# The Effect of Photovoltaic Industrial Policies on Enterprise Innovation Performance

Yueran Wang

China University of Geosciences (Wuhan, China)

17320504508@163.com

**Abstract.** As a policy-dependent industry, it is crucial to analyze the impact of policies on enterprise performance in China's photovoltaic industry. The study takes the text of PV policies issued in China during the period of 2018-2022 and the performance of enterprises as the object, and also introduces enterprise R&D investment as a mediating variable, carries out regression analysis on the effect of PV industry policies, and examines the effectiveness of PV industry policies from the perspective of enterprise innovation. The results of the studies show that, as PV enterprises tend to move towards the "parity era" in recent years; policy strength has a significant negative impact on the performance of private enterprises, and the impact on the performance of state-owned enterprises and Chinese-foreign joint ventures is not obvious; in the eastern and central regions, the policy strength is stronger, and the amount of policy texts is higher; enterprises in the western region lack innovation and R&D vitality.

**Keywords:** Photovoltaic Industry; Industrial Policy; Innovation Performance

## 1 Introduction

Photovoltaic industry is a policy-dependent industry, and government intervention plays a crucial role in the overall catch-up process of the industry [1] .To a certain extent, industrial policy can effectively incentivize enterprise innovation and promote enterprise innovation performance, but it can also inhibit enterprise economic performance [2] .When the government implements a static incentive and punishment mechanism, the government's incentive and punishment is not related to the enterprise's willingness to technological innovation, under the dynamic incentive and punishment mechanism, the behavioral strategies of both the government and the enterprise will arrive at an equilibrium, and the reduction of the government's incentive cost can promote enterprise innovation [3]. For enterprises, R&D investment and R&D results can significantly improve performance, while performance is also positively and significantly affected by the intensity of R&D costs and development expenditure intensity [4],a prerequisite for enterprises to obtain industrial investment funds is a stable government policy, so incentive policies will have a significant positive impact on the designated industries[5]. As a matter of fact, in recent years, China's PV industry policy research results have been greatly improved in terms of quantity and quality, but they



T. Yao et al. (eds.), *Proceedings of the 2024 3rd International Conference on Engineering Management and Information Science (EMIS 2024)*, Advances in Computer Science Research 111,
https://doi.org/10.2991/978-94-6463-447-1_2

have not completely changed the problem of policy research focusing on the design principles of policy making. The research on the power mechanism of the impact of PV industrial policy on enterprise innovation performance and the completeness of the influencing factors are lacking. Therefore it is necessary to explore the impact of policy on enterprise innovation performance.

## 2 Research Methods

### 2.1 Data Source

This paper collects and organizes 113 photovoltaic industry policies issued by China's ministries and departments at the ministerial level and above from 2019 to 2022 in the database of Beida Faber. Firstly, the keywords "photovoltaic", "solar energy" and "renewable energy" in the sample are searched; secondly, the policies that are most closely related to the photovoltaic industry are selected to be counted; finally, the photovoltaic industry policies released by the National Energy Administration, the National Development and Reform Commission and other relevant departments as well as the China Renewable Energy Industry Association are collected and organized to ensure the completeness and accuracy of the photovoltaic policies.

This paper selects the panel data of A-share listed photovoltaic enterprises on the Shanghai and Shenzhen stock exchanges in 2019-2022, and the total number of enterprises whose listing time is before December 2022 and whose main business includes "photovoltaic" in the annual report is 432 in total. Financial and st-type enterprises, enterprises with zero patent applications for four consecutive years, and enterprises with a lot of financial data vacancies are excluded; statistics are based on enterprise size, fixed asset size, asset-liability ratio, return on assets, cash flow, shareholding concentration, and age of the enterprise. Finally, the number of patent applications of enterprises is manually organized. The relevant financial data of the enterprises in the research sample come from the official websites of listed companies, and the data on the number of patent applications come from the Cathay Pacific Data Patent Database.

