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Quantitative Research on China's PV Industry Policy based on PMC-index Model

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Abstract: Photovoltaic industry is an important new energy industry, and photovoltaic industry policy is an important part of the photovoltaic industry. To analyze the structure and evolution of China's photovoltaic industrial policies and scientifically evaluate China's photovoltaic industrial policies, this paper analyzed the texts of China's photovoltaic industrial policies from 2007 to 2023. Firstly, the structure and evolution of PV industrial policies were analyzed based on the division of PV industrial instruments. Then, the PMC-index model was established to evaluate six national PV industrial policies. The results show that: in terms of policy structure and evolution, there is a gap in the proportion of various policy instruments, and the structure of photovoltaic industry policies has changed; In terms of policy evaluation, among the six national-level photovoltaic industry policies, one policy was assessed as excellent, four policies were assessed as acceptable, and one policy was assessed as poor. The quality of the six policies and the degree of response of the six policies to the photovoltaic industry are above an acceptable level. There are shortcomings in the policies, which are embodied in insufficient incentive measures, lack of coordination of policies in multiple periods, and the scope of policies needs to be further expanded. Based on the research of this paper, the government should pay attention to promoting the construction of photovoltaic projects, strengthening technological innovation in the photovoltaic industry, and expanding the application range of photovoltaic power generation when formulating the photovoltaic industry policies.

Keywords: Policy instruments; PMC-index model; Quantitative evaluation; Photovoltaic industry

1. Introduction

The solar photovoltaic industry is the most active area for the development of the renewable energy industry. [1] As an important new energy industry, the photovoltaic industry plays an important role in improving the energy structure and solving serious environmental problems. The photovoltaic industry creates abundant energy through solar power generation. The use of these energy sources reduces the use of fossil fuels and alleviates environmental problems such as air pollution and global warming. At the same time, the photovoltaic industry also plays an important role in promoting the transformation of the development mode and promoting high-quality economic development. In the field of production, the scientific and technological progress of photovoltaic products has improved the development level of industrial science and technology. In the field of consumption, the wide application of photovoltaic products has driven energy consumption and effectively stimulated the vitality of the energy market. The photovoltaic industry has promoted the level of regional economic development.

The end of last century to the beginning of this century is the initial stage of China's photovoltaic industry. In this period, China's photovoltaic industry faced the problem of backward technology and small market size.

After 2002, China's photovoltaic industry began to develop rapidly. There were many photovoltaic enterprises established in China. China has quickly become one of the important players in the global photovoltaic industry. According to the National Energy Administration, by the end of December 2023, China's installed solar power capacity reached 610 million kilowatts. The huge photovoltaic industry is already an important industry in China.

In the past few decades, China's photovoltaic industry has made great achievements, but at the same time it has also experienced many challenges. In 2008, affected by the global financial crisis, China's photovoltaic product prices fell sharply, triggering the bankruptcy crisis of photovoltaic companies. In 2011, China's photovoltaic industry fell into serious overcapacity, and there were losses and bankruptcies again. To help photovoltaic enterprises out of the dilemma, the government introduced the Golden Sun Demonstration Project, photovoltaic electricity price subsidies and other policies to support the photovoltaic industry. With the help of the government, the photovoltaic industry has gradually come out of the dilemma. In addition to these periods, in fact, the government plays an important role in every link and every period of the development of China's photovoltaic industry. After the adjustment of the government's photovoltaic industry policies, China's photovoltaic industry has undergone great changes. The scale of the photovoltaic industry has been improved, and the competitiveness of the photovoltaic industry has been enhanced. However, at present, there is still a gap between the actual development of China's photovoltaic industry and the expected development goals. The photovoltaic industry has problems such as insufficient innovation ability and uncoordinated development within the industry. At the same time, some photovoltaic industry policies have brought about problems such as overcapacity and increased government burdens. Therefore, it is necessary to evaluate the existing photovoltaic industry policies. Policy evaluation is very important to measure the quality of public. [2] The government can formulate more scientific photovoltaic industry policies through policy evaluation.

At present, the research based on photovoltaic industry policies mostly focuses on the use of photovoltaic enterprises and government indicator data to study a certain type of policy. There is a lack of systematic evaluation of the PV industry policy texts. Therefore, this study evaluates China's PV industry policies based on text mining and the PMC-index model. The contributions of this study include the following points. Firstly, based on the analysis framework of policy tools, the photovoltaic industry policies are divided, and the structure and evolution of the photovoltaic industry policies are analyzed. Secondly, the evaluation system based on the PMC-index model is constructed to evaluate China's photovoltaic industry policies. Finally, 6 representative PV industrial policies are selected, the advantages and disadvantages of the policies are evaluated, and suggestions for improving the PV industrial policies are put forward.

The remainder of this article is structured as follows. Section 2 is a literature review, which reviews the photovoltaic industry research and policy text research. Section 3 divides the policy instruments and constructs the PMC-index model. Section 4 analyzes the structure and evolution of policies, and evaluates 6 representative policies based on the PMC-index model. Section 5 summarizes the full text and puts forward some suggestions.

2. Literature Review

This study analyzes the photovoltaic industry policy text, so in this part, the photovoltaic industry and policy text research is reviewed. By integrating the research findings from these two aspects, we can gain a more comprehensive understanding of the photovoltaic industry. At the same time, we can learn the methods of policy text research and lay a foundation for future policy text research.

2.1. Photovoltaic Industry

The photovoltaic industry is large in scale and involves many fields. Many studies start from a certain area of the photovoltaic industry and study the development of the photovoltaic industry itself. Some studies have analyzed the establishment and application of photovoltaic power stations, conducted economic analysis of photovoltaic power stations, and explained the development of the photovoltaic industry [3,4,5]. Some studies take photovoltaic module recycling as the research object, analyze the barriers to the recycling of photovoltaic modules, and put forward suggestions for the healthy development of photovoltaic industry [6,7]. In the process of analyzing the development of the photovoltaic industry itself, some studies combine the photovoltaic industry with some economic entities to analyze the connection between the photovoltaic industry and economic entities. These economic agents include households [8,9], businesses [10,11], and governments [12,13,14]. Through these studies, the impact of the photovoltaic industry and the constraints of the photovoltaic industry are clearly demonstrated. Among these economic entities, the government is an important one. And policy research is an important area in the interaction between the photovoltaic industry and the government. Many researchers study the development of the photovoltaic industry by analyzing the photovoltaic industry policies issued by the government. Castaneda et al. [15], Luan and Lin [16], Liu et al. [17], Deng et al. [18] analyzed the impact of changes in subsidy policies on the development of the photovoltaic industry according to the relevant data of photovoltaic subsidy policies. Zhang et al. [19] used random effects GLS regression to analyze the impact of talent policy on the photovoltaic industry, examined the intermediary effect of human capital, and analyzed the heterogeneity of property rights and R&D intensity. Silveira et al. [20] conducted a comparative analysis of the photovoltaic industry policies and data in Spain, Germany and Brazil, and specifically analyzed the content of the photovoltaic industry policies in the three countries. Hu and Wu [21] constructed the supply chain game model to analyze the influence of government competition policy on the profits of manufacturers and the overall profits of the supply chain. Gao [22] used the Poisson regression model to assess the impact of regulatory policies fiscal incentives on the U.S. PV installation industry. Keshavadasu [23] conducted case studies on solar power projects and analyzed regulatory policies related to photovoltaic projects. Based on the analysis of the photovoltaic industry itself in the related fields and related subjects of the photovoltaic industry, the characteristics of the photovoltaic industry and the problems encountered in the development of the photovoltaic industry are shown.

However, research on one area of the photovoltaic industry is relatively narrow in scope. Therefore, some studies have conducted a comprehensive analysis of the photovoltaic industry from a macro perspective by integrating multiple fields and multiple subjects. Some studies describe the development of the photovoltaic industry in a region from a spatial perspective, and use spatial analysis to grasp the regional development characteristics of the photovoltaic industry. [24,25] Some studies have studied the industrial chain of the photovoltaic industry. In these studies, researchers analyze the upstream, midstream and downstream areas of the photovoltaic industry to quantify the value of the photovoltaic industry chain and grasp the operation of the photovoltaic from a macro perspective. [26,27,28] In addition to focusing on a certain problem for the macro analysis of the photovoltaic industry, Zhang et al. [29] used the data of photovoltaic industry enterprises to comprehensively analyze the business performance, industrial agglomeration and spatial characteristics of the photovoltaic industry according to existing research. This study is more comprehensive than previous studies.

The current research based on the photovoltaic industry has been involved at both the micro and macro. Researchers focus on the outstanding problems in the development of the photovoltaic industry, and study multiple subjects of the photovoltaic industry. In the study of photovoltaic industry, the government is an important subject, so the photovoltaic industry policy has become an important research object. In the photovoltaic industry policy research, researchers mostly focus on the study of a single photovoltaic industry policy. In these studies, researchers analyzed the effect of PV industry policies by using relevant indicators of the government and photovoltaic enterprises. The research on a single photovoltaic industry policy can conduct an in-depth analysis of a certain policy and a prominent problem of photovoltaic. However, these studies cannot fully grasp the development of the photovoltaic industry, and lack the analysis of the overall characteristics of the photovoltaic industry. Therefore, it is necessary to analyze several photovoltaic industry policies according to the text of photovoltaic industry policies. The analysis of several photovoltaic industry policies can comprehensively analyze the evolution of photovoltaic industry policies and the characteristics of photovoltaic industry policies in different periods. At the same time, it can conduct a macro analysis of the photovoltaic industry policies and comprehensively analyze the development of photovoltaic industry. At present, in the research of the photovoltaic industry, there are few studies on the comprehensive analysis of the photovoltaic industry policies according to the photovoltaic industrial policy texts.

