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Performance Evaluation on Intellectual Property Rights Policy System of the Renewable Energy in China

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Abstract: With the intensive consumption and price rising of traditional fossil fuels, the development and utilization of renewable energy has attracted worldwide attention. Meanwhile, due to enhanced energy constraints and increasingly grim greenhouse gases, many countries all over the world have been developing renewable energy technologies to promote sustainable growth economically. Intellectual property rights (IPR) policy linked to renewable energy provides institutional guarantee for the development of renewable energy industry and technology. This study works to test the performance of IPR policies of renewable energy industry in China. We employed Cobb-Douglas production function and built on a quantitative policy indicator measurement system over the period from 2004 to 2013 to evaluate the impact of IPR policy of renewable energy industry on innovation and market development in China, which provides an all-round study on the IPR system by clearing up all IPR policy system that is related to the renewable energy industry. The results of Multiple Regression Models indicated that the current IPR policy of renewable energy industry are disconnected from China's reality because the innovation ability of the renewable energy industry has not been improved rapidly and that both the market transformation ability and market prospect of new energy technology patents are weak.

Keywords: intellectual property rights; policy; renewable energy industry; innovation; China

1. Introduction

Global greenhouse gas emissions must be curbed before 2020 if the rise in the global average temperatures is to be kept below 2 °C, and irreversible hazards are prevented. Massive investments in the development of low carbon technologies are required to achieve this goal. Particularly in developing and emerging economies, where energy demand has been continuously rising, the quick development and use of renewable energy technologies are essential. To ensure that these technologies will become available in a timely and affordable manner, some call for more flexibility in dealing with the relevant intellectual property rights (IPR). Patented energy technology takes two to three decades to reach the mass market or become widely used in subsequent inventions [1]. Only if innovators have their invention protected over a long period of time, there will be incentives for them to innovate sufficient returns to innovators' investment. Therefore, there exists close relationship between intellectual property rights, renewable energy technology and sustainable development.

Renewable energy industry is viewed as a critical area of Chinese national strategic emerging industries. The phrase "renewable energy" first appeared in national policy in the 1991 People's Republic of China's Ten-Year Plan of the National Economy and Social Development and the Eighth Five-Year Program Outline before it appeared together with the "Intellectual property rights" in the 1995 State Council's Decision on Accelerating Scientific and Technological Progress. In terms of the conception of "IPR policy of the renewable energy industry", from the perspective of whether these policies are directly related to IPR or not, they are divided into an IPR core system as well as an IPR supporting system respectively. The former means the systems where the term of "IPR" is in the title of the policy, and clearly puts forward to promote the creation, application, protection and management of renewable energy technologies IPR, such as "Suggestions on Strengthening IPR Work of Strategic Emerging Industries" (the policy of Suggestions on Strengthening IPR Work of Strategic Emerging Industries can be read in https://wenku.baidu.com/view/ca9adcf8910ef12d2af9e71a.html), a document jointly issued in April 2012 by the State Intellectual Property Office, the National Development and Reform Commission, and certain other departments. Meanwhile, these types of system also cover other IPR systems, like "Patent Law" and "Anti-unfair Competition Law". The latter means the policy whose title does not appear directly the word of IPR. In fact it can promote technology creation, use, protection and management, including all kinds of policies of finance, taxation, science and technology, education and industry, etc. An example of such policy is the "Instructions to Promote the Internationalization of Strategic Emerging Industries" (the policy of Instructions to Promote the Internationalization of Strategic Emerging Industries can be found in https://wenku.baidu.com/view/65b5f5651ed9ad51f01df282.html), a policy issued by ten departments including the Commerce Department and the State Intellectual Property Office, in 2011, which explicitly put forward that the creation, application, protection and management of IPR should be promoted. Enterprises are encouraged to apply for patents and register trademarks overseas as doing so will strengthen the appraisal of intangible assets, such as scientific and technological achievements and patents, and promote the healthy development of technology innovation and transformation. Furthermore, relevant laws and regulations of IPR in international trade should be improved step by step, IPR disputes should be properly addressed, the strike of IPR infringement should be reinforced, and the abuse of IPR should be prevented. IPR policy linked to renewable energy industry researched by this work is mainly within the framework of policy enacted by the National People's Congress and its standing committee of China, the state council and its ministries and commissions of China, the State Intellectual Property Office in China, and the Chinese National Energy Administration.

The study works to explore the performance of IPR policy of renewable energy industry in China. In contrast to existing studies which viewed patent application or research and development (R&D) spending as industry technological performance, and mainly concentrated on one policy area, this study employs Cobb-Douglas production function, and builds on a quantitative policy indicator measurement system over the period from 2004 to 2013 to evaluate the impact of IPR policy of renewable energy industry on innovation and market development in China. The approach of this study gives some new considerations in on-going debates in policy evaluation and energy industry development. First, by designing policy evaluation index system, we avoid one-sidedness of proxy variables. Second, this study is most likely to cover all IPR policy of renewable energy industry in China.

Though the history of 'renewable energy' has been more than 20 years in all kinds of policies in China, the development of renewable energy industry is not optimistic: the lack of independent innovation, IPR as well as core technologies which has formed the bottleneck of China's renewable energy industry development [2]. In recent years, the policy of promoting the development of renewable energy industry is emerging, including a large number of IPR policy, and policy-issuing agencies include the central government, local government, and industry associations. While there were increasingly more patents emerging in China and innovation was becoming increasingly popular in the country, patent quality, to some extent, did not keep pace with the speed with which patents were being issued, and in reality, China's innovating capabilities were exaggerated [3]. Have the IPR policy of renewable energy industry been demonstrated to be successful with respect to performance measures, and has renewable energy industry attained its expected goal? In this paper, we find evidence that the current IPR policy of renewable energy industry are disconnected from China's reality because the innovation ability of renewable energy industry has not been improved rapidly, and both the market transformation ability and market prospect of renewable energy technology patents are weak.