### 2.2 Model Design

This paper constructs the following regression model:

$$Patent_{i,j} = \beta_0 + \beta_1 IP_{i,j} + \beta_2 Control_{i,j} + \varepsilon_{i,j} \quad (1)$$

$$R\&D_{i,j} = \beta_0 + \beta_1 IP_{i,j} + \beta_2 Control_{i,j} + \varepsilon_{i,j} \quad (2)$$

$$Patent_{i,j} = \beta_0 + \beta_1 IP_{i,j} + \beta_2 R\&D_{i,j} + \beta_3 Control_{i,j} + \varepsilon_{i,j} \quad (3)$$

Where, denotes the patent application volume of the Patenti,j enterprise in year t, IPi,j is the strength and the policy influence of the i enterprise in year j, R&Di,j denotes the level of R&D investment of the i enterprise in year j, and Cotroli,j denotes the control variable of the i enterprise in year j. εi,j is the perturbation term [6] .

Based on the fact that the dependent variable selected in this paper is the number of enterprise invention patent applications, which is typical discrete count data, the count

regression model should be used for estimation. Statistically, the sample ratio of 432 enterprises with no patent applications in this study is less than 5%, and the sample variance is larger than the mean, so this paper adopts the negative binomial model for empirical analysis.

### 2.3 Definition And Measurement of Variables

**(1) Explained Variables.**

This paper measures enterprise innovation performance by the number of enterprise invention patent applications.

**(2) Explanatory variables.**

In the dimension of policy quantification, this study proceeds from the three dimensions of policy content, policy form and policy strength [7].

In the policy content dimension, according to the research of Cui Wenhua [8], the PV industry policies are divided into guiding measures, support measures, normative measures, and regulatory measures, and they are refined according to the above four categories. At the same time, this paper assigns a value to the policy content with the variable "0-1", if the policy covers the corresponding measures, the value of the policy is 1, and vice versa is 0.

In the dimension of policy form, according to the legal status of the PV industrial policy form (e.g. policy regulations or departmental rules, etc.) and the level of the issuing department, the form of the PV industrial policy is assigned a score of "1-5". The higher the score, the higher the legal status of the form and the higher the level of the issuing department. Specific judging criteria are shown in Table 1;

**Table 1.** Criteria for judging the form of photovoltaic industrial policy

| value of a score | Forms of Policy |
|---|---|
| 5 | Laws promulgated by the National People's Congress and its Standing Committee (referred to as laws) |
| 4 | Regulations promulgated by the State Council and ministerial decrees of various departments (referred to as regulations and ministerial decrees) |
| 3 | Provisional regulations/opinions/plans promulgated by the State Council; regulations and provisions of various departments (referred to as opinions and provisions) |
| 2 | Opinions, outlines, plans, measures, temporary regulations of various departments (referred to as measures) |
| 1 | Notifications |

In the dimension of policy strength, with reference to the details of the quantitative criteria for the strength of PV industrial policies developed by Peng Jisheng [9] study, the collated policies are scored article by article, and the sum of the strengths of the 14 types of PV industrial policy content is used as a measure of the strength of the industrial policies.

Let $PE_t$ denote the strength of policy issuance in year t, and $AE_t$ denote the strength of policy action in year t, where i, j denote issued and canceled policies, respectively, $A_{it}$ and $C_{jt}$ denote the strength of policies issued in year t for i, and j that lapsed, $B_{it}$ and $D_{jt}$ denote the form of policies issued and canceled in year t for policies i, j, respectively, and $N_t$ and $M_t$ denote the number of policies issued and invalidated in year t, respectively.

$$P\,E_t = \sum_{i=1}^{N_t} A_{it} * B_{it} \tag{4}$$

$$AE_t = \begin{cases} P\,E_1 \\ AE_{t-1} + P\,E_t - \sum_{j=1}^{Mt} C_{jt} * D_{jt} \end{cases} \tag{5}$$

**(3) Research Variables.**

On the basis of existing research, this paper selects enterprise size, fixed asset size, gearing ratio, return on assets, cash flow, equity concentration, and enterprise age to control the impact of each variable at the enterprise level on the innovative performance of enterprises. Among them, this paper selects fixed asset size as a control variable. The name, definition and code of each variable are shown in Table 2;

**Table 2.** Study variables and definitions

| Category of variable | Variable Name | Variable Definition | Variable Code |
|---|---|---|---|
| Dependent Variable | Enterprise Innovation Performance | Number of enterprise invention patent applications | Patent |
| Independent Variables | Photovoltaic Industry Policy | Sum of the strength of 14 types of policy measures | IP |
| Mediator variable | Enterprise R&D Investment | Enterprise R&D investment/revenue | R&D |
| Control Variables | Enterprise Size | Natural logarithm of total enterprise assets | Size |
| | Fixed Asset Scale | Enterprise fixed assets/total enterprise assets | PPE |
| | Asset Gearing Ratio | Total liabilities/total assets | Lev |
| | Return on Assets | Firm's net profit / firm's total assets | ROA |
| | Enterprise Age | Age of the enterprise since listing | Age |
| | Cash Flow | Money funds / Total assets | Cash |
| | Shareholding Concentration | Sum of shareholding ratio of top ten shareholders | S-Holder |
| | Nature of Ownership | State-owned enterprises, private enterprises | Ownership |
| | Regional Location | Enterprises with registered address in eastern, central and western regions | Area |