2.2. Policy Text

In the analysis of policy texts, drawing statistical charts is a common analysis method. Researchers turn the policy texts into data and draw statistical charts based on the data to analyze the policy content. Zhao et al. [30] divided air pollution control policies and then created statistical charts to show policy evolution, policy topics, and policy frequency. Ma et al. [31] drew statistical charts to analyze the evolution of circular economy policies, and then use the results of statistical analysis to explore the phenomenon of policy accumulation. In addition to drawing statistical charts to show policy content, researchers have developed a variety of ways to mine text content. These methods of mining text content help researchers fully understand the policy content, and then help researchers to accurately analyze the policy content. Park [32] mined the texts of Chinese cultural and creative policies by adopting the term frequency-inverse document frequency (TF–IDF) measure and the degree of centrality value, and then conducted a network analysis to analyze the policy discourse of cultural and creative policies. Lu and Do Park [33] combined text mining and network analysis with time series to analyze trends in China's green consumption policies. Wo et al. [34] used Chinese intelligent coal mine policy texts to generate semantic, and conduct co-occurrence analysis and centrality analysis to illustrate policy evolution trends. Lee and Jeong [35] used the methods of text mining, matrix data analysis and topic analysis to analyze South Korea's AI education policy, and then point out the impact of the policy and the direction of the policy in the future.

With the deepening of policy text research, more and more quantitative analysis methods have been introduced in policy text research. Regression analysis, LDA topic model and the PMC-index model are three important quantitative analysis methods for policy texts. Regression analysis is a commonly used quantitative analysis method in economics. In the field of policy text research, scholars convert industrial policy texts into data and combine them with other economic data for regression analysis. Hille and Oelker [36] converted renewable energy policy tools into binary variables and then combined these variables with energy and innovation indicators to illustrate the impact of policy and innovation on renewable energy development through regression analysis. Zhang and Shen [37] set binary variables according to the recycled water policy texts, and then combined with Cox regression model to analyze the implementation logic of the policy. Bölük and Kaplan [38] set dummy variables according to the renewable energy policy texts, and used two methods of panel fixed effect and dynamic panel estimation to analyze the impact of renewable energy policies on renewable energy generation. LDA model is a form of text mining designed to discover hidden topic structures in some large documents. [39] It provides a way to quantify research topics. [40] In the process of using the LDA model, social platforms [41], literature [39,42], and policy texts [43,44,40] are the important analysis objects of the model. Among these research objects, policy text is a more rigorous and authoritative research object. By organizing and understanding a large amount of policy text information, LDA model can fully explore the topics of policy texts and carry out quantitative analysis. Therefore, it is widely used in the research of industrial policy texts. At present, LDA model is used in important industrial policies such as new energy vehicle policies [40], education policies [44] and business environment policies [43]. The PMC-index model is a quantitative analysis method to analyze a policy text from multiple dimensions. It analyzes the advantages and disadvantages of a policy by quantitatively analyzing multiple indicators of a policy. In the field of industrial policy text research, the PMC-index model has been applied to high-tech industry policy [45], waste classification management policy [46] and green development policy [47].

In the field of policy text research, researchers use a variety of methods to mine policy texts and draw statistical charts to analyze policy texts. The analysis of policy texts is mostly qualitative. These qualitative analyses have a rough understanding of the evolution and effects of industrial policies, and can't accurately evaluate the industrial policies promulgated by the government. Therefore, some quantitative analysis models are introduced into policy text research. Researchers use quantitative analysis to accurately assess policy levels and analyze policy evolution. In the quantitative analysis of policy texts, regression analysis, LDA model and PMC-index model are three widely used analysis methods. Among them, regression analysis and LDA model are used more, while PMC-index model is currently only used in the analysis of some industries, and is rarely used in the analysis of photovoltaic industry policy texts.

To sum up, the existing research in the field of photovoltaic industry and policy texts have shortcomings. To make up for these deficiencies, this paper takes the photovoltaic industry policy texts as the research object and analyzes several photovoltaic industry policies. In the study of policy text, the photovoltaic industry policies are divided, and statistical charts are drawn to analyze the photovoltaic industry policies. At the same time, the PMC-index model is used to evaluate the photovoltaic industry policies. These analyses combine qualitative analysis with quantitative analysis and provide reference for industrial policy research.

3. Research Design

3.1. The Division of Photovoltaic Industry Policy Instruments

Policy instruments are the core elements of policy documents. [48] Policies achieve their objectives through policy instruments. [49] The division of policy instruments helps to clearly show the structure and evolution of the photovoltaic industry policies. Therefore, this study divides the policy instruments before analyzing the policies. In existing studies, researchers have used a variety of classification methods to classify policy instruments. Borrás and Edquist [50] divided policy instruments into regulatory policy instruments, economic transfer policy instruments and soft policy instruments according to the traditional division of public policies. Huang et al. [51] divided the policy instruments into three types, including regulatory, incentive, and social. Rothwell and Zegveld [52] classified policy instruments into supply-type, demand-type, and environment-type based on policy content and policy impact areas. This classification is widely used in the field of policy research. Many researchers use this approach to study policy content [53,54,55]. Bretter and Schulz [56] categorized policy instruments into four types, including command-and-control, market-based, information-based, and voluntary. According to the policy content and characteristics, Pitelis et al. [57] divided the policy instruments into technology-push policy instruments, demand-pull instruments, and systemic instruments. Bergek et al [58] classified policy instruments into general economic instruments, general regulatory instruments, technology-specific economic instruments and technology-specific regulatory instruments based on policy influence mechanisms and policy domains. Hurlimann et al. [59] combined existing research with the industry areas they studied and divided policy instruments into six types, including strategies, laws, regulations, guidelines, voluntary instruments, and programs. Based on Rothwell and Zegveld's research, combined with the actual development of the photovoltaic industry, this paper divides the photovoltaic industry policy instruments into supply-type instruments, demand-type instruments, environment-type instruments, and economic-type instruments. The supply-oriented policies start from the supply side of the photovoltaic industry and improve the supply level of the photovoltaic industry by optimizing the supply situation of the elements of the photovoltaic industry. The environment-oriented policies create a good environment for the development of the photovoltaic industry, so that the participants within the photovoltaic industry can orderly participate in industrial activities, while attracting more people to participate in the photovoltaic industry. The economic-oriented policies regulate the capital flow of the photovoltaic industry through various ways to provide financial support for the main body of the photovoltaic industry. Through these regulations, the government reduces the burden on the main body of the photovoltaic industry. The demand-oriented policies stimulate the demand for photovoltaic products from multiple levels, expand the market scope of the photovoltaic industry, and promote the development of the photovoltaic industry. Based on the four types of policy instruments, this paper combines the characteristics of the four types of policy instruments and the characteristics of the photovoltaic industry to divide the four types of photovoltaic industry policy instruments. The specific division of policy instruments for the photovoltaic industry is shown in Table 1.

Table 1. Photovoltaic industry policy instrument classification

Type of policy instruments	Name of policy instruments	Meaning of policy instruments
Supply-oriented policy instruments	Scientific and technological support	The government directly or indirectly supports the development of science and technology.
	Personnel training	The government improves the talent education and training system to provide talent security for the photovoltaic industry.
	Public service	The government strengthens the development of public service platforms and public service systems.
	Infrastructure	The government strengthens the construction of supporting infrastructure for the photovoltaic industry.
	Land support	Providing land support for the photovoltaic industry and strengthening land security.
Environment-oriented policy instruments	Norms and standards	The government formulates the photovoltaic industry norms and standards to achieve the normalization and standardization of the photovoltaic industry.
	Goal programming	Planning for future tasks and goals.
	Supervision and administration	Strengthening supervision and management of the photovoltaic industry.
	International cooperation	The government encourages various domestic entities to carry out international exchanges and cooperation with overseas

		governments and institutions.
Economic- oriented policy instruments	Capital investment	The government directly provides financial support to the photovoltaic industry.
	Financial support	The government encourages financial and derivative institutions to provide loans, guarantees, venture capital and other support for the photovoltaic industry.
	Tax incentives	The government gives tax breaks to the photovoltaic industry.
	Consumption subsidy	The government provides subsidies for photovoltaic consumption.
Demand-oriented policy instruments	Government procurement	Government procurement of products and services related to the photovoltaic industry.
	Application and demonstration	Carrying out pilot demonstrations in the photovoltaic industry and promote photovoltaic products.
	Overseas trade	The government encourages enterprises to trade overseas and regulates trade activities.

3.2. Policy Text Selection and Coding

Before analyzing the photovoltaic industry policy texts, it is necessary to collect photovoltaic industry policy texts. Due to the lack of China's photovoltaic industrial policy texts before 2007, it is difficult to collect them. Therefore, this study only collected the PV industrial policy texts of China from 2007 to 2023 when collecting the PV industrial policy texts. The photovoltaic industry policy texts of this paper are mainly from the Peking University magic weapon database. This database collects the policies of major sectors in major Chinses cites and is used in many studies related to the analysis of policy texts [45,46,47]. The specific collection process of photovoltaic industry policy texts is as follows. First, in the Peking University magic weapon database, this study set "photovoltaic", "solar energy" and "new energy" as the search keywords. Then, the search period was set to be 2007-2023, and China's national and local PV industry policy texts were searched in the database. Then, from the collected photovoltaic industry policy texts, the policy texts unrelated to this study were eliminated. In this study, there are three kinds of photovoltaic industry policy texts that are excluded. The first is announcements, approvals, letters, meeting notices and other informal policy documents. The second is some policy texts that only discuss renewables and new energy in depth and rarely mention the photovoltaic industry. The third is some policy texts without substantive content. After collecting, supplementing and eliminating the PV industry policy texts, this study finally sorted out a total of 1388 PV industry policy texts at the national and local levels in China. After the collection of policy texts, this study summarized these policy texts into a table, and sorted the industrial policy texts of the photovoltaic industry according to the time of policy announcement. Then, the photovoltaic industry policy texts were divided into several policy clauses, with the policy clauses as the basic analysis unit. Finally, 1388 PV industry policy texts were coded in the form of "Policy number - clause".