The OECD has indicated that IPR plays a vital role in incentivizing innovation and the transmission of knowledge and economic performance [4]. The relationship between IPR and economic performance is described as an inverted-U curve where IPR norms arrive the highest point of rigidity from which the trade-off between the positive aspects of IPR for owners is eclipsed by the negative aspects [5]. However, some researchers question the inverted-U relationship because they think that the interests of IPR would taper off [6], and these studies believe that innovation can greatly increase IPR protection strength [7,8]. This thought has prompted the northern countries to promote strong IPR strength in the world and enhanced their technological innovation ability [9]. Also, higher IPR protection in the developing countries promotes intra-firm technology transfer, particularly patent-based technologies [10].

Regarding the relationship between IPR system and innovation, Daron and Ufuk, arguing that patents make a difference in innovation and economic performance, studied to what extent as well as in what form the IPR of innovators should be protected [11]. To research the reciprocity of IPR and competition, and especially to comprehend the policies effects on future incentives, they employed a dynamic framework in their study. They also verified that there was a steady–state equilibrium between competition and IPR and described some of its features. They then conducted a quantitative analysis to determine the influence of diverse types of IPR policy on equilibrium growth and well-being. Accordingly, the most significant result of their analysis was that exhaustive patent protection is unreasonable and that, on the contrary, the best policy was state-dependent IPR protection, noting that when such protection was afforded to the leader of the technology, they found to be further ahead than those who closely followed the leaders. Geroski focused on the study of IPR and its system, which was popularly used in numerous developed countries and regions, thinking that the system would have a negative impact on those countries [12]. The most obvious concern was that patent licenses that granted exclusive rights in society would limit the application of those rights in space. Furthermore, it was considered possible that the fierce competition in the present market would be controlled because every product would be made according to patent licenses. However, there were also some other effects. For example, as the system was likely to change policy aims, it would be able to stimulate people's innovative thinking. Geroski argued that even if patents together with the other policies in the system could not totally ban innovation, they might, to some extent, distort the incentives from various perspectives so that they would reduce and do harm to the value of what people innovate [13]. In terms of competition, the Federal Trade Commission in the US concluded that competition and patent policy contribute to innovation, and therefore, it is necessary that the two should reach a balance to generate positive effects [13]. Also, we have to note that in the process of interpreting the rules of one policy, there existed errors and biases that would minimize the effectiveness of other policies [13].

Archibugi and Filippetti think that IPR regime and its potential can contribute to innovation and also promote diffusion [14]. This finding has lead researchers to emphasize the policy importance of the government with respect to the development of technology. Mao and Cheng believe that the distribution of IPR was a country's arrangement of its place in the strategic emerging industry chain, that patent pool policies helped to integrate the research and development resources of strategic emerging industry, and that softer IPR policy will accelerate industry development by meeting different technologies demand [15]. Zhu confirms this result, concluding that IPR and international standard competition regarding the patent pool were of great significance to a country or region's economic development, industrial upgrading, and security [16]. Yang and Li, basing their study of A-share listed renewable energy industry companies in Shenzhen and Shanghai for the 2007 to 2010 period, are successful in building a structural equation model to test the contributions of IPR to the managing performances of enterprises [17]. The second is on the renewable energy policies' contributions to technological and economic performance and coordination with respect to relevant taxes, and IPR pledge policy. In addition, there existed certain rules in China's current tax policy that are not beneficial to the development of the strategic newly emerging industries. For instance, citing Heilongjiang Province as an example, Liu and Cai thought that the input tax of equipment purchased during the R&D period cannot be deducted because no end product is sold, and that individual income tax of R&D personnel is heavy [18].

Overall, the existing studies have advanced the field and also have offered theoretical supports and references to this research. However, there are some weaknesses. (1) Few studies on IPR policy of renewable energy industry employed measurement models to carry out quantitative researches. However, these descriptive comparative studies are relatively difficult to expedite specific relationships between policies, economic growth and technology progress, and also hard to precisely evaluate the effects of IPR policy on economic performances of renewable energy technology; (2) The existing studies mainly concentrated on one policy area, like the single policy domain of finance or banking. However, such a narrow focus does permit the full capacity of exploring the macro-performance of policy system. The research aims at conducting a study on IPR policy linked to renewable energy industry with employing an integrative, systematic method to carry out a comprehensive study and then establishing a current IPR policy panorama. Based on establishing a multiple regression model to study the performance of current policy system, the study identifies its deficiencies.

The rest of this paper proceeds as follows: the second section presents the policy data and its measurement, as well as econometric model. Our empirical results are discussed in Section 3. Finally, the fourth section offers conclusions and gives policy implications.

2. Data and the Empirical Model

In order to test the policy performance, using the key words "renewable energy" and "IPR", we searched database of Magic Weapon of Peking University (pkulaw). The database of pkulaw contains all China's central and regional laws and regulations since 1949, and is the most mature, professional and advanced legal information omnidirectional search system at present. Moreover, it can carry out data mining and knowledge discovery of legal information, which is conducive to carpet search for the IPR policy of renewable energy. In addition, the database is very popular in IPR policy studies and has been used by many researchers, such as Zhu and Stephen et al. [19,20]. After grouping these policies according to release departments, we checked official websites of State Intellectual Property Office of the P.R.C, Ministry of Science and Technology of the P.R.C and the Chinese National Energy Administration to ensure no policy has been omitted. The retrieval results show that until 2013, there were 373 IPR policy regulating renewable energy industry, among which there were 18 laws, 52 regulations, 293 department rules, 1 judicial interpretation, 5 group stipulations of the Central Committee of Communist Party of China, and 4 industry stipulations (Figure 1). In this paper, the statistics were collected and summarized by the authors.