# 3 Study Results and Analysis

## 3.1 Descriptive Statistics

Figure 1 shows the trend of China's photovoltaic industry policy strength from 2019 to 2022. It can be seen that China's photovoltaic industry policy role strength presents a continuous upward trend while the release strength shows a downward trend after experiencing a short period of significant improvement in 2020, even lower than the initial state in 2019.

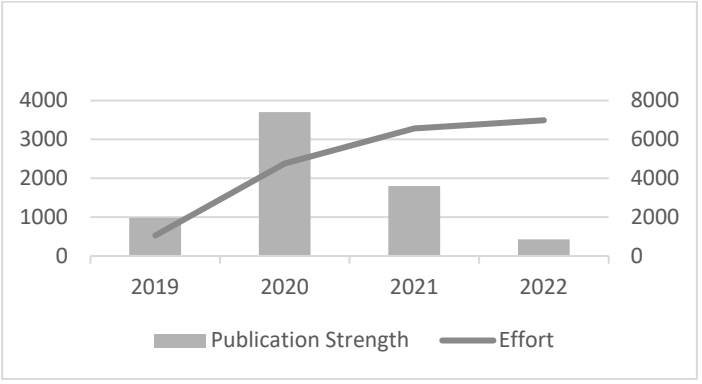


**Fig. 1.** Strength of PV industry policy release and role in China, 2019-2022

The reason may lie in the fact that China's PV industrial policy at this stage is constantly shifting towards parity priority and subsidy regression. In 2018, the central decision-making level issued the Notice on Matters Relating to Photovoltaic Power Generation in 2018, so the industrial policy regression in 2019 has a short-term bout of effect, with a significant reduction in the number of policy texts, and the strength of the release and the strength of the role of the performance of a lower level. In 2020, affected by the goal of building a moderately prosperous society in all aspects, the national level promulgated the PV policy of poverty alleviation and alleviation of poverty dimension increased significantly; at the same time, affected by the epidemic, the government promulgated the relevant preferential policies, and all over the world in the aspect of policy safeguard, technological advancement, and regulatory work, the policy role of the strength and the strength of the release of the policy showed a substantial increase. In 2021, the PV installed subsidies continued to retreat, the approval of the project by the state down to the provincial and municipal energy authorities, PV began to bear the task of pulling the local economy, tax revenue, the release of the policy to reduce the strength of the role of the strength of the phenomenon continued to rise. 2022, in the policy force and the "Bicarbon" target support, China's Continuously optimize the establishment of the national photovoltaic industry and market, promote the establishment of new energy supply and consumption system, promote the overall technical level of the photovoltaic industry, and promote high-quality development.

Table 3 shows the results of descriptive statistical analysis of the main variables of this study. On account of the sample data, the statistics on the number of invention

patent applications of different PV enterprises show that there are large differences in the innovation performance of different enterprises; enterprises are increasingly focusing on R&D investment. The catching up of Chinese PV enterprises is also gradually realized through the developmental innovation war path.

**Table 3.** Descriptive statistics analysis

| Variant | Obs | Max | Min | Mean | Std.D.Ev | Median |
|---|---|---|---|---|---|---|
| Patent | 35 | 2 097 | 5 | 262.771 | 467.802 | 69 |
| R&D | 35 | 4.353 | 0 | 0.206 | 0.726 | 0.068 |
| Size | 35 | 25.431 | 20.655 | 22.779 | 1.315 | 22.416 |
| PPE | 35 | 0.75 | 0.008 | 0.235 | 0.182 | 0.174 |
| LEV | 35 | 0.959 | 0.145 | 0.539 | 0.184 | 0.548 |
| ROA | 35 | 0.079 | -0.002 | 0.034 | 0.019 | 0.031 |
| Cash | 35 | 0.748 | 0.036 | 0.186 | 0.143 | 0.148 |
| S-Holder | 35 | 0.812 | 0.05 | 0.44 | 0.189 | 0.439 |
| Age | 35 | 23 | 0.5 | 7.529 | 6.434 | 6 |