3.3. The Construction of PMC-index Model

After dividing the photovoltaic industry policy instruments, this part constructs the PMC-index model used in this study. The construction of PMC-index model includes the following four steps: first, variable classification and parameter identification; second, multi-input-output table construction; third, PMC-index calculation; fourth, PMC surface drawing.[60]

(1) Firstly, variable classification and parameter identification are carried out. In this study, 10 primary variables and 41 secondary variables are set. The setting of variables is based on the content of China's national level photovoltaic industry text and the division of photovoltaic industry policy instruments in Section 3.1. Table 2 and Figure 1 are high-frequency vocabularies and social network charts produced in this paper based on the text of China's national PV industry policies from 2007 to 2023.

In the photovoltaic industrial policies at the national level, the government and enterprises are two important subjects. The production and consumption links of the photovoltaic industry are closely related to these two subjects. In the production link, the government actively promotes the construction of photovoltaic power stations and photovoltaic power grids. In the consumption sector, the government actively promotes the demonstration and application of photovoltaic projects. In the high frequency vocabulary, technology, application and manage are three words with high frequency. They represent the three important functions of photovoltaic industry policy, which are to promote technological innovation in the photovoltaic industry, promote the application of photovoltaic products, and improve the management of the photovoltaic industry. Technology is an important part of PV industry policy. In the social network graph, the word technology is at the center, connecting several high-frequency words. The improvement of technology can help the photovoltaic industry to improve production efficiency, strengthen management level, and expand the scope of product application.

Table 2. high-frequency glossary

High-frequency word	**Word frequency**	**High-frequency word**	**Word frequency**	**High-frequency word**	**Word frequency**
photovoltaic	4682	set an example	1127	market	737
energy	3749	application	1121	innovation	729
project	3721	power grid	1105	condition	727
develop	2934	power station	1068	resource	717
construct	2733	manage	1058	electricity	693
electric power generation	2670	engineering	933	policy	692
technology	2454	renewable	922	service	691
enterprise	2037	system	856	standard	663
country	1957	exploit	808	manufacture	649
solar energy	1249	area	797	industry	637

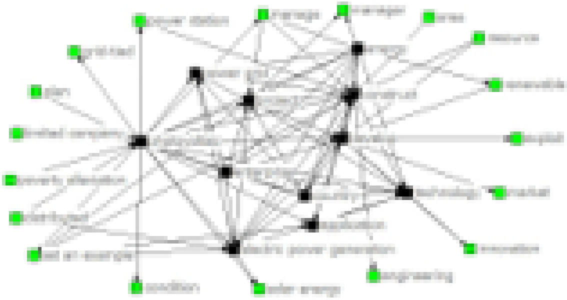

Figure 1. Social network graph

At the same time, this study refers to the division of variables by Wang et al [2], Liu et al [45], Estrada, M.A.R [60] and Xu et al [46]. The specific settings of the variables are shown in Table 3. Among the 10 first-level variables, X1, X2, X6, X8, and X10 judge the quality of a policy by showing the basic characteristics of the policy, and X3, X4, X5, X7, and X9 judge the response degree of the policy to the photovoltaic industry from the field, function, incentive measures, function level, and receptor of a policy.

After completing the setting of variables, parameter identification is carried out in this study. This paper assumes that each secondary variable is equally important and has the same weight in the multi-input-output table. The parameter values of all secondary variables are set to binary 0 and 1. When the policy content contains the corresponding secondary variable, the value of the secondary variable is 1; if it does not, the value of the secondary variable is 0.

Table 3. Photovoltaic industry policy quantitative evaluation variable setting

First-level variables	Second-level variables	Source of basis
(X1) Nature of policy	(X1:1) Forecast, (X1:2) Supervision, (X1:3) Suggestion, (X1:4) Description	Liu et al [45]
(X2) Term of validity of the policy	(X2:1) Long-term (> 10 years), (X2:2) Medium-term (5-10 years), (X2:3) Short-term (1-5 years), (X2:4) Within the year	Liu et al [45]
(X3) Policy domain	(X3:1) Economic field, (X3:2) Social field, (X3:3) Technical field, (X3:4) Political field, (X3:5) Environmental field	Estrada, M.A.R [60]
(X4) Policy function	(X4:1) Product promotion, (X4:2) Technological innovation, (X4:3) Supervision and administration, (X4:4) Government procurement	Modified from the high-frequency glossary and social network graph
(X5) Incentive measure	(X5:1) Financial support, (X5:2) Talent support, (X5:3) Electricity price subsidy, (X5:4) Tax reduction and exemption, (X5:5) Infrastructure construction, (X5:6) Fund support, (X5:7) Scientific and technological support, (X5:8) Public service support, (X5:9) Land support	Modified according to Table 1
(X6) Policy perspective	(X6:1) Macroscopic perspective, (X6:2) Mesoscopic perspective, (X6:3) Microscopic perspective	Wang et al [2]
(X7) Function level	(X7:1) National level, (X7:2) Regional level, (X7:3) Industrial level,	Modified from the high-

	(X7:4) Enterprise level, (X7:5) New technology (product) level	frequency glossary and social network graph
(X8) Policy level	(X8:1) National level, (X8:2) Province, autonomous region and municipality level, (X8:3) Prefecture level, (X8:4) District and county level	Xu et al [46]
(X9) Policy receptor	(X9:1) Enterprise, (X9:2) Government, (X9:3) Consumer	Modified from the high-frequency glossary and social network graph
(X10) Policy disclosure		Xu et al [46]

Table 4. The multi-input-output table

First-level variables	**Second-level variables**								
X1	X1:1	X1:2	X1:3	X1:4					
X2	X2:1	X2:2	X2:3	X2:4					
X3	X3:1	X3:2	X3:3	X3:4	X3:5				
X4	X4:1	X4:2	X4:3	X4:4					
X5	X5:1	X5:2	X5:3	X5:4	X5:5	X5:6	X5:7	X5:8	X5:9
X6	X6:1	X6:2	X6:3						
X7	X7:1	X7:2	X7:3	X7:4	X7:5				
X8	X8:1	X8:2	X8:3	X8:4					
X9	X9:1	X9:2	X9:3						
X10									

(2) Secondly, this study constructs a multi-input-output table. Multi-input-output table is a data analysis framework that quantifies variables from multiple dimensions, which contains a lot of data. The multi-input-output table is shown in Table 4.

(3) Thirdly, the PMC-index is calculated. The PMC-index is calculated in four steps. First, set the first-level variables and the second-level variables into the multi-input-output table. Second, the second-level variables are assigned according to equations (1) and (2). Third, the value of the first-level variable is calculated by equation (3). Fourth, use equation (4) to sum all the first-level variable values to calculate the PMC-index value of the corresponding policy.

$$X \sim N[0,1] \tag{1}$$

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

$$X_t\left(\sum_{a=1}^{n}\frac{X_{ta}}{T\left(X_{ta}\right)}\right) \tag{3}$$

t represents the first-level variable; *a* represents the second-level variable; t=1,2,3,4,5,6,7,8,9,10,…,∞; $T(X_{ta})$ represents the number of second-level variables under a first-level variable.

$$PMC=\begin{bmatrix} X1\left(\sum_{a=1}^{4}\frac{X_{1a}}{4}\right)+X2\left(\sum_{b=1}^{4}\frac{X_{2b}}{4}\right)+X3\left(\sum_{c=1}^{5}\frac{X_{3c}}{5}\right)+ \\ X4\left(\sum_{d=1}^{4}\frac{X_{4d}}{4}\right)+X5\left(\sum_{e=1}^{9}\frac{X_{5e}}{9}\right)+X6\left(\sum_{f=1}^{3}\frac{X_{6f}}{3}\right)+ \\ X7\left(\sum_{g=1}^{5}\frac{X_{7g}}{5}\right)+X8\left(\sum_{h=1}^{4}\frac{X_{8h}}{4}\right)+X9\left(\sum_{i=1}^{3}\frac{X_{9i}}{3}\right)+X10 \end{bmatrix} \quad (4)$$

After calculating the PMC-index of each policy according to the above four steps, the policy is then evaluated. The policy score is divided into the following grades: 0-4.99 is poor, 5-6.99 is acceptable, 7-8.99 is excellent, and 9-10 is perfect. At the same time, to measure the policy quality and response degree, this paper calculates Q-index (policy quality index) and B-index (response degree index), as shown in equation (5) and equation (6). The policy quality index and response degree index are divided into four grades for evaluation, in which 0-1.99 is poor, 2-2.99 is acceptable, 3-3.99 is excellent, and 4-5 is perfect.

$$Q=X1+X2+X6+X8+X10 \quad (5)$$

$$B=X3+X4+X5+X7+X9 \quad (6)$$

(4) Draw PMC surfaces. The PMC surface presents the PMC-index in a graphical form to show the characteristics of the policy. Drawing a PMC surface requires the creation of a PMC matrix, which requires the help of 10 first-level variables used in calculating the PMC-index. Since X10 has no second-level variable among the 10 first-level variables, and the values of X10 are all 1 during policy evaluation, the first-level variable X10 is removed when drawing PMC surfaces to maintain symmetry and balance. The remaining 9 first-level variables are sorted into a third-order square matrix, that is, the PMC surface. PMC matrix corresponding is shown in equation (7).

$$PMC\ surface=\begin{pmatrix} X1 & X2 & X3 \\ X4 & X5 & X6 \\ X7 & X8 & X9 \end{pmatrix} \quad (7)$$

4. Analysis and Results

4.1. Photovoltaic Industry Policy Instrument Analysis

According to the division of PV industrial policy instruments in 3.1, this study determines the PV industrial policy instruments used in the collected PV industrial policy texts. Based on the judgment of the policy instruments in the collected policies, this study draws statistical charts of the evolution of the policy instrument structure of the photovoltaic industry.