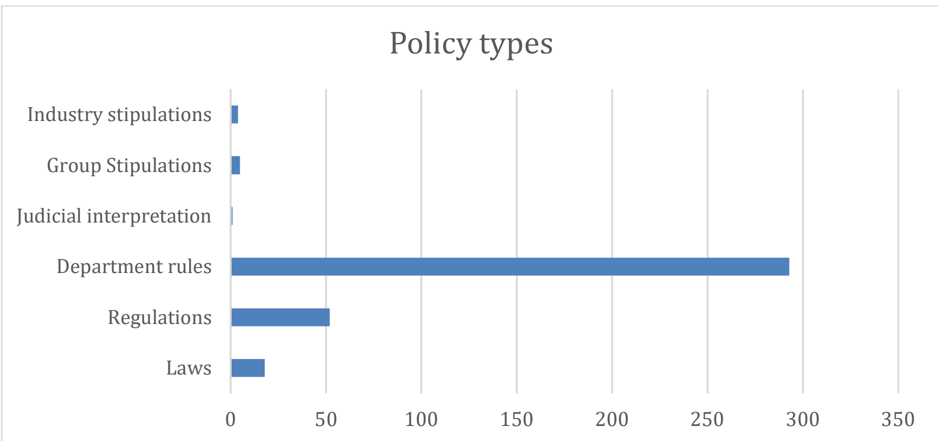

Figure 1. Intellectual property rights (IPR) policy types of renewable energy.

There are two popular approaches that have been developed to conduct quantitative study of policy. The first is experimental design, including before-after analysis, projection-after the implementation, and control object-experimental object analysis [21]. Gary concentrated the activities of the state of Nevada on mineral property into a legal change index. After examining the empirical and legal studies of mining laws, he chose 15 categories to describe the importance of mineral property [22]. Computational method of policy is to look at each law carefully and compare these laws with previous laws. The second is statistical analysis whose performance is to use proxies. Lerner studied the determinants of patent system of 60 countries in the past 150 years, finding that economic development and legal traditions play an important role in making IPR standards, and that patents are a popular indicator and have many advantages because they are replicable, standardized and accessible [23]. In addition, Yin and Lu, Yin, Pan, and Lu analyzed the FDI policy of China's central and local government and the content of the policy is quantified [24,25]. However, the policy measures are limited and one-sided, and the key shortage is that policy hierarchy is not taken into account because current studies focus on policy at the same level, while the policy at different levels will involve more policy queues, which will be more complicated [26].

In addition, some studies focus on policy coordination, especially the contribution of innovation policy to economic performance [27,28]. Although these studies quantified the policy of innovation, technology and economic growth, they do not study policy coordination from the content of policy. Among these studies were certain noteworthy features. For example, Peng et al. made two attempts to incorporate a quantitative analysis into China scientific and technological policy studies [26]. Using a technology innovation policy as a study case, they conducted significant exploratory research in policy quantization and depicted the policy synergy evolutionary path and its influence on economic performance through quantized policies. Their major contribution, however, is that they create a specific operation manual for policy quantitative criteria and come to some enlightening conclusions. Collecting technology policy issued between 1978 and 2006, they selected for a quantitative analysis on 423 policies of those that are most relevant to scientific and technical innovation. From the analysis, they developed a quantitative description of the evolutionary track of China's technology innovation policy since 1978. A pioneering aspect of this paper is that the variable of science and technology policy was introduced into the Cobb-Douglas production function to explore the influence of policy on economic and technical performances. Sheng and Kong conducted an empirical study of the influence of IPR policy on technical innovation performance in China and concluded that national government should take advantage of appropriate policy, realize the positive growth effect of full IPR protection, improve IPR policies, and continue to maintain legislative authority [29]. Thus, this study draws on the methods of Gary and Peng et al. to quantify IPR policy of renewable energy industry in China [22,26].

This study references and constructs its index system based on that constructed by Peng et al. [26] and follows the count method of Gary [22]. However, to measure the IPR policy system of renewable energy industry, the study adds the index of policy relevancy and changes the type of policy measure from five in Peng's study to four. In the index system of Peng et al., there is no policy relevancy. However, in this study, we choose the dimension of policy relevancy because our study focuses on IPR policy. Therefore, we have to eliminate policies that are not related to IPR in a large number of renewable energy policies. Moreover, policy relevancy can make up the insufficient of policy hierarchy because policy hierarchy is more concerned about administrative levels, whereas policy relevancy emphasizes policy texts. In addition, there is a dimension of financial foreign exchange measures, and our study thinks that there may be duplication of financial foreign exchange measures and other economic measures, which may lead to multiple collinearity of econometric models. Thus, we categorize financial foreign exchange measures into other economic measures. Also, according to the development of China's new energy industry, we offer a new counting standard. In addition, we narrow the measure range of Peng et al., who focus on all science and technology policy, to IPR policy of renewable energy. The indexes (independent variables that include legal hierarchy of policy, policy goals, policy relevancy, and policy measures) to assess policy performance are designed as follows:

(1) Organizations issuing policies and types of policies. The legal hierarchy of polices is graded according to the organizations issuing the policies as well as the types of policies. As the legal hierarchy of the policies represents its weight, a higher legal hierarchy ensures a greater weight of the policy. Generally speaking, a policy should be widely interpreted. In China, policy includes the laws and the rules or regulations (as determined by the government). Thus, the policy system incorporates constitution, basic laws, judicial interpretations, administrative, departmental and local regulations, and government established rules that are made and published by various departments. The legal hierarchy of a policy is as follows: the Constitution has the greatest power, which is followed by the basic laws. Whether the judicial interpretations and the basic laws have the same authority is not clear, but it is clear that the legal hierarchy of administrative regulations, department regulations, and local decrees are less powerful than the laws. Moreover, the different types of policies released by the State Council and various ministries and commissions also possess varying degrees of legal power. This article identifies different policy types according to the body that advances the policy, that is, the higher the legal status and administrative level, the greater the weight of the policy.

