good. A score of 1 on the perspective (X9) indicates that supply-oriented policy tools consider all levels of the country, region, enterprise, and industry, as well as macro and micro aspects. Low scores on policy timeliness (X2), policy receptors (X4), and policy areas (X7) indicate that the combination of long-term, medium-term, and short-term policies is ignored when using supply-type policy tools, and the scope of action is narrow.

The PMC index score of demand-based policy tools is 5.59, which is adequate, but its score is the lowest among the three types of policy tools. In terms of the nature of the policy, there is a lack of policy texts in terms of forecasting and supervision, and content (X5) about grid-connected power generation and technical standards is lacking. Policy measures (X6) are less involved in talent training.

The PMC index score of the environmental policy tool is 7.79, which is excellent. It has the highest score among the three types of policies, and its scores are all higher than the average level, indicating that environmental policies perform comprehensively in all aspects. The score of the policy receptor (X4) is 0.67, which has certain limitations. The policy measures (X6) involve less tax incentives and personnel training.

Figure 5 shows the radar chart of the three types of policy tools, which can clearly reflect the strengths and weaknesses of the wind power industry policy development process and serve as a reference for the revision and improvement of industrial policies in the future. As displayed in the radar chart, the main reasons for the gap in the scores of policy tools are the nature of policy (X1), the time limit of policy (X2), and the field of policy (X7). Environmental policy tools have obvious advantages in these aspects. Demand-based tools should be supplemented in these areas. The three types of policy tools have deficiencies in policy receptors (X4) and policy measures (X6). The government should expand the groups of wind power industry policies, enrich the content of industrial measures, and promote industrial development in all aspects.

From the PMC scores and the number of policy instruments used, the PMC index scores from high to low are environment-type, supply-type, and demand-type, which is consistent with the above results about the number of policy tools, which further indicates that there is a relationship between the effect of the policy instruments used and the number of policies. Based on the above analysis for different policy tools, the following optimization paths are proposed. Supply-type policies X2-X4-X7, demand-type X1-X2-X3-X5-X6-X7-X8, and environmental-type X4-X6.

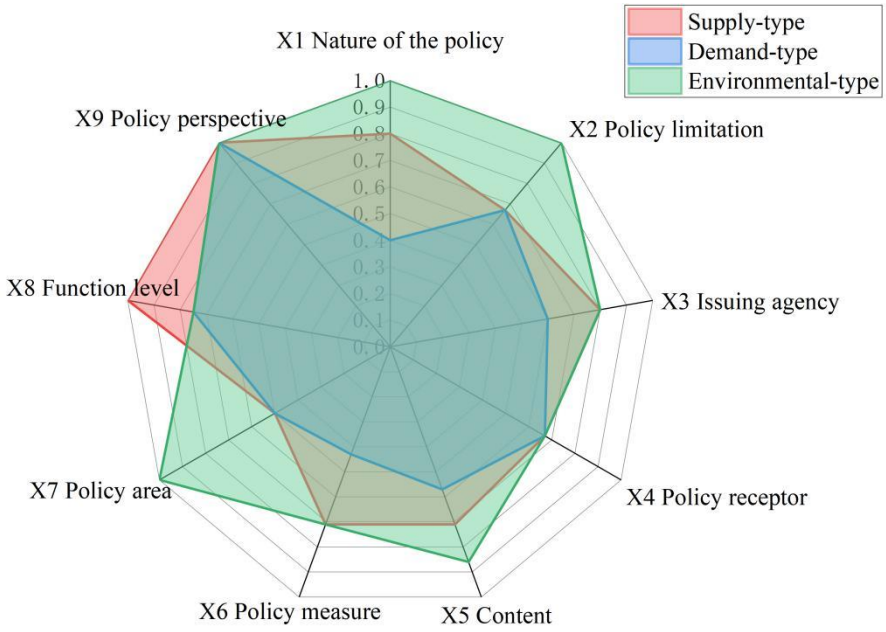


Figure 5. Radar chart of PMC index of three types of policy tools for the wind power industry.

6. Conclusions & Discussion

By analyzing the content of the wind power industry policy texts using policy tools and the PMC index model, this study quantitatively evaluates and analyzes the wind power industry policies and draws three conclusions. (I) The proportion of the use of three types of policy tools is not coordinated, and environmental policies are used the most. Supply-oriented and demand-oriented policies are rarely used, and the push and pull forces are obviously insufficient, which are not conducive to the balanced development of the industry. (II) The overall situation of China's wind power industry policy is good, and the wind power industry policy lacks relevant policies and policies for ordinary residents in terms of policy receptors. The measures are insufficient in technical support and talent construction. (III) The supply-oriented policy is robust, but there are limitations in policy timeliness and policy fields. Demand-based policies are adequate but have certain deficiencies in terms of policy nature, involved content, and policy measures. The environmental policy is at an excellent level, indicating that the environmental policy is more comprehensive in its formulation, and it can be optimized in terms of policy receptors and policy measures.