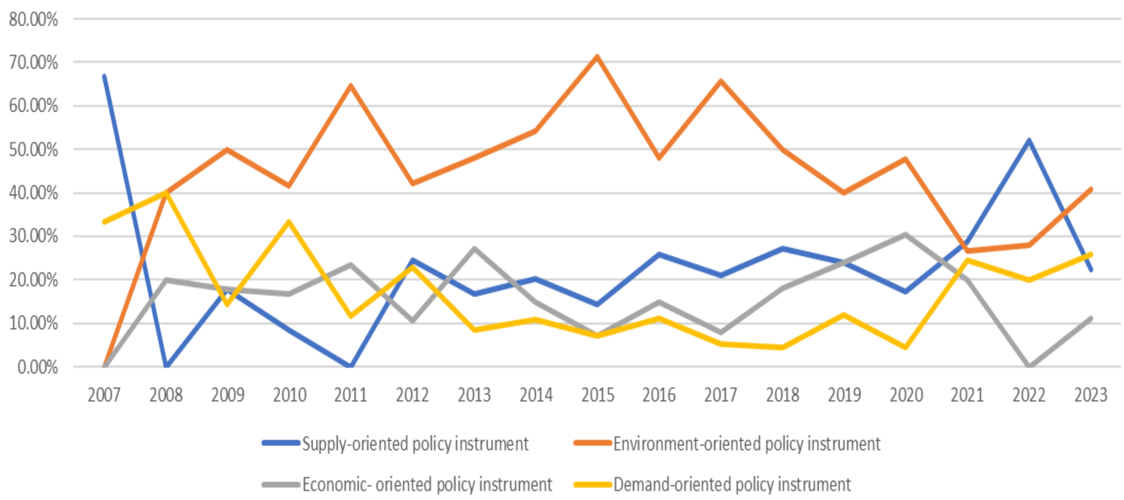

Figure 2. The proportion of four types of policy instruments at the national level

Figure 2 shows the changes in the policy instrument structure of China's national PV industry policy from 2007 to 2023. From 2007 to 2023, the change in the proportion of four types of photovoltaic industry policy instruments showed a fluctuating state. From 2013 to 2021, environmental policy instruments accounted for the largest proportion, supply policy instruments and economic policy instruments accounted for the middle proportion, and demand policy instruments accounted for the least proportion. During this period, the government focused on creating a good development environment for the photovoltaic industry, and indirectly affected the development of the photovoltaic industry by strengthening international cooperation, implementing certain control measures, and strengthening the planning of the photovoltaic industry. In the past two years, the structure of photovoltaic industry policy instruments at the national level has changed, and the government has regulated the photovoltaic industry using various types of policy instruments. The proportion of supply-oriented policy instruments, economic-oriented policy instruments and demand-oriented policy instruments has increased, and the proportion gap between the four types of photovoltaic industry policy instruments has narrowed. There are many reasons for the change in the structure of photovoltaic industry policy instruments at the national level. Firstly, the construction of a good development environment can lay a good foundation for the development of the photovoltaic industry. Secondly, the effective regulation of the supply side, demand side and capital flow of the photovoltaic industry is based on the good development environment of the photovoltaic industry. At the same time, 10 years ago, China did not establish an environment that could promote the sustainable development of the photovoltaic industry. Therefore, from 2013 to 2021, the government sought to establish a good environment for the development of the photovoltaic industry, and environmental policy instruments were more important in the national level photovoltaic industry policy. In the past two years, with the improvement of the photovoltaic industry planning and management system, the development environment of the photovoltaic industry has been continuously optimized. On this basis, the government strengthened the optimization of the supply and demand of the photovoltaic industry, and at the same time regulated the funds of the photovoltaic industry to strengthen the support for the photovoltaic industry. The government hoped to promote the development of photovoltaic products and the upgrading of the photovoltaic industry through these regulations. This has narrowed the gap in the proportion of four types of photovoltaic industry policy instruments in the past two years.

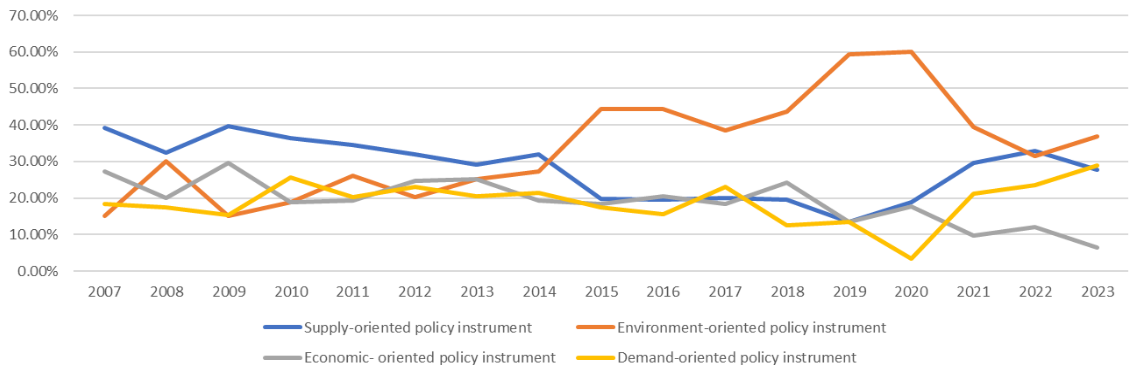

Figure 3. The proportion of four types of policy instruments at the local level

Figure 3 shows the changes in the structure of policy instruments for China's PV industry policy at the local level from 2007 to 2023. From 2007 to 2014, supply-oriented policy instruments accounted for the largest proportion. From 2015 to 2021, environmental policy instruments accounted for the largest proportion. In the past two years, the gap in the proportion of the four types of policy instruments has gradually narrowed. There are many factors that have caused changes in local photovoltaic industry policies. In the early stage of photovoltaic development, many areas of China's photovoltaic factors were insufficient, which made the survival of the photovoltaic industry difficult. To support the regional photovoltaic industry and promote regional development, the local government strengthened its support for the production factors of the photovoltaic industry. Local government increased the use of supply-oriented policy instruments, which made the ratio of supply-oriented policy instruments large. With the investment of production factors in the photovoltaic industry, the production level of local photovoltaic enterprises continued to improve. Loval government began to focus on creating a good development environment for the photovoltaic industry, focusing on strengthening standardized management and planning to help the development of photovoltaic enterprises. This transformation of local government made environmental policy instruments account for the largest proportion of local photovoltaic industry policies from 2015 to 2021. In the past two years, with the optimization of the development environment of the local photovoltaic industry, local government have begun to pay attention to the use of various types of policy instruments to regulate the regional photovoltaic industry from multiple levels. This has led to the narrowing of the gap in the proportion of various local photovoltaic industry policy instruments in the past two years.

Next, the dynamic changes of four photovoltaic industry policy instruments are analyzed in detail.

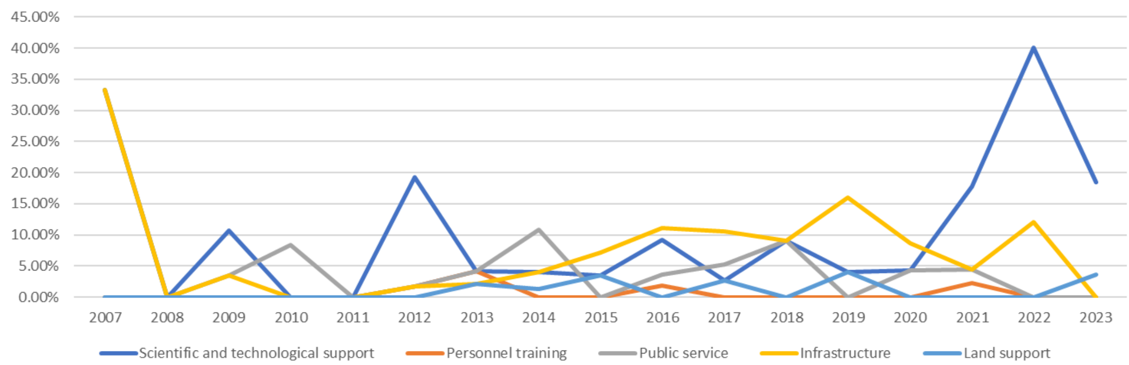

Figure 4. The proportion of five supply-oriented policy instruments at the national level