(2) Policy goal. Policy goals are classified into four types—encouraging innovation, promoting transformation, improving management, and strengthening protection. A more specific policy goal that has more objectives to encourage innovation, promote transformation, improve management, and strengthen protection is of greater weight than policies that have few objects. Similarly, a policy goal that involves more legislation and more law enforcement is of heavier weight.

(3) Policy relevancy. The authors have designed the index to analyze the relevancy between policy of renewable energy industry and IPR, which is further classified into four levels, namely, highly relevant, relevant, generally relevant, and marginally relevant. Highly relevant refers to the condition that the whole policy is relevant to IPR; relevant refers to the subtitle of the policy, which is relevant to IPR; generally relevant refers to the level-3 title or a paragraph of the policy that is related to IPR; marginally relevant refers to the condition that there are only several sentences that are related to IPR.

(4) Policy measure. This dimension mainly refers to the supporting measures that promote IPR, including fiscal and taxation measures, talent measures, administrative measures, and other economic measures. When the policy supporting measure is more specific and more strongly supported, it is of greater weight. The indexes and their scores are presented in Appendix A.

After marking the values of every policy, this paper accumulates every index of every relevant policy for every year. This paper follows with interests in yearly data for the various technical policy indexes from 2004 to 2013. The formula of the measurement model is as follows:

$$TPG_i = \sum_{j=1}^{n} PG_j * P_j \tag{1}$$

According to Peng et al. [26], in the formula, "i" means the year ranging over the period from 2004 to 2013; "N" refers to the number of policy issued in year i; "j" represents ordinal number of the policy issued in year i ranging from 1 to n; "PG_j" refers to the values of the NO. j policy goals and measures. In terms of calculating the yearly legal hierarchy of the policy, PG_j = 1. "TPG_i" represents the overall legal hierarchy of technical policies and general situations of various policy goals and measures in year i. In addition, P_j represents the legal hierarchy of the j policy.

If a policy is not abolished, it will sequentially influence the economic subject. Correspondingly, it is the accumulation of policy up to a certain point rather than the policy promulgated in one specific year affecting the operations of the real economy operation. Thus, the policy's scores at a certain point are accumulated through using the formula $NTPG_i = TPG_{i-1} + TPG_i$. In line with this formula, various indictors of the technical policy are calculated, including policy number, legal hierarchy of the policy, policy goals, and policy measures. During the process of calculation, adjustments needs to be made according to the abolishment of certain policies and the overlapping of policies in different periods [26].

In order to carry out a profound study of the effects on the economic performance of renewable energy industry from the perspective of IPR policy, such as their types, goals, measures, and relevancy, with borrowing the method of Gray [22] and Thrainn [30], this research introduces the policy variables into the Cobb-Douglas production function and establishes the following measurement model. The meanings of the relevant variables are presented in Table 1. As the dependent variables (MI and PG) are continuous variables and their values are arbitrary values within the range of real numbers, an OLS regression model based on Cobb-Douglas production function can meet our requirements. In addition, regression models are widely applied in energy policy as well as science and technology policy [31].

Table 1. Definition of the variables.

Name of Variables	Meaning	Name of Variables	Meaning
N	number of policies	IH	legal hierarchy of policy
SP	strengthening protection	EI	encouraging innovation
PT	promoting transformation	IM	improving management
EM	other economic measures	AM	administrative measures
HM	human resource measures	TM	fiscal and taxation measures
PR	policy relevancy	L	number of scientific and technical staff
I	scientific and technical input from national finance	MI	marketization index
PG	number of the patents granted in renewable energy		

Models presented by means of Equations of (2)–(6) can explore the technical and economic performance of renewable energy industry based on policy number, legal hierarchy of the policy, policy relevancy, policy goals and policy measures, respectively, and TP represents the economic performance of renewable energy industry where the marketization index refers to technologies with licenses. As the marketization index and the granted patents are the outputs of economy, they are regarded as the performance of renewable energy industry.

$$\ln TP = \alpha + \beta_1 \ln I + \beta_2 \ln L + \beta_3 \ln N \tag{2}$$

$$\ln TP = \alpha + \beta_1 \ln I + \beta_2 \ln L + \beta_3 \ln IH \tag{3}$$

$$\ln TP = \alpha + \beta_1 \ln I + \beta_2 \ln L + \beta_3 \ln PR \tag{4}$$

$$\ln TP = \alpha + \beta_1 \ln I + \beta_2 \ln L + \beta_3 \ln SP + \beta_4 \ln EI + \beta_5 \ln PT + \beta_6 \ln IM \tag{5}$$

$$\ln TP = \alpha + \beta_1 \ln I + \beta_2 \ln L + \beta_3 \ln EM + \beta_4 \ln AM + \beta_5 \ln HM + \beta_6 \ln TM \tag{6}$$

3. Results and Discussion

To investigate whether the phenomenon of spurious regression might occur, before evaluating the models, an Augmented Dickey-Fuller (ADF) test and a co-integration test should be conducted on all variables in the models. First, the variables reflecting the number of policy, the legal hierarchy of the policy, the policy relevancy, the policy goals and the policy measures are assessed. The test results, presented in Table 2, suggest that Models (2), (3), (4), and (5) are all zero-order co-integrated, and thus meet the necessary conditions of co-integration which portrays the nonlinear adjustment mechanism between economic variables. However, the numerical result of the policy numbers in Model (1) does not pass the ADF test. After the first-order difference is performed, its ADF test result is stable, however, and can also be used in the empirical analysis. We use STATA to do these tests.