In summary, policy recommendations are made as follows:

(I) Strengthen the frequency of the use of supply-oriented and demand-oriented policy tools, highlight the pull and thrust of wind power industry policies, and promote industrial development in terms of funds, talent, and technology so that the industry develops harmoniously at all levels.

(II) Broaden the audience of the wind power industry policy, and pay increased attention to the importance of ordinary residents to the development of the industry. Encourage ordinary people to use renewable energy products, develop products that people need, and ensure the effectiveness of publicity and guidance.

(III) Increase support for wind power industry technology and talents. Technology is the core of industrial development. Special funds can be set up to encourage independent research and the development of enterprises to improve the technical level of the industry. The government can also take the lead in promoting the technological progress of the industry through measures such as technical proposals. Pay attention to the talent development in the industry as people are the foundation of industrial development. Preferential policies, like housing subsidies, could be used to attract high-end talent. Simultaneously, it is necessary to increase human resources training, constantly update the knowledge and knowledge structure of technical personnel, and improve the quality of personnel.

(IV) Broaden the dimension of policy tool use. Supply-oriented policy tools attach importance to the combined use of long-term, medium-term, and short-term goals, and the formulation of short-term and medium-term goals should be based on long-term goals and promote the realization of long-term goals. Expanding the role of industrial policies requires developments in various fields such as economy, society, and politics. The wind power industry should be developed from multiple perspectives, focusing on the coordinated development of various fields. Demand-based policy tools should increase forecasting, supervision, and other policies to guide industrial development. In addition, attention should be paid to grid-connected power generation and the formulation and implementation of technical standards, and the construction of industrial demonstration zones should be strengthened to lead the development of various places by demonstration.

This paper has some limitations in terms of policies and the number of texts, which are selected only for the national-level policies and lack provincial- and municipal-level policies. In the future, research can be carried out based on policies at the provincial-level, and text mining can be in-depth by using crawler technology, grounded theory coding, and other technologies so that policy evaluation can be more scientific. In addition, future research can be conducted on the effect of policy implementation.

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References

1. Alvarez, I.; Lorenzo, M.N. Changes in offshore wind power potential over the Mediterranean Sea using CORDEX projections. *Reg. Environ. Chang.* **2019**, *19*, 79–88. [CrossRef]
2. Shen, X.C.; Lyu, S.J. Wind power development, government regulation structure, and vested interest groups: Analysis based on panel data of Province of China. *Energy Policy* **2019**, *128*, 487–494. [CrossRef]
3. Liu, T.T.; Chen, Z.; Xu, J.P. Empirical evidence based effectiveness assessment of policy regimes for wind power development in China. *Renew. Sustain. Energy Rev.* **2022**, *164*, 112535. [CrossRef]
4. Zhang, Y.; Liu, J.; Zhang, J.; Wang, C. Analysis on the development of new energy in Postsubsidy period in China. *Electr. Power* **2019**, *4*, 1–7.
5. Zhang, Y. Vertical structure of industrial chain, Government regulation and predicament of wind power industry. *Ecol. Econ.* **2019**, *5*, 88–93.
6. Jiang, Z.H.; Liu, Z.Y. Policies and exploitative and exploratory innovations of the wind power industry in China: The role of technological path dependence. *Technol. Forecast. Soc. Chang.* **2022**, *177*, 121519. [CrossRef]
7. Zhang, S.; Wei, J.; Chen, X.; Zhao, Y. China in global wind power development: Role, status and impact. *Renew. Sustain. Energy Rev.* **2020**, *127*, 109881. [CrossRef]
8. Christie, C.A.; Lemire, S.T. Why Evaluation Theory should be used to inform evaluation policy. *Am. J. Eval.* **2019**, *4*, 490–508. [CrossRef]
9. Miljand, M. Using systematic review methods to evaluate environmental public policy: Methodological challenges and potential usefulness. *Environ. Sci. Policy* **2020**, *105*, 47–55. [CrossRef]
10. Dai, S.; Zhang, W.; Zong, J.; Wang, Y.; Wang, G. How effective is the green development policy of China's Yangtze river economic belt? A quantitative evaluation based on the PMC Index model. *Int. J. Environ. Res. Public Health* **2021**, *18*, 7676. [CrossRef]
11. Kayser, V.; Blind, K. Extending the knowledge base of foresight: The contribution of text mining. *Technol. Forecast. Soc. Chang.* **2017**, *116*, 208–215. [CrossRef]
12. Saidur, R.; Islam, M.R.; Rahim, N.A.; Solangi, K.H. A review on global wind energy policy. *Renew. Sustain. Energy Rev.* **2010**, *7*, 1744–1762. [CrossRef]
13. Hou, W.; Li, S.; Liu, X. Analysis of the impact of industrial support policies and market demand of importing countries on the export of Renewable energy products in EU. *J. China Univ. Geosci. (Soc. Sci. Ed.)* **2019**, *4*, 103–114.