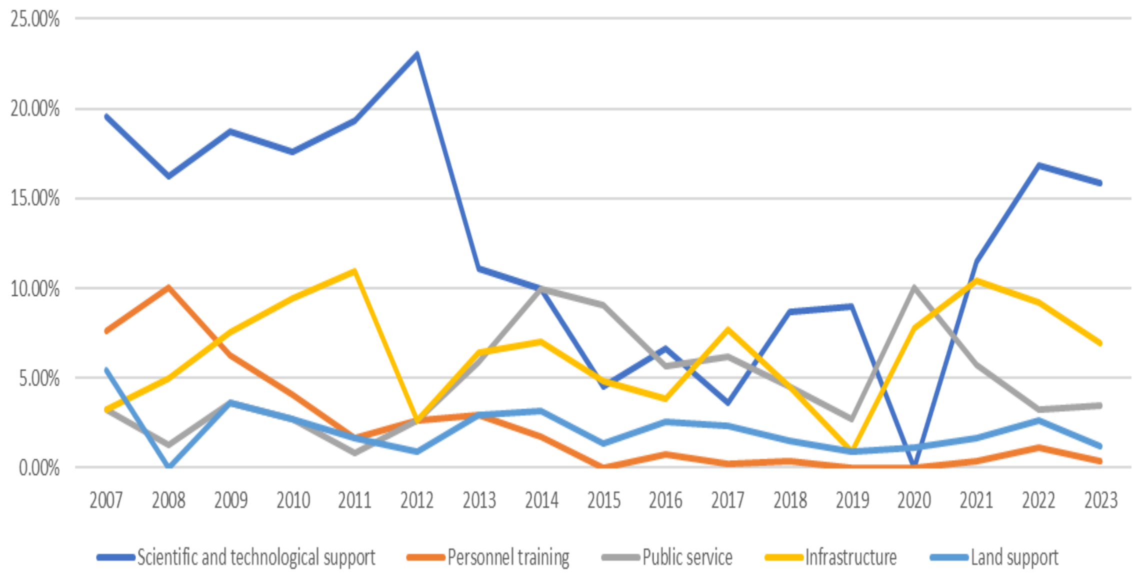

Figure 5. The proportion of five supply-oriented policy instruments at the local level

Figure 4 and Figure 5 show the changes in the proportion of five supply-oriented policy instruments at the national and local levels respectively. Among the supply policy instruments used by the national and local government, the personnel training, public service and land support policy instruments account for a small proportion, while the science and technology support and infrastructure policy instruments account for a large proportion. The large proportion of policy instruments supporting science and technology shows that the government fully recognizes the importance of science and technology. The government promotes the high-quality development of the photovoltaic industry by continuously strengthening investment in science and technology. Infrastructure policy instruments help promote the construction of photovoltaic industry projects and expand the scale of the development of photovoltaic industry. The high proportion of this policy instrument indicates that the government pays attention to strengthening the construction of photovoltaic industry infrastructure to promote the construction of projects and expand the scale of photovoltaic industry.

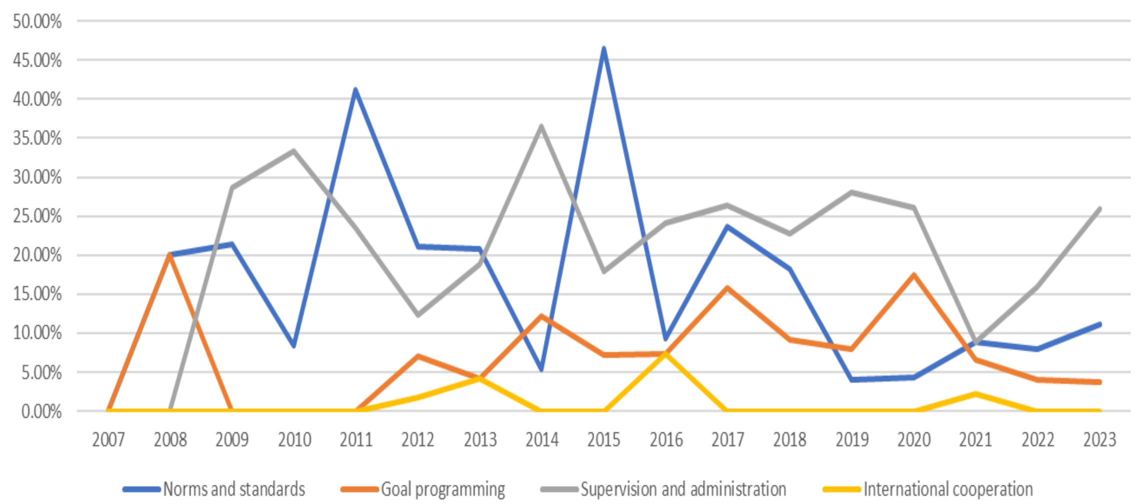

Figure 6. The proportion of four environment -oriented policy instruments at the national level

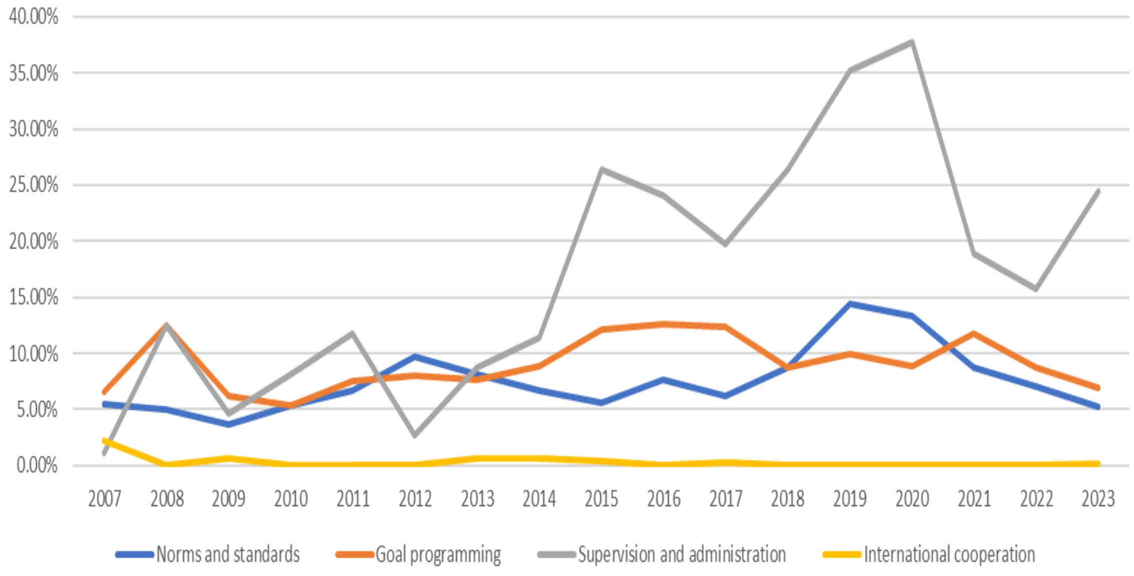

Figure 7. The proportion of four environment -oriented policy instruments at the local level

Figure 6 and Figure 7 show the changes in the proportion of four environment-oriented policy instruments at the national and local levels respectively. Among the national and local environmental policy instruments, the proportion of supervision and management policy instruments is higher. The proportion of this policy instrument and the other three environmental policy instruments has opened a gap. The supervision and management policy instruments have a more direct impact on the photovoltaic industry, and can standardize the behavior at a faster speed. At the same time, this policy instrument has a wide range of applications. Therefore, the policy instrument has become an important part of the environmental policy instrument.

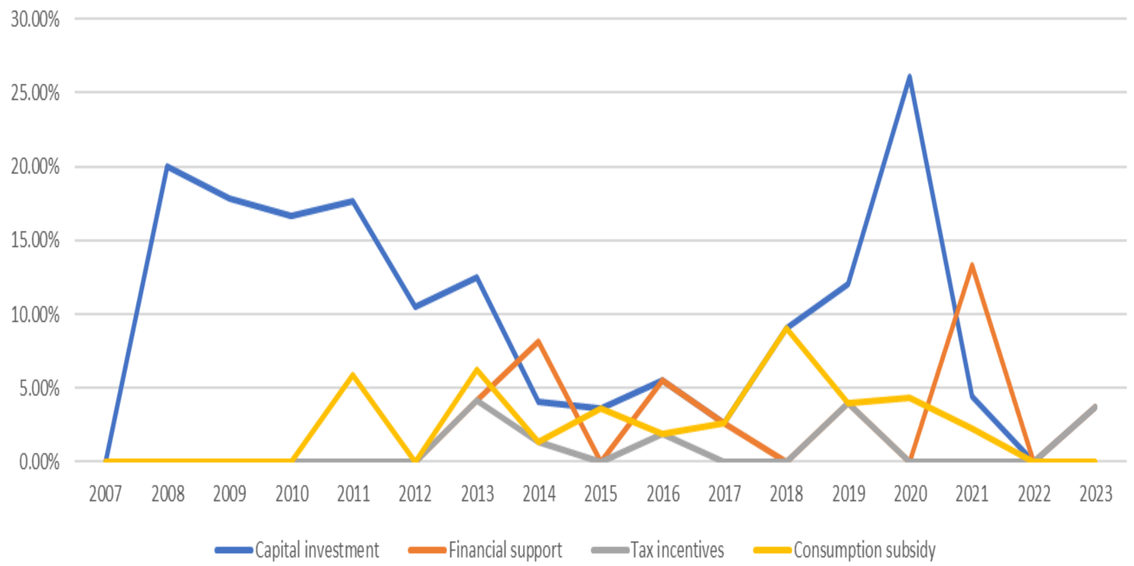

Figure 8. The proportion of four economic -oriented policy instruments at the national level

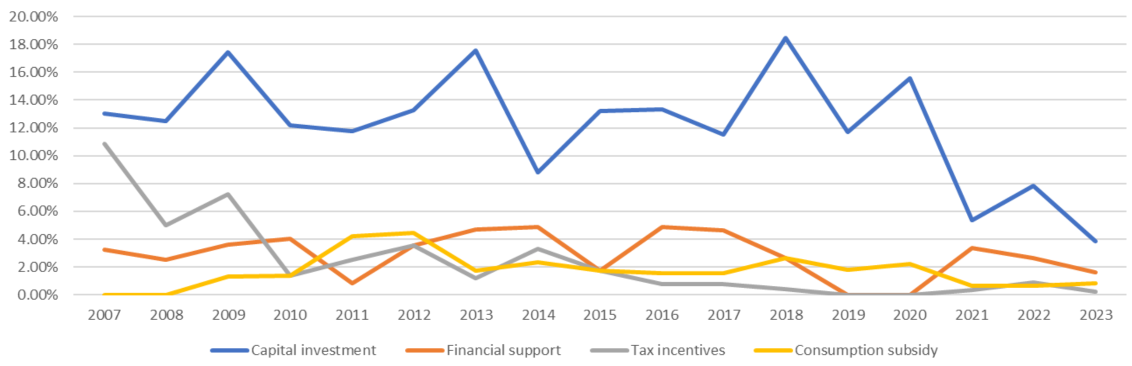

Figure 9. The proportion of four economic -oriented policy instruments at the local level

Figure 8 and Figure 9 show the changes in the proportion of four economic-oriented policy instruments at the national and local levels respectively. Among the national and local economic policy instruments, the capital investment policy instruments account for a higher proportion than the other three economic policy instruments. The capital investment policy instrument is a policy instrument for the government to directly intervene in the photovoltaic industry. Compared with the financial support policy instrument, tax preferential policy instrument, and consumer subsidy policy instrument that indirectly intervene in the photovoltaic industry, this policy instrument has a wider range to use. At the same time, this policy instrument is easy to operate and can quickly have a positive impact in the photovoltaic industry. Therefore, this policy instrument is an economic policy instrument which is widely used by the government.