Table 2. The Augmented Dickey-Fuller (ADF) test results.

Variables	ADF Test Statistics	Critical Value	Conclusion	Significance Level
lnPG	−6.702416	−2.93722	Stable	1%
lnMI	−7.574206	−3.00741	Stable	1%
lnI	−18.39596	−2.93722	Stable	1%
lnL	−2.963548	−2.93722	Stable	1%
lnN	−2.04397	−2.95397	Unstable	1%
lnIH	−2.479729	−3.00741	Stable	1%
lnPR	−2.179506	−2.02119	Stable	5%
lnSP	−2.002408	−1.59729	Stable	10%
lnEI	−2.790058	−2.02119	Stable	5%
lnPT	−3.077997	−3.00741	Stable	1%
lnIM	−1.677001	−1.59729	Stable	10%
lnEM	−2.610826	−2.04397	Stable	5%
lnAM	−2.127826	−2.02119	Stable	5%
lnHM	−2.225427	−3.00741	Stable	1%
lnTM	−2.062283	−3.00741	Stable	1%

Second, a co-integration test is conducted on the variables of 5 models, and results are presented in Table 3. To validate the results, a regression test on the 5 models is performed to assess the residual series and formalise the co-integration relationship between independent and dependent variables as well as their long-term equilibrium relationships. The results indicate that the residual series of the models are stable, and the unit root is in non-existent. Thus, the independent variables are able to linearly interpret the dependent variables in all models.

Table 3. The unit root test results of residual series.

Null Hypothesis	ADF Unit Root Test Value of Residual Series	1% Critical Value	5% Critical Value	10% Critical Value
The unit root of residual series of policy numbers equation being in the existence	−4.026256 ** −3.316856 ***	−3.2714 −3.2714	−2.08232 −2.08232	−1.5998 −1.5998
The unit root of residual series of policy efforts equation being in the existence	−3.851869 * −3.815898 ***	−3.2714 −3.2714	−2.08232 −2.08232	−1.5998 −1.5998
The unit root of residual series of policy correlation equation being in the existence	−3.694233 *** −9.148982 ***	−3.2714 −3.2714	−2.08232 −2.08232	−1.5998 −1.5998
The unit root of residual series of policy measures equation being in the existence	−9.79775 *** −9.79775 **	−3.2714 −3.2714	−2.08232 −2.08232	−1.5998 −1.5998
The unit root of residual series of policy targets equation being in the existence	−3.757848 ** −3.757848 ***	−3.2714 −3.2714	−2.08232 −2.08232	−1.5998 −1.5998

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

To sum up, test results show that there is co-integration between independent and dependent variables in all models and a long-term equilibrium relationship between the economic performance of IPR policy of renewable energy industry and policy numbers, legal hierarchy of the policy, policy correlation, policy goals, and policy measures. Thus, spurious regression of all models is determined to be non-existent.

Results of the regression estimation of Models (2) to (6) are demonstrated in Table 4, respectively. Overall, all regression equations pass the test, thus indicating that intellectual property rights policies can persuasively explain the economic performance of the renewable energy industry.

Table 4 indicates that the number and legal hierarchy of IPR policy in renewable energy appear to markedly influence the technical performance of the industry and that with more policies and stronger policy legal hierarchy, the economic performance would be improved. In other words, increasing the number of policy and the legal hierarchy of policy would significantly enhance the performance of renewable energy industry. Furthermore, it is concluded that the policy's contribution to economic performance can be precisely explored using these two indexes. With a 1% growth in policy number, invention patents granted in renewable energy technology and technologies with licenses implemented would increase by 0.168% and 4.22%, respectively. When the legal hierarchy of the policy increases by 1%, invention patents granted in renewable energy technology and technologies with licenses implemented would increase by 0.050% and 0.040%, respectively. Accordingly, IPR policy is a marked driving force in the development of renewable energy industry, and policy number plays a fundamental role in this development. The greater the number of policies is, the more attention the government will pay to IPR of renewable energy. The positive effect of the number of policy indicates that in the process of policy implementation, and the policy function is not alienated. In other words, policy is not divorced from the actual level and speed of science and technology development in China. In addition, even if the legal hierarchy of IPR policy has weaken positive effect on number of the patents granted in renewable energy and marketization index, there is no doubt that it has an important role in promoting the technology market.