## 3.2 Basic Regression Results

Table 4 shows the effect of China's photovoltaic industry policy on enterprise innovation performance in 2019-2022. The model shows that the policy strength will have a significant negative impact relationship on enterprise performance; the overall situation of industrial policy may be different due to the type of policy and the purpose of the policy, the impact is not obviously found; enterprise R&D investment as an intermediary variable plays an intermediary role, and the strength of the policy has a significant inhibitory effect on the performance of the enterprise.

Table 4 Empirical results of photovoltaic industrial policy on the multi-color effect of corporate innovation

**Table 4.** Empirical results of photovoltaic industrial policy on the multi-color effect of corporate innovation

| Variant | Model1 | Model 2 | Model 3 |
|---|---|---|---|
| | Patent | R&D | Patent |
| IP | -0.162<br>(-3.076) | 0.043<br>(0.344) | -0.162<br>(-3.084) |
| R&D | — | — | -0.330<br>(-1.396) |
| Size | 0.558<br>(4.256) | 0.332<br>(0.990) | 0.561<br>(4.219) |
| ROA | -2.025<br>(-0.228) | -25.745<br>(-0.987) | -3.359<br>(-0.375) |
| PPE | -0.045<br>(-1.699) | -0.748<br>(-0.308) | -3.767<br>(-3.963) |
| Lev | 1.856<br>(1.980) | 3.474<br>(1.286) | 1.959<br>(2.063) |

| | | | |
|---|---|---|---|
| Cash | 0.459 | 6.423 | 0.475 |
| | (0.381) | (2.534) | (0.392) |
| S-Holder | 2.870 | -0.287 | 2.911 |
| | (3.151) | (-0.136) | (3.195) |
| Age | -0.045 | 0.068 | -0.042 |
| | (-1.699) | (1.134) | (-1.548) |

The reasons for the emergence of the research results may be: first, the enterprise lacks of high-tech, after getting government subsidies to use the funds in the lower technology content of the project, and the government subsidy policy for the enterprise to expand production, the enterprise tends to apply the level of investment in the expansion of the industrial scale, easy to trigger the enterprise overcapacity, resulting in the phenomenon of excess resources. Second, the shortage of effective use of funds norms and incentives, policy efforts can not stimulate the inherent innovation vitality of photovoltaic enterprises. Third, at present in the domestic PV enterprise financing channels are limited, financing cost is high, technology development and innovation activities without sustained motivation and financial support.

### 3.3 Heterogeneity Test

**(1) Different ownership nature.**

From the statistical data, the Chinese-foreign joint venture PV enterprises increased substantially, probably because the market is affected by the global carbon reduction and the Ukraine crisis impact on the strong demand for PV products, PV products show volume and price increase trend, the export value of a new high.

Due to the number of state-owned enterprises involved in the effective count of the sample size of only 2, so this paper will be listed in the sample of photovoltaic enterprises into the private sector and sino-foreign joint ventures, regression results shown in Table 5. From the results, it can be seen that the policy has a significant negative impact on the performance of private enterprises, but the performance of state-owned enterprises and Sino-foreign joint ventures is not significantly affected. The reason may be that, on the one hand, private firms have greater financing constraints and less incentive to carry out R&D and innovation after receiving government subsidies. On the other hand, Chinese and foreign joint ventures have advantages in marketing, management and R&D technology, low taxes and fewer tax types, and financing, so that the accelerated subsidy rebate policy, for example, does not have a significant effects on them.