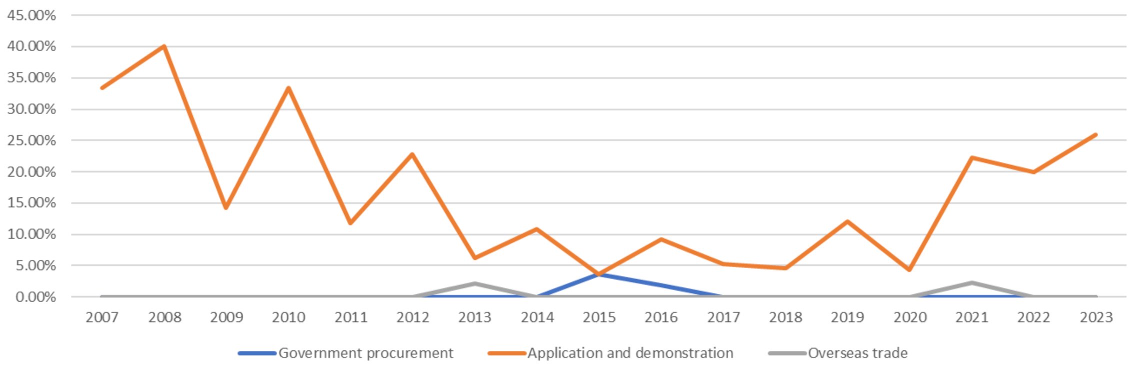

Figure 10. The proportion of three demand -oriented policy instruments at the national level

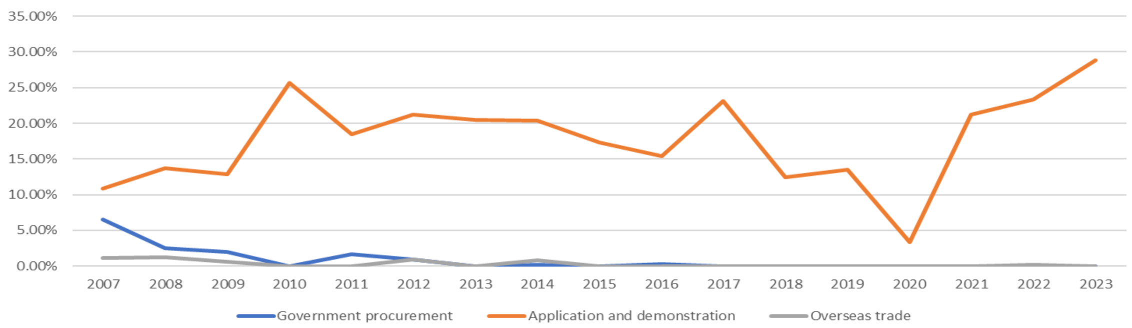

Figure 11. The proportion of three demand -oriented policy instruments at the local level

Figure 10 and Figure 11 show the changes in the proportion of three demand-oriented policy instruments at the national and local levels respectively. Among the national and local demand-oriented policy instruments, the proportion of application and demonstration policy instruments is high, while the proportion of the other two policy instruments changes little and remains at a very low level. Compared with the expansion of government demand and international demand, the government's regulation of the demand for photovoltaic industry is more focused on expanding the demand for photovoltaic products in the domestic market. Application and demonstration policy instruments are implemented through the establishment of application demonstration zones and the application of photovoltaic products to various scenarios in social life. This policy instrument effectively stimulates the domestic photovoltaic market and promotes the continuous progress of the photovoltaic products. It is not only conducive to expanding the market size of the photovoltaic industry, but also constantly promote the innovation and upgrading of the photovoltaic products to adapt to the photovoltaic market. Therefore, this policy instrument becomes a demand-oriented policy instrument with a high proportion.

4.2. PMC-index Model Analysis of Photovoltaic Industry Policy Texts

Based on the photovoltaic industry policy texts collected in this study, six policies were selected as samples for evaluation. This study collected the photovoltaic industry policies at the national and local levels from 2007 to 2023. Among them, the photovoltaic industry policies at the national level have a greater impact on China's photovoltaic industry than the photovoltaic industry policies at the local level. At the same time, the formulation of the photovoltaic industry policies at the local level is often influenced by photovoltaic industry policies at the national level. The photovoltaic industry policies at the national level have played a guiding role. The characteristics of China's photovoltaic industry policy can be deeply understood by evaluating the national level photovoltaic industry policies. Therefore, this study selected six national photovoltaic industry policies for evaluation. The specific contents of the six photovoltaic industry policies are shown in Table 5.

Table 5. Six policy samples of PMC-index model

Item	Policy name	Release time
P1	Some opinions on promoting the healthy development of photovoltaic industry	4 July 2013
P2	Notice on further implementation of distributed photovoltaic power generation policies	2 September 2014
P3	Notice on actively promoting the work of wind power and photovoltaic power generation without subsidies at parity online	7 January 2019
P4	Notice on the issuance of the Smart Photovoltaic Industry Innovation and Development Action Plan (2021-2025)	31 December 2021
P5	Notice on matters related to promoting the healthy development of photovoltaic industry chain	13 September 2022
P6	Guiding Opinions on promoting recycling of decommissioned wind power and photovoltaic equipment	21 July 2023

After determining the six policy samples needed for this study, this study conducted binary assignment of secondary variables in the multi-input-output table of the six policies according to the specific content of each policy. The multi-input-output table of the six photovoltaic industrial policies is shown in Table 6. Then, based on the multi-input-output table of six policies, this study calculates the first-level variable value (results are rounded to two decimal places), PMC-index, Q index (policy quality index), and B index (response validity index) of each policy, and evaluates the policy according to the calculated results. Based on the index values of six policies, the averages values of each index are calculated (results are rounded to two decimal places). The first-level variable values and three indicators of six PV industrial policies are summarized in Table 7. Based on these indicators, this study draws PMC surface maps for six policies. The PMC surfaces of the six PV industrial policies are shown in Figure 12-17.

Table 6. Multi - input-output table of six photovoltaic industry policies

First-level variables	Second-level variables	P1	P2	P3	P4	P5	P6
X1	X1:1	1	0	0	1	0	1
	X1:2	1	1	1	0	1	1
	X1:3	1	1	1	1	1	1
	X1:4	1	1	0	1	0	0
X2	X2:1	1	0	0	0	1	0
	X2:2	0	1	0	0	0	1
	X2:3	1	0	1	1	0	1
	X2:4	0	0	0	0	0	0
X3	X3:1	1	1	1	1	1	1
	X3:2	1	1	0	1	0	0
	X3:3	1	1	0	1	1	1
	X3:4	1	1	1	1	0	1
	X3:5	0	0	0	1	0	1
X4	X4:1	1	1	1	1	0	0
	X4:2	1	0	0	1	1	1
	X4:3	1	1	1	0	1	1
	X4:4	0	0	0	0	0	0
X5	X5:1	1	1	1	1	0	1
	X5:2	1	0	0	1	0	0
	X5:3	1	1	0	0	0	0
	X5:4	1	0	0	0	0	1
	X5:5	1	0	1	0	1	0
	X5:6	1	1	0	1	0	1
	X5:7	1	1	0	1	1	1
	X5:8	1	1	0	1	0	0

	X5:9	1	0	1	0	0	0
X6	X6:1	1	0	0	0	0	0
	X6:2	1	1	1	1	1	1
	X6:3	1	1	1	0	1	1
X7	X7:1	1	1	1	1	1	1
	X7:2	0	1	1	1	0	1
	X7:3	1	1	1	1	1	1
	X7:4	1	1	1	1	1	1
	X7:5	1	0	0	1	1	1
X8	X8:1	1	1	1	1	1	1
	X8:2	0	0	0	0	0	0
	X8:3	0	0	0	0	0	0
	X8:4	0	0	0	0	0	0
X9	X9:1	1	1	1	1	1	1
	X9:2	1	1	1	1	0	1
	X9:3	1	1	0	0	0	0
X10		1	1	1	1	1	1

Table 7. Summary of PMC-index values of six PV industrial policies

	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**Mean value**
X1	1.00	0.75	0.50	0.75	0.50	0.75	0.71
X2	0.50	0.25	0.25	0.25	0.25	0.50	0.33
X3	0.80	0.80	0.40	1.00	0.40	0.80	0.70
X4	0.75	0.50	0.50	0.50	0.50	0.50	0.54
X5	1.00	0.56	0.33	0.56	0.22	0.44	0.52
X6	1.00	0.67	0.67	0.33	0.67	0.67	0.67
X7	0.80	0.80	0.80	1.00	0.80	1.00	0.87
X8	0.25	0.25	0.25	0.25	0.25	0.25	0.25
X9	1.00	1.00	0.67	0.67	0.33	0.67	0.72
X10	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PMC-index	8.10	6.58	5.37	6.31	4.92	6.58	6.31