Increase in the number of policies and the legal hierarchy of the policy has a marked positive influence on the performance of renewable energy industry, and their contribution rates are both relatively high. Accordingly, the authors of this paper hold that in the process of the improvement of IPR policy in renewable energy technology, attention should be paid to the increase in the number of policies, especially the increase in the policies released by the departments in charge of science and technology. At the same time, more attention should be paid to policy hierarchy as well. The years 2004 to 2011 have witnessed a steady development of IPR policy in the renewable energy industry. With respect to the number of policy established, the speed of policy issuance increased greatly, with more than 170 policies being issued by various institutions, which accounted for 45.6% of the total IPR policy in the renewable energy industry. Policies jointly issued by institutions such as the National Development and Reform Commission, the Department of Treasury, the Ministry of Science and Technology and the State Intellectual Property Office account for a high percentage, while the percentage of policy issued independently by the Ministry of Science and Technology or the Department of Energy are relatively low. As a traditional management system is in place in the science and technology management departments (the Commission of Science and Technology, the Ministry of Science and Technology) and the State Intellectual Property Office does not have enough economic and administrative resources, their influence on the promulgation and implementation of policy or their influence on the main technological innovation bodies (such as enterprises, universities, etc.) is far less than the influence of the Economic and Trade Commission, the National Development and Reform Commission, the Ministry of Finance, the Ministry of Taxation, and other agencies in charge of a large number of economic and administrative resources. Furthermore, in the context of reform and opening to the outside world, those agencies (mainly the Ministry of Foreign Trade and Economic Cooperation, the Customs, etc.) are the key foreign economic departments responsible for implementing the strategy of exchanging the market with technology. Therefore, to some extent, the management department of science and technology can make policy decisions about technology innovation, but the specific implementation must be coordinated with those departments owning strong economic and administrative resources. Furthermore, there is a tremendous cost associated with the process of coordination, and in some cases, the management department of science and technology is trapped within those powerful departments. "The core institutions issuing policies are not the departments in charge of science and technology, but those controlling key economic and administrative resources, mainly due to the tradition of favorable allocation of economic and administrative resources as well as the fact that various departments all try to pursue the most economic and administrative resources for themselves" [26]. As a result, each department is more concerned with their own interests than with economic performance. To change this situation and to increase policy discourse within the department of science and technology and improve economic performance, more policies that promote the development of science and technology should be issued by the department of science and technology. In addition, with respect to the legal hierarchy of the policy, there appears to be a downward trend during this phase regarding the policy issuing institutions [32]. The major issuing institutions are the ministries and commissions of the state council rather than the National People's Congress and its standing committee, though it is the former that independently or jointly issues various specific measures. Thus, on the surface, the legal hierarchy of the policy is declining, yet the results of the regression analysis indicate that the legal hierarchy of the policy contributes greatly to the economic performance. A possible reason is that the increase in policy decision makers, the strengthening of the labor division and the increased level of cooperation among various departments have enhanced the efficiency of policy. The result is that the policy number and the legal hierarchy of the policy during this period have improved the IPR policy performance of renewable energy industry. Accordingly, the authors hold that, given the legal hierarchy of the policy's marked influence on the economic performance of the renewable energy industry, emphasis should be placed on the issuing of high-validity policies, such as laws.

Table 4. Regression results of models (2)–(6).

		α	**I**	**L**	**N**	**R^2**	**D-W**			
Model (2)	PG	7.768 0.902	1.167 * 2.216	−0.317 −0.525	0.168 ** 0.274	0.791	1.209			
	MI	11.778 0.139	6.93* 1.336	−2.589 −0.435	4.22 *** 0.699	0.756	2.183			
		α	**I**	**L**	**IH**	**R^2**	**D-W**			
Model (3)	PG	3.756 5.96	1.227 * 29.805	−0.051 −1.074	0.05 * 1.066	0.695	0.084			
	MI	1.745 54.065	0.01 8.685	0.064* 8.007	0.04 ** 2.106	0.623	0.059			
		α	**I**	**L**	**PR**	**R^2**	**D-W**			
Model (4)	PG	−2.147 −3.838	1.414 * 4.135	0.032 0.749	0.171 *** 5.436	0.595	0.137			
	MI	23.09 4.136	4.898 15.325	−3.069 −7.201	1.685 ** 5.367	0.755	0.193			
		α	**I**	**L**	**SP**	**EI**	**PT**	**IM**	**R^2**	**D-W**
Model (5)	PG	7.272 12.177	1.375* 9.619	−0.382 −9.252	−1.654 * −5.312	2.408 ** 0.621	−1.113 ** −5.282	2.337 ** 1.949	0.798	0.338
	MI	1.743 8.617	0.001 * 4.523	0.064 * 8.398	−0.003 ** −0.608	0.001 * 3.000	−0.001 * −1.289	0.002 *** 0.221	0.612	0.171
		α	**I**	**L**	**EM**	**AM**	**HM**	**TM**	**R^2**	**D-W**
Model (6)	PG	6.319 3.028	1.445 ** 3.712	−0.195 −5.531	−1.136 ** −0.816	−1.56 ** −0.238	0.169 *** 0.987	2.269 * 5.934	0.798	0.357
	MI	1.744 3.9	0.001 6.839	0.064 * 6.148	−0.001 ** −1.088	−0.002 * −5.923	0.001 ** 4.899	0.003 ** 2.358	0.643	0.24

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Model (4) shows the relationship between policy relevancy and economic performance of the renewable energy industry, with the R^2 being 0.595 and 0.755, which indicates that policy relevancy is closely related to industry performance, and thus, it has a marked positive influence on performance. With a 1% growth in policy relevancy, invention patents granted in renewable energy technology would increase by 0.171%, and technologies with licenses implemented would increase by 1.685%. With higher policy relevancy, there would be more invention patents granted in renewable energy technology and more technologies with licenses implemented.