**Table 5.** Regression results by nature of ownership

| Variables | Private Enterprise | | | Sino-Foreign Joint Ventures | | |
|---|---|---|---|---|---|---|
| | Model 1 Patent | Model 2 R & D | Model 3 Patent | Model 1 Patent | Model 2 R & D | Model 3 Patent |
| IP | -0.326 | -0.057 | -0.326 | 0.039 | 0.087 | -0.005 |
| | (-5.595) | (-0.485) | (-5.595) | (0.463) | (0.243) | (-0.061) |
| R&D | — | — | -0.397 | — | — | 20.502 |
| | | | (-1.663) | | | (2.131) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Size | 0.729 | 0.604 | -0.505 | 0.122 | -0.555 | 0.686 |
| | (4.344) | (1.527) | (-2.046) | (0.559) | (-0.492) | (2.560) |
| ROA | -11.741 | -31.527 | -13.505 | 28.900 | 70.337 | 22.694 |
| | (-1.189) | (-1.172) | (-1.353) | (1.271) | (0.562) | (0.859) |
| PPE | -3.961 | -0.904 | -3.964 | -1.718 | -2.996 | -4.226 |
| | (-3.679) | (-0.361) | (-3.678) | (-0.778) | (-0.270) | (-1.513) |
| Lev | 5.713 | 4.380 | 5.955 | -1.418 | -8.364 | 0.758 |
| | (5.217) | (1.584) | (5.338) | (-0.758) | (-0.793) | (0.277) |
| Cash | -1.167 | 6.262 | -1.092 | 3.636 | 7.919 | 3.602 |
| | (-0.791) | (2.393) | (-0.736) | (1.658) | (0.759) | (1.590) |
| S-Holder | 5.811 | 0.087 | 5.848 | -4.633 | -0.789 | -4.378 |
| | (4.879) | (0.035) | (4.908) | (-2.976) | (-0.111) | (-2.804) |
| Age | -0.006 | 0.076 | 0.002 | -0.132 | 0.169 | -0.145 |
| | (-0.177) | (1.087) | (0.074) | (-1.730) | (0.433) | (-1.755) |

The explanation may lie in the fact that, first, due to the special status of state-owned enterprises, they focus on maximizing social welfare. Government R&D subsidies can effectively ensure the continuous investment of research investment by enterprises, which in turn motivates them to carry out research investment, but private enterprises as well as Sino-foreign joint ventures purely pursue profit maximization, and thus focus on technological innovation to seize technological advantages or maintain competitive advantages. Secondly, the analysis in this paper mainly focuses on the innovation performance of downstream industries, as the technological innovation activities of enterprises have natural positive social externalities and high risk, and require high investment, while enterprise innovation is mainly led by internal R&D decisions, state-owned industries are affected by their corporate nature, the degree of equity concentration is more obvious, which is not conducive to the expansion of enterprise scale.

**(2) Different regional environments.**

On the basis of empirical analysis, this paper divides the provinces (municipalities and autonomous regions) where the sample enterprises are located into three groups: east, central and west, in order to test the innovation effect of PV industrial policy on enterprises in the regional environment. The model regression results are shown in Tables 6 and 7.

**Table 6.** Eastern Region Regression Results

| Variables | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| | Patent | R&D | Patent |
| IP | -0.009 | 0.163 | -0.009 |
| | (-0.154) | (1.346) | (-0.159) |
| R&D | — | — | -0.129 |
| | | | (-0.541) |
| Size | 0.069 | 0.416 | 0.069 |
| | (0.444) | (1.157) | (0.444) |
| ROA | 8.946 | -39.877 | 8.946 |
| | (0.920) | (-1.476) | (0.920) |

| | | | |
|---|---|---|---|
| PPE | -2.657<br>(-2.474) | -0.482<br>(-0.194) | -2.657<br>(-2.474) |
| Lev | -0.690<br>(-0.672) | 4.275<br>(1.618) | -0.690<br>(-0.672) |
| Cash | 2.502<br>(2.028) | 6.060<br>(2.401) | 2.502<br>(2.028) |
| S-Holder | -0.219<br>(-0.205) | -0.029<br>(-0.013) | -0.219<br>(-0.205) |
| Age | -0.048<br>(-1.452) | 0.065<br>(0.881) | -0.048<br>(-1.452) |

**Table 7.** Central Region Regression Results

| Variables | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| | Patent | R&D | Patent |
| IP | -0.336<br>(-3.095) | -0.106<br>(-0.216) | -0.060<br>(-0.548) |
| IP | — | — | 56.049<br>(4.812) |
| R&D | 0.857<br>(3.484) | -0.351<br>(-0.281) | -0.097<br>(-0.386) |
| Size | 127.705<br>(4.390) | 59.881<br>(0.565) | 20.623<br>(0.693) |
| ROA | -7.409<br>(-3.087) | -2.835<br>(-0.237) | -6.720<br>(-2.046) |
| PPE | 7.735<br>(3.061) | -4.138<br>(-0.342) | 1.364<br>(0.535) |
| Lev | -6.413<br>(-0.817) | -3.873<br>(-0.103) | -6.413<br>(-0.817) |
| Cash | 6.867<br>(3.226) | 1.064<br>(0.109) | 6.867<br>(3.226) |
| S-Holder | 0.219<br>(4.338) | 0.001<br>(0.006) | 0.219<br>(4.338) |

From the results of Table 6 and Table 7, it can be seen that the PV industry policy does not show significance to the eastern enterprises, and it is significant to the central enterprises at the level of 1%, which indicates that the central policy strength has a notable negative impact on the innovation performance of enterprises.