Rank	1	2	4	3	5	2	
Level	excellent	acceptable	acceptable	acceptable	poor	acceptable	
Q index	3.75	2.92	2.67	2.58	2.67	3.17	2.96
B index	4.35	3.66	2.70	3.73	2.25	3.41	3.35

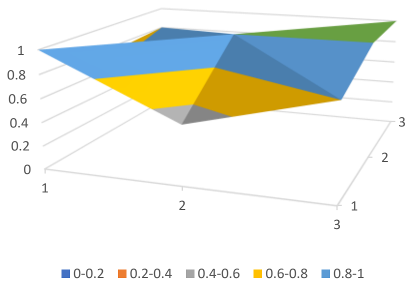

Figure 12. PMC surface diagram of P1

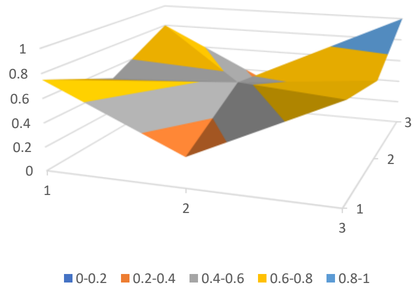

Figure 13. PMC surface diagram of P2

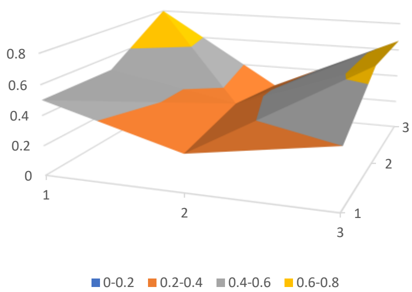

Figure 14. PMC surface diagram of P3

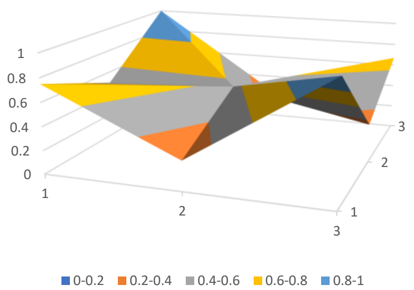

Figure 15. PMC surface diagram of P4

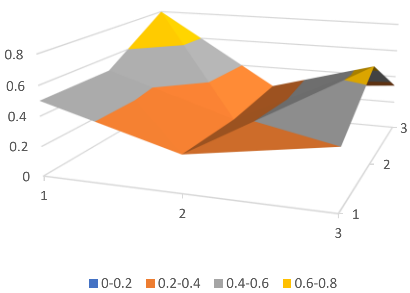

Figure 16. PMC surface diagram of P5

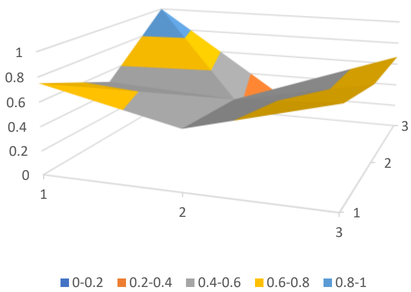

Figure 17. PMC surface diagram of P6

Among the six photovoltaic industry policies, the PMC-index value of P1 policy ranks first and reaches an excellent level. This policy scores higher on multiple first-order variables and achieves better results at multiple levels. P1 policy involves a variety of incentive measures. This policy plays different functions in multiple fields and serves multiple subjects. P1 policy has set goals for the development of the photovoltaic industry. And this policy put forward five aspects of recommendations, including the development of the photovoltaic market, adjusting the industrial structure, regulating the industrial order, improving the photovoltaic grid connection, and strengthening industrial support. This makes the policy score high on multiple first-order variables and the PMC-index. The PMC surface of P1 policy is in a high level raised state. The shape of the curved surface shows that this policy has no obvious shortcomings and has outstanding places in many aspects. The Q index score of P1 policy is at an excellent level, and the policy quality of P1 is high. At the same time, the B index of P1 policy comprehensively responds to the photovoltaic industry from five levels: field, function, incentive measures, function level, and receptor level.

The PMC-index scores of P2 and P6 policies rank second and are rated as acceptable. P2 policy promotes multiple forms of distributed photovoltaics. At the same time, this policy uses a variety of ways to manage distributed photovoltaic projects, including improving project quality management, strengthening the management of the filing work mechanism, strengthening the construction of the monitoring system, and promoting the supervision of the distributed photovoltaic market. The P6 policy sets goals for recycling of photovoltaic equipment and constantly improves the recycling system of photovoltaic equipment. The scores of the two policies in X4(policy function), X5(incentive measure) and X6(policy perspective) are different from those of P1 policy. The score gap between the two policies and P1 policy is larger in X5(incentive measure), and smaller in X4(policy function) and X6(policy perspective). The P2 policy lacks infrastructure and land incentives for distributed PV projects. The P6 policy lacks talent incentives and supporting service incentives in the field of photovoltaic equipment recycling. The PMC surfaces of the two policies have local depressions, but the depressed areas are few. The flaw in both policies is incentives. In terms of Q index and B index scores, compared with P1 policy, the two policies have lower scores in both indicators, but the difference is not large. The Q index and B index scores of both policies are above acceptable levels. The quality of the specific measures of the two policies is acceptable, and the response of the measures of the two policies to the photovoltaic industry is at an excellent level.

The PMC-index scores for P4 and P3 policies ranked third and fourth among the six policies. The P4 policy indicates the goals and main tasks of the development of smart photovoltaic, and introduces the main scenarios of future smart photovoltaic applications. The P3 policy explains the requirements and incentives for the construction of photovoltaic power generation projects. The PMC-index rating of the two policies is at an acceptable level. Compared with P2 and P6 policies, these two policies have more first-order variables with low scores. P4 policy has low scores on X2(Term of validity of the policy), X6(Policy perspective), and X9(Policy receptor). Among them, the score of P4 policy in X6(Policy perspective) is the lowest among the six policies. The P4 policy only plans the development of smart photovoltaic in the past five years, and lacks an analysis of the long-term development of smart photovoltaic. At the same time, the analysis perspective is single, and the analysis of macro and micro perspectives of smart photovoltaic is lacking. P3 policy has low scores on X1(Nature of policy), X2(Term of validity of the policy), X3(Policy domain), X5(Incentive measure), and X9(Policy receptor). The P3 policy has the problem of insufficient incentive measures and limited scope. This policy provides financial, infrastructure and land support for the affordable Internet access project, and lacks support for project talents and photovoltaic affordable Internet access supporting services. Compared with PMC surfaces of P2 and P6 policies, there are more depressed areas in P3 and P4 policies. The P3 and P4 policies have more flaws than the P2 and P6 policies. The Q index scores of P3 and P4 policies are lower than those of P2 and P6, but still at acceptable levels. The quality of both policies is acceptable. The B index score of P3 policy is lower among the six policies, with a weak response to the photovoltaic industry. The B index score of P4 policy is higher in the six policies. This policy has a strong response to the photovoltaic industry and can effectively solve the problems existing in the photovoltaic industry.

The PMC-index score of P5 policy ranks fifth among the six PV industry policies, which is the lowest level. The PMC-index rating of this policy is poor. The values of the first-level variables of P5 policies are all lower than 1 except X10(policy disclosure), and the scores of the first-level variables are generally low. Especially in the two first-level variables X5(Incentive measure) and X9(Policy receptor), there is a large gap between the P5 policy and the other five policies. The PMC surface of P5 policy has a large area of depression. This policy has many problems in policy areas and incentive measures. The incentive measures of P5 policy are insufficient and the scope involved is narrow. The content of P5 policy focuses on the healthy development of photovoltaic industry chain. This policy does not set a clear goal for the development of the photovoltaic industry chain. The regulation object of P5 policy mainly involves enterprises, and the policy fails to play the role of the government and consumers in the photovoltaic industry chain. When supporting the development of the photovoltaic industry chain, this policy focuses on supporting technology in the field of production and manufacturing, and fewer incentives are used. The P5 policy lacks economic incentives for the PV industry chain. In terms of Q index and B index scores, although the indicators of P5 policy scores are also acceptable levels, the scores are low, and the overall quality of the policy and the response to the photovoltaic industry are not strong.