Model (5) presents different policy goals' influences on the technical and economic performance of renewable energy. R^2 in the regression model of policy goals is 0.798 and 0.612, indicating that policy goals markedly influence industry economic performance. However, the four different policy goals have different influences. While the goals of stimulating innovation and improving management have marked positive influence, the goals of promoting transformation and strengthening protection have marked negative influence. Empirical results prove that, in the short run, promoting the transformation of scientific and technical achievements result in a negative influence on the number of invention patents granted in renewable energy technology because of the disparity in the requirements of IPR strategy and transformation achievements as well as the incongruity in costs and returns of the transformation. In the long run, however, such promotion of achievements can, to a large extent, improve the proportion of output value of new products, thus boosting the promotion of new technologies and new products. In the short term, strengthening protection would exert negative influence on China's renewable energy industry because it would increase both production and social costs. However, in the long term, policies emphasizing IPR protection can improve the output of renewable energy technology and increase social returns. Therefore, if IPR policy that stimulates innovation, strengthen protection, improve management and promote protection can be synergised, they can absolutely improve the industry's performance.

According to the results of the regression model analysis, different policy goals have varied influences on the economic performance of renewable energy industry, among which stimulating innovation has the most marked positive influence. Given that the level of technological innovation is not high, and the regional development is not currently balanced in China, to improve China's renewable energy technology, the assimilation and attraction of technology innovation should be emphasized, as such innovation is the development route of independent innovation. On the one hand, technologies from abroad should be fully adopted and transformed into China's own production capacity; on the other hand, investments in domestic innovations should be increased to improve China's capabilities with respect to independent innovation. However, other goals, such as strengthening protection and promoting transformation, have a marked negative influence on economic performance. Thus, to maximize the positive effects of IPR protection on economic growth, the country should use a series of appropriate auxiliary policy that support IPR protection, perfect the country's IPR policy and maintain the continuous authority of the legislation. The latter includes strengthening IPR protection, balancing the policy targets, strengthening policy measures that have a direct incentive effect on the subjects of technological innovation, adjusting the strength of the various policy measures, and coordinating various policy measures to protect the incentive effect of technology innovation.

Model (6) shows that the R^2 of the policy measures' model is 0.798 and 0.643, which indicates that policy measures are closely related to the economic performance of renewable energy technology, though with different influences. Overall, policy measures have a marked influence on the number of patents granted, but their influence on patent implementation is relatively weak. Among different policy measures, talent measures have a marked positive influence on patent grants in renewable energy technology, which indicates that talent measures can greatly boost patent grants. Because of this, the increase in talent input can improve the technology level and the optimisation of human capital can enhance the output per capita. However, the influence of talent measures on patent implementation is relatively weak. As fiscal and taxation measures exert marked positive influence on patent grants in renewable energy, with stronger support in fiscal and taxation measures and input, there would be more patents granted in renewable energy. However, the influence of fiscal and taxation measures on patent implementation is relatively weak. By comparison, although administrative measures have a marked negative influence on the performance of the renewable energy industry and can impede patent grants, they do not have much influence on the implementation of renewable energy patents. While other economic measures demonstrate a negative influence on economic performance, these influences are not evident.

Various policy measures have quite different influences on the performance of the renewable energy industry. (1) Fiscal and taxation measures have a marked positive influence on the performance of renewable energy industry (especially the number of invention patents granted in renewable energy industry), but limited influence on patent implementation. Other economic measures have a less marked negative influence on economic performance. Thus, it is necessary to optimize and reform the fiscal and taxation measures as well as other economic measures and to promote the marketization and industrialization of patents. To achieve these objectives, the synergy of various policies must be emphasized, and the fiscal and taxation policies must align with policies stimulating innovation. For instance, economic incentives such as stock stimulation should be fully implemented to motivate the research and development institutions and staff and to attain the objective of stimulating technology innovation. Second, the enforcement of policies should be improved, and attention should be paid to the offset of policy function resulting from recessive goals. Third, the government departments should put aside their own interests and emphasize the overall interests of departmental, thus committing to the common goal of the policy system—to promote independent innovation; (2) Talent measures demonstrate a marked positive contribution on economic performance, thus proving that the country attaches significant importance to the acquisition of talented persons at the policy level. Therefore, training should be further strengthened and should include training related to research and development in renewable energy technology and for legal service institutions. Accordingly, the flow of talent should be encouraged, which will inherently enhance performance through the optimization of human capital; (3) Administrative measures, which are the most aggressive measures and the ones most often used in China's innovation policy, demonstrate a marked negative influence on economic performance, especially on the number of patents granted. Under the stimulation of administrative intervention measures, both the government and the microscopic main bodies of technology are in an urgent pursuit of technology, though they are neglecting the economic growth. Too much direct government intervention, inadequate authorization, and delegation power to lower levels combined with complicated administrative procedures lower the economic performance.

4. Conclusions

In this work, we evaluate IPR policy performance of the renewable energy industry in China through an examination of the effect of policies on innovation and marketization. We find that the current IPR policies of the renewable energy industry are disconnected from China's reality because the innovation ability of the renewable energy industry has not been improved rapidly, and both the market transformation ability and market prospect of new energy technology patents are weak. Based on a quantified policy indicator system, this study finds that policy number, policy hierarchy, and policy relevancy are positively related to innovation and marketization. In terms of policy goal, stimulating innovation and improving management have a positive impact on innovation and marketization, whereas promoting transformation and strengthening protection are negative. Regarding policy measure, talent measure and fiscal and taxation measures are positive, though their effects on marketization are weak.

Sustainable development and environmental crises has promoted the discussion of IPR of renewable energy technology in China. Given the influence that the sustainability of renewable energy can have on innovation and marketization, more policy and high-validity policy related to IPR are needed to promote growth. In addition, to promote the development of the renewable energy industry, direct government intervention should be reduced and be replaced by economic and legal measures, and accordingly, the authors posit that the goals of a policy should be well-coordinated and synergized and that to intensify IPR protection, promote transformation, and improve management, the government should pursue multi-objective decision making rather than independent innovation stimulation. Future studies should investigate the local IPR policy of renewable energy and explore different effects of policy in different political hierarchies.