This can reflect the regional differences on the development of photovoltaic projects have an important impact on the economic level of the region, such as the eastern region, the relative superiority of the location advantage, the key raw material reserves, railroads and highways, convenient transportation, enterprise financing channels to broaden the policy continued to guide the industry under the guidance of high-quality development. For the northwest region, light energy is abundant, power generation cost is relatively low, occupies the national important photovoltaic market, but the northwest region is facing severe consumption pressure, there is a high risk of power abandonment, the main grid, site layout and transmission capacity has been difficult to satisfy the needs of rapid development of the photovoltaic industry, in order to attract and retain the energy-intensive enterprises, enterprises use the way to depress the

tariffs, the concessions are large, which leads to corporate innovation Lack of investment, there are still deficiencies. Especially after the announcement by the NDRC in 2021 that the central government will no longer subsidize PV projects, the difference in this regard is even more obvious.

## 4 Conclusions

The main research results and conclusions of this paper are as follows:

(1) Policy strength will have a negative effect on enterprise performance, and enterprise R&D investment plays a mediator role in enterprise performance.

(2) From the perspective of the nature of enterprise ownership, the nature of enterprise ownership also has different impact effects on enterprise innovation performance. Policies have an inhibitory effect on the performance of private enterprises, and have a non-significant effect on the performance of state-owned enterprises and Sino-foreign joint ventures.

(3) From the perspective of different regional environments where enterprises are located, regional differences have an important impact on the development of PV projects. East and central regions, the location advantage is relatively superior, the policy strength is relatively greater, the amount of policy text is also more; while the western region market size is smaller, the degree of competition is weaker, the enterprise lack of innovation and research and development vitality.

(4) PV enterprises on policy dependence weakened. With the PV policy changes in recent years, the PV industry is becoming more and more popularized, popularization, PV enterprises tend to move towards the "parity era" that does not require subsidies. Enterprises are gradually reducing their reliance on policies.

## References

1. Gao P. Government in the catching-up of technology innovation: Case of administrative intervention in China[J]. Technological Forecasting & amp; Social Change, 2015 (96) :4-14.
2. WANG Fengyun, WEN Xinyou, LI Xiaohu. Research on the dynamic impact of electricity price subsidy on renewable energy generation[J]. Price theory and practice,2019(04):54-58.
3. LI Fengmei, LIU Shilin, GAO Yuchen et al. The impact of industrial policy on innovation and economic performance of photovoltaic enterprises in China[J]. Science and Science and Technology Management,2017,38(11):47-60.
4. XU Xuan, HUANG Junling, WEN Ke. Intermittent equilibrium of policy change in China's photovoltaic industry: based on policy process theory[J]. Science and Technology Management Research,2022,42(20):48-56.
5. Murray B C, Cropper M L, Del C F C, et al. How effective are US renewable energy subsidie s in cutting greenhouse gases? [J].American Economic Review, 2014, 104 (104) :569-7.
6. CHENG Cheng, AN Runfei, DONG Kangyin, REN Xiaohang, WANG Zhen, ZHAO Guohao. Research on innovation strategy of renewable energy power generation enterprises under the guidance of carbon trading mechanism--Based on the perspective of evolutionary game[J/OL]. China Management Science:1-13[2023-04-24].

7. MA Dandan, HUANG Jiahao, HE Xin. "Qualitative study on photovoltaic industry policy during the 14th Five-Year Plan period[J]. China Market,2022,1119(20):82-84.
8. Fu Hongjuan. Research on the impact of China's photovoltaic industry policy on corporate innovation performance [D]. North China Electric Power University (Beijing), 2020.
9. PENG Jisheng, SUN Wenxian, ZHONG Weiguo. An empirical study on the evolution and performance of technological innovation policies in China (1978-2006)[J]. Research Management, 2008(4):134-150.