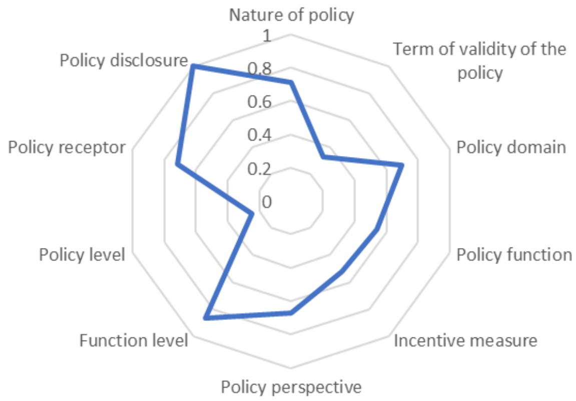

Figure 18. Radar chart of the mean values of ten first-level variables

After the specific analysis of the six photovoltaic industrial policies, this paper then makes an overall analysis of the six policies based on the mean radar map of the ten first-level variables of the six policies. Figure 18 is a radar chart of the average values of the six PV industrial policies. The mean value for nature of policy is 0.71. The photovoltaic industry policies are comprehensive in nature. These policies can describe the situation of the photovoltaic industry, forecast and supervise the development of the photovoltaic industry, and make reasonable suggestions for the photovoltaic industry. The mean value for term of validity of the policy is 0.33. Photovoltaic industry policies focus on the realization of a single deadline. The formulation of multi-period goals and measures is lacking in the policies. This will lead to a lack of coherence in policies, and the effect of policy implementation will be affected. The mean value for policy domain is 0.7. The six PV industrial policies can cover multiple fields including the economic field, the social field, the technical field, the political field, and the environmental field. Photovoltaic industry policies can promote the development of photovoltaic enterprises in these areas and promote all-round social progress. The mean value for policy function is 0.54. The six photovoltaic industrial policies failed to play all the functions of photovoltaic industrial policies. None of the six policies has played the government procurement function of the photovoltaic industry policy. While the other three functions, including product promotion, technological innovation, and supervision and management, some of the six policies did not fully play these functions. The mean value for incentive measure is 0.52. The photovoltaic industry policies have a single type of incentive measures. Many incentive measures have not been applied to the PV industry policies to support the development of the PV industry. Photovoltaic industry policies failed to generate comprehensive incentives for each subject of the photovoltaic industry. The mean value for policy perspective is 0.67. The PV industry policies can analyze and make recommendations for the PV industry from multiple perspectives. The content of the six photovoltaic industry policies involves the operation of the overall photovoltaic industry in the country, the operation of various parts of the photovoltaic industry, and the behaviors of various subjects of the photovoltaic industry, including enterprises, consumers, and the government. The six photovoltaic industry policies carried out macroscopic, mesoscopic and microscopic analysis of the photovoltaic industry. The mean value for function level is 0.87. The six national-level photovoltaic industry policies have played a role at multiple levels. Industrial policies have had an impact on the photovoltaic industry at the national level, regional level, industry level, enterprise level, and new product level have an impact on the photovoltaic industry. The six photovoltaic industry policies have given full play to the influence of policies on industrial development. The mean value for policy level is 0.25. The six policies are all national photovoltaic industry policies, so the policy level variable values of the six policies are the same, all of which are 0.25. The mean value for policy receptor is 0.72. The six photovoltaic industry policies are closely related to photovoltaic companies, governments, and consumers and can affect multiple individuals at the same time. These policies can provide guidance for the production and promotion of photovoltaic products by enterprises, the management of the photovoltaic industry by the governments, and the use of photovoltaic products by consumers. The mean value for policy disclosure is 1. The six PV industry policies are all public, so the policy disclosure variable values of the six policies are the same, all of which are 1.

5. Conclusions and policy suggestions

5.1. Conclusions

This paper first studies the structure and evolution of China's PV industrial policy based on the text of China's national and local PV industrial policy. Then, this paper selects 6 representative national PV industrial policies, uses PMC-index model to analyze the content of selected PV industrial policy samples, and evaluates each policy based on the analysis results. This study finally draws the following conclusions:

(1) From 2013 to 2021, among the photovoltaic industry policies at the national level, the proportion of environmental policy instruments is the highest, the proportion of supply policy instruments and economic policy instruments is in the middle, and the proportion of demand policy instruments is the lowest. In this period, the government focused on the use of environmental policy instruments when using the photovoltaic industry policies at the national level to regulate the photovoltaic industry. Using environmental policy instruments, the government has continuously optimized the development environment of the photovoltaic industry. In the photovoltaic industry policies at the local level, supply-oriented policy instruments accounted for the largest proportion from 2007 to 2014, and environment-oriented policy instruments accounted for the largest proportion from 2015 to 2021. From 2007 to 2021, the management focus of local government on the photovoltaic industry has changed from improving the supply level of the photovoltaic industry to optimizing the development environment of the photovoltaic industry. From 2022 to 2023, in the photovoltaic industry policies at the national level and the local level, the gap in the proportion of four types of policy instruments (supply, environment, economy, demand) has narrowed. The government used a variety of types of policy instruments to manage the photovoltaic industry.

(2) In the photovoltaic industry policies at the national level and the local level, each of the four categories of photovoltaic industry policy instruments has measures with high frequency of use. Among the supply policy instruments, science and technology support policy instruments and infrastructure policy instruments are the most

used instruments by the government. Promoting the scientific and technological development of the photovoltaic industry and the infrastructure construction of the photovoltaic industry is an important part of the government to promote the supply level of the photovoltaic industry. The government invests less in the elements of talent, public service and land. The supply structure of the photovoltaic industry is flawed. Among the environmental policy instruments, supervision and management policy instruments are the most used instruments by the government. The government pays attention to strengthening the management of the photovoltaic industry to regulate the behavior of the photovoltaic industry individuals, and then promote the construction of a good environment for the photovoltaic industry. Other environmental policy instruments, including regulatory standards, target planning, and international cooperation, are less commonly used by the government. Photovoltaic industry development environment construction system is still insufficient. Among the economic policy instruments, capital investment is the most used mode of capital regulation. The government focuses on direct regulation of photovoltaic industry funds. There is little indirect regulation of photovoltaic industry funds, and the government has a single mode of operation of photovoltaic industry funds. Among the demand-oriented policy instruments, application and demonstration policy instruments are the most used policy instruments by the government. The government stimulates the demand for photovoltaic products mainly through the establishment of application and demonstration zones and the application of photovoltaic products in various practical life scenarios. The government has a single model for stimulating demand.

(3) Under the evaluation system of PMC model, one of the six national PV industry policies selected in this paper is excellent, four are acceptable, and one is poor. There are gaps in the overall level of these policies. The policy quality index and response validity index of the six photovoltaic industry policies are above the acceptable level. The quality of the six national-level photovoltaic industry policies is guaranteed, and the policy content is scientific and feasible. At the same time, these policies can respond to the photovoltaic industry, and the policy content can respond to the problems existing in the photovoltaic industry. The average scores of six policies in X1(nature of policy), X3(policy domain), X6(policy perspective), X7(function level), X9(policy receptor), and X10(Policy disclosure) are higher, while the average scores of six policies in X2(term of validity of the policy), X4(policy function), X5(incentive measure), and X8(policy level) are lower. The high score of X10 variable is because all the six policies are public. The low score of X8 variable is because the six policies collected in this paper are all national PV industry policies. The six policies are comprehensive in nature and can have multiple levels of impact on multiple individuals and multiple sectors of the photovoltaic industry from multiple perspectives. But these policies have some drawbacks. In the six policies, the combination of long-term and short-term goals and measures is lacking. In the policies, incentive measures are insufficient, and various types of incentive measures are not used to incentivize the photovoltaic industry in many ways. The photovoltaic industry policies are insufficient to support the photovoltaic industry and cannot give full play to its role.

(4) This paper also has some limitations in the study of photovoltaic industry policy. In the process of collecting photovoltaic industry policies, this study may miss some policy texts. This makes it impossible for this study to comprehensively analyze the content of PV industry policy. In the analysis of the text content, the index analysis system constructed in this paper can not cover all aspects of the photovoltaic industry, and the evaluation of the implementation effect of the photovoltaic industry policy is not accurate enough. In the future, with the progress of text mining technology and the improvement of policy evaluation system, researchers can comprehensively analyze the production and consumption links of the photovoltaic industry based on comprehensive policy texts, and then conduct research on the development of the photovoltaic industry in multiple fields.

5.2. Policy Suggestions

Based on the dynamic evolution analysis of China's PV industrial policies and the quantitative evaluation of six PV industrial policies with the help of PMC-index model, the following recommendations are made in this paper.

(1) Promote the construction of photovoltaic projects. The government should regularly set plans for the construction of photovoltaic projects, and clarify the area and time of photovoltaic project construction. In the process of the construction of photovoltaic projects, the government should strengthen the record management, construction management and acceptance management of photovoltaic projects. For the construction of photovoltaic projects, it is necessary to improve the incentive system. The government should encourage talents with a high level of knowledge to enter the field of photovoltaic project construction and provide talent support for the photovoltaic industry. At the same time, promote grid-connected services, strengthen the construction of supporting power grids for photovoltaic projects, and improve support for related infrastructure and public services. For projects that are short of funds, the government can provide support for photovoltaic projects by providing financial subsidies, encouraging financial institutions to provide financial services for photovoltaic projects, and reducing the tax burden.

(2) Strengthen technological innovation in the photovoltaic industry. Develop a 5-year technological breakthrough plan for the photovoltaic industry, and strive to make technological breakthroughs in the field of extraction of photovoltaic raw materials and the manufacturing of photovoltaic cells and modules in the next 5 years. In the development process of the photovoltaic industry, information and intelligence should be an important direction of technological innovation in the photovoltaic industry. In the next five years, the scope of smart photovoltaics should be further. The government should actively build several photovoltaic industry technological innovation platforms, strengthen international exchanges and cooperation, promote the transformation of scientific research results, and promote the integrated development of the photovoltaic industry technology innovation field. For individuals or teams with outstanding contributions in the field of technology innovation in the photovoltaic industry, the government should give certain financial incentives.

(3) Expand the application range of photovoltaic power generation. Actively promote photovoltaic power generation to cover the government, enterprises, and consumers. Promote the application of photovoltaic power generation in all types of buildings, and encourage government agencies and industrial enterprises to install photovoltaic power generation systems. Support the installation of distributed photovoltaic systems in family homes. Strengthening integration with other areas is essential for photovoltaic power generation applications. Photovoltaic power generation can be combined with transportation, agriculture and communication. The government should actively promote the construction of photovoltaic + transportation projects, photovoltaic + agriculture projects and photovoltaic + communication projects. At the same time, the government should actively build photovoltaic application and demonstration areas, regularly plan several photovoltaic power generation application and demonstration cities, and form a complete set of photovoltaic application operation mechanism.

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