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Appendix A

Table A1. Indicators system of policy measure.

Values \ Indicators		5	4	3	2	1
Legal Hierarchy of Policy		Laws issued by National People's Congress and its Standing Committee	Regulations issued by State Council and decrees issued by its Ministries and Commissions	Interim regulations issued by State Council and regulations and provisions issued by its Ministries and Commissions	Suggestions, measures, and interim provisions issued by Ministries and Commissions	Notices
Policy goals	Stimulating innovation	Independent innovation and original innovation of renewable energy technologies; a renewable energy national technologies innovation system; renewable energy technologies innovation in every respect	Improving "second venture" with technology innovation capability; Increasing fiscal and taxation preference, and economic input	Domestication and localization; lowing the approval authority of renewable energy technology transformation; specialized renewable energy technology innovation plan	Suggestions and transformation of renewable energy technology; policies supporting on economic input and taxation	Mention of innovation of renewable energy technology
	Promoting transformation	The transformation of scientific and technological achievements of renewable energy from the perspective of legislation	Commercialization and industrialization of renewable energy technical achievements and internationalization of scientific and technological industry of renewable energy; Promotion of the transformation of scientific and technical achievements in every respect	Emphasis on the transformation of scientific and technological achievements; to establish a good basis for the transformation of scientific and technological achievements; in some ways, to promote the transformation of scientific and technological achievements	Strengthening technology transfer and application promotion of renewable energy	Only relation to the transformation of scientific and technological achievements of renewable energy
	Strengthening protection	Improving the management of IPR is an important driving force to improve technological innovation of renewable energy, and providing a full range of strong guidance from the legislative, publicity, implementation and other aspects	To improve the management of IPR of renewable energy technologies from legislation	Specific measures to improve of the management of IPR of renewable energy technology	Clearly putting forward to improve the management of IPR of renewable energy technology, but no specific measures	Only mentioning IPR management of renewable energy technology
	Improving management	Giving strong support to the introduction of renewable energy technologies, including preferential policies and administrative efficiency	Vigorously supporting the introduction of renewable energy technology, and improving administrative efficiency	Supporting the introduction of renewable energy technology and giving preferential policies in some respects	Support for specific renewable energy technology import, and administrative approval being stricter	Restrictions on low level or repeated introduction of renewable energy technology, no preferential policies, strict administrative examination and approval

Table A1. *Cont.*

Values \ Indicators		5	4	3	2	1
Policy relevancy			Highly relevant	Relevant	Generally relevant	Marginally relevant
Policy measures	Fiscal and taxation measures	Supporting interest subsidies; income tax rate is not higher than 10% or half of the existing corporate income tax, and free taxes in several years	Supporting interest subsidies; income tax rate is not higher than 15% or half of the existing corporate income tax, and free 1–2 taxes in several years	Priority in interest subsidies; the rate of income tax is not more than 15%, only for particular conditions and regional enterprises, and free 1–2 kinds of tax	Interest subsidies is viewed as main measures, but strength or order is not be explained; the rate of income tax is more than 24%	interest subsidies as only one of the supporting measures; the rate of income tax is more than 33%; or no specific measures
	Talent measures	Full respect for the talent and knowledge, material and spirit reward; maximum encourage the flow of talent; to select a variety of distribution system; to improve the social welfare and security system	To establish a system of technological innovation, technological transformation and other activities, to encourage people to flow; better social welfare and security system	Bonus and rewards to the people who have made important contribution to the transformation of renewable energy technical achievement; recorded in the personal files, one of the important foundations of assessment, promotion, promotions, job classification; relatively perfect social welfare and security system	To simplify the entry and exit procedures for domestic and foreign technical and commercial personnel of renewable energy; to encourage personnel to flow	No specific provisions of encouraging the talent, only to regulate personnel constitute of enterprises or scientific research institutions
	Administrative measures	To establish product catalog of renewable energy for enterprise's technology innovation products direct procurement and protection	Delegated approval authority, to expand the scope of approval management; to establish and to improve the service and guidance system; to simplify administrative procedures and to take a priority rule	Delegated approval authority, relax the approval of the scope of management; to establish a more perfect service guide system, simplify administrative procedures; to relax the approval, quota, permit system, etc.; supervision system	Reserve the approval authority, take special exception handling method; guarantee the implementation of the regulatory system of the approval, quota, permit system and so on; the government's attitude is not against or limited	Take strict government control to intellectual property rights of renewable energy technology
	Other economic measures	To give support to the largest, from many aspects; The widest conditions and the highest proportion of technology price of renewable energy; the loosest limitation in depreciation, depreciation, and return ratio on the residual rate	To give relatively large support in finance; The relatively wide conditions and the relatively high proportion of technology price of renewable energy; the relatively loose limitation in depreciation, depreciation, and return ratio on the residual rate	To give a certain economic support from the financial management, such as related costs included in the cost of management; making clear the scope and a strict proportion of technology price of renewable energy; to give a loose on 1–2 aspects from the aspects of depreciation, depreciation, residual rate and return ratio	To give some economic support, no detailed provisions of the price ratio; more stringent regulations in depreciation, depreciation, salvage and return of the proportion	Only to give economic support, but there is no specific provisions; very strict technical price requirement of renewable energy; very strict requirement in depreciation, depreciation, residual rate and return ratio

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