14. Zheng, Y.; Zhang, M. Offshore wind power technology policy: An international comparative study based on X-Y dimensions. *Forum Sci. Technol. China* **2017**, *10*, 177–185.
15. Yuan, L.; Xi, J. Review on China's wind power policy (1986–2017). *Environ. Sci. Pollut. Res.* **2019**, *25*, 25387–25398. [CrossRef]
16. Zhang, H.; Yang, J.; Ren, X.; Wu, Q.; Zhou, D.; Elahi, E. How to accommodate curtailed wind power: A comparative analysis between the US, Germany, India and China. *Energy Strategy Rev.* **2020**, *32*, 100538. [CrossRef]
17. Huang, J. Empirical analysis of the influence of subsidy policy on wind power industry development. *Ecol. Econ.* **2018**, *5*, 115–120.
18. Zhang, R.; Ni, M.; Shen, G.Q.P.; Wong, J.K.W. An analysis on the effectiveness and determinants of the wind power Feed-in-Tariff policy at China's national-level and regional-grid-level. *Sustain. Energy Technol. Assess.* **2019**, *34*, 87–96. [CrossRef]
19. Lin, B.Q.; Luan, R.R. Are government subsidies effective in improving innovation efficiency? Based on the research of China's wind power industry. *Sci. Total Environ.* **2020**, *710*, 136339. [CrossRef]
20. Liu, D.; Liu, Y.; Sun, K. Policy impact of cancellation of wind and photovoltaic subsidy on power generation companies in China. *Renew. Energy* **2021**, *177*, 134–147. [CrossRef]
21. Yue, Q.; Shao, W.; Bi, X.; Hu, H. Evolutionary game analysis of Offshore wind power planning and subsidy policy in China. *Trans. Oceanol. Limnol.* **2021**, *6*, 66–73.
22. Zhao, Y.; Li, Q. Regional differences and industrial effects of wind power on-grid pricing policies. *Resour. Sci.* **2021**, *1*, 12–22.
23. Wang, X.; Zhou, H. Analysis of the mechanism of industrial policy on innovation performance of wind power enterprises. *RD Manag.* **2018**, *2*, 33–45.
24. Jiang, Z.H.; Shi, J.R.; Liu, Z.Y.; Gong, L. Beyond bean counting: Is the policy effective for the innovation efficiency of wind power industry in China? *Res. Eval.* **2022**, *31*, 132–144. [CrossRef]
25. Lin, B.Q.; Chen, Y.F. Impacts of policies on innovation in wind power technologies in China. *Appl. Energy* **2019**, *247*, 682–691. [CrossRef]
26. Peng, Y.L.; Ren, J.J. Research on fiscal and Tax Policies to promote the development of Wind power in China. *Econ. Problems* **2018**, *8*, 28–31+83.
27. Hsiao, C.Y.-L.; Sheng, N.; Fu, S.; Wei, X. Evaluation of contagious effects of China's wind power industrial policies. *Energy Part B* **2022**, *238*, 121760.
28. Li, L.Y.; Ren, X.Q.; Yang, Y.; Zhang, P.; Chen, X. Analysis and recommendations for onshore wind power policies in China. *Renew. Sustain. Energy Rev.* **2018**, *82*, 156–167. [CrossRef]
29. Qin, H.; Xiao, H.; Wu, J.; Li, L. Quantitative evaluation of Regional Innovation policy in Xinjiang. *Forum Sci. Technol. China* **2021**, *10*, 50–61.
30. Cai, D.; Chai, Y.; Tian, Z. Quantitative evaluation of digital economy policy text in Jilin Province based on PMC index model. *Inf. Sci.* **2021**, *12*, 139–145.
31. Rothwell, R.; Zegveld, W. *Reindustrialization and Technology*; Longman: London, UK; M E Sharpe: Armonk, NY, USA, 1985.
32. Zhang, H.; Xu, Z.; Sun, C.; Elahi, E. Targeted poverty alleviation using photovoltaic power: Review of Chinese policies. *Energy Policy* **2018**, *120*, 550–558. [CrossRef]
33. Zhang, Y.; Zhou, Y. New energy vehicle subsidy policy tools mining and quantitative evaluation. *China Popul. Resour. Environ.* **2017**, *10*, 188–197.
34. Chen, F.; Wang, Z. Research on the influence of Ming Four Scholars based on social network analysis. *J. Nanjing Arts Inst. (Fine Arts Des.)* **2021**, *5*, 81–86.
35. Liu, J.; Li, F. Mining and quantitative evaluation of policy tools for Beijing-Tianjin-Hebei industrial coordination. *Stat. Decis.* **2021**, *20*, 76–80.
36. Zhang, Y.; Geng, Z. Quantitative evaluation of regional science and technology innovation policies in China: Based on PMC index model. *Sci. Technol. Manag. Res.* **2015**, *14*, 26–31.
37. Estrada, M.A.R. Policy modeling: Definition, classification and evaluation. *J. Policy Model.* **2011**, *4*, 523–536. [CrossRef]
38. Liu, J.; Mao, H. Evaluation of fire safety management policy based on PMC index model. *Fire Sci. Technol.* **2021**, *9*, 1405–1409.