Research on the Changing Contribution of Patent Family Size to Patent Value: A Case Study of the Solar Energy Field (Postprint)

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Abstract

[Purpose / Significance] This study aims to clarify the dynamic patterns of patent family size' s contribution to patent value, while providing an important reference for optimizing patent strategic layout and patent value assessment. [Method / Process] Taking the new clean energy solar power field as an example, datasets of high-value and low-value patents are identified, experiments targeting the differences in patent family size between high-value and low-value patents are designed, and verification is performed using SPSS 22. [Results / Conclusion] The contribution of patent family size to patent value is not static; as patent family size continues to expand, the differences in the distribution of patent family sizes between high-value and low-value patents become insignificant, at which point the contribution of increased patent family size to patent value diminishes markedly.

Full Text

Research on the Changing Contribution of Patent Family Size to Patent Value: A Case Study of the Solar Energy Field

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Abstract

[**Purpose/Significance**] This study aims to clarify how changes in patent family size contribute to patent value, providing an important reference for optimizing patent strategic layout and patent value evaluation. [**Methods/Process**] Using the solar energy field as a case study, we identified datasets of high-value and low-value patents, designed experiments to examine differences in patent family size between these groups, and used SPSS 22 for verification. [**Results/Conclusion**] The contribution of patent family size to patent value is not constant. As patent family size continues to expand, the difference in the proportion of patents across family sizes between high-value and low-value patents is no longer significant, and the marginal contribution of patent family size to patent value diminishes markedly.

Keywords: patent family; patent value; solar energy technology; high-value patents; low-value patents
Classification Number: G306.0

1. Research Progress

The role of patent families as an indicator of patent value has been confirmed by numerous scholars. For instance, D. Harhoff et al. [6] explicitly stated in 2003 that patent family size, described as the number of countries represented in a patent family, can be used to measure the market size of an invention and thus its value. In 2007, E. Sapsalis [7] proposed a four-factor model for determining patent value: non-patent citations (NPC), backward patent citations (BPC), co-authorship (COA), and family size (FS), and conducted empirical research using biotechnology patent data. In 2014, M. Grimaldi et al. [8] developed a framework combining qualitative and quantitative patent information for patent value assessment, ultimately identifying five key criteria: technical scope, forward citation frequency, international scope, patent strategy, and economic relevance. The first three criteria analyze the level of technological innovation and geographic coverage of patents, while the latter two contain strategic economic information. O. Lanjouw et al. [9] used four indicators—number of patent claims, forward citations, backward citations, and patent family size—to evaluate patent quality by technology category. Building on previous research, A. J. C. Trappey et al. [10] in 2012 proposed 12 patent value assessment indicators for use in principal component analysis and back-propagation neural network models, including patent family assessment to quantify patent value. In 2016, J. L. Wu et al. [11] used kernel principal component analysis (KPCA) to extract key patent value assessment indicators, including number of patent attorneys, citation count, number of claims, IPC count, number of inventors, time lag from application to grant, number of priority countries, and time lag from priority date to grant. In 2017, Y. Zhang et al. [12] constructed an entropy-based patent value indicator system using 11 metrics: number of inventors, patent family size,

transfer frequency, number of claims, number of cited patent documents, number of cited non-patent literature, citation count, IPC count, number of technical terms, time intervals, and number of patent attorneys. This system was used to filter low-value patents and identify high-value patents with technological innovation potential. From these studies, it is evident that patent family size has become a widely recognized indicator of patent value, with larger patent families generally indicating higher patent value.

As research has progressed, some scholars have questioned the degree of influence that patent families have on patent value. For example, D. Guellec et al. [13] supported the positive correlation between patent value and patent family size but also argued that patent family size cannot linearly reflect patent value.

Based on these perspectives, this paper argues that the contribution of patent family size to patent value should be variable. While patent family size is a recognized indicator of patent value, how this contribution changes remains unclear. Therefore, this study uses the solar energy field as a case study to further clarify how changes in patent family size contribute to patent value, providing an important reference for patent value assessment.

2.1 Selection of High-Value and Low-Value Patent Datasets

In this study, we select litigated patents, transferred patents, and standard-essential patents as proxies for high-value patents.

In 2004, J. R. Allison et al. [14] conducted an in-depth study on litigated patents and concluded through rigorous experiments that there is a strong bidirectional relationship between patent litigation and patent value: litigated patents tend to have higher value than average patents, and high-value patents are more likely to be litigated. In 2007, Allison et al. [15] further confirmed that litigated patents have higher value than non-litigated patents. Zhang Kequn et al. from Wuhan University [16] also adopted this view, using patent litigation as a proxy variable for patent value in their analysis of factors influencing patent value at different technology development stages. Based on these studies, the bidirectional relationship between patent litigation and patent value is well established, making litigated patents a scientifically justified subset of high-value patents.

Patent transfer refers to the transfer of patent ownership or holding rights from the transferor to the transferee, with the transferee paying an agreed-upon price. This is a compensated activity, and for the transferee, only valuable patents are worth purchasing. Additionally, certain taxes must be paid during the transfer process, so patent transfer can to some extent reflect patent value. Since patent transfers sometimes result from changes in internal technology strategic layout or resource allocation optimization within enterprises, which may not fully reflect patent value, this paper selects patents transferred between different companies (subsidiaries under the same parent company are also considered the

same company). As technology continues to advance, the integration of patents and technical standards has become a new development trend. Technical standards are more advanced than patents, and mastering technical standards represents achieving a dominant position in the technology field [17]. To maximize economic benefits, patent owners strive to convert high-value patents into technical standards in their field, thereby achieving market monopoly. Based on this analysis, this paper selects litigated patents, transferred patents, and patents that have become standards as subsets of high-value patents.

This paper selects patent applications with current legal statuses of abandoned, terminated, rejected, and withdrawn as the subset of low-value patents. Before patent rights are granted, applications for which applicants fail to complete statutory requirements or make requested amendments within specified time limits are considered withdrawn, and applications that do not comply with legal requirements and cannot be granted patent rights are considered rejected. After patent authorization, some patent holders stop paying annual fees for low-value patents, resulting in a legal status of "terminated," or submit written statements to abandon their patent rights, resulting in a status of "abandoned." Therefore, combining these four categories as a subset of low-value patents is scientifically justified.

2.2 Research Approach

As an ideal clean energy source and alternative energy for the future, solar energy has attracted widespread attention from countries worldwide. Therefore, this study selects the solar energy field as the target area for research. First, we analyze the current status of patent families in the solar energy field and use non-parametric tests to confirm that patent family size has a significant impact on patent value in this domain, thereby validating the scientific validity and rationality of patent family size as a patent value assessment indicator. Subsequently, we group patents according to patent family size to further explore the changing trend of how patent family size contributes to patent value, providing scientific references for national and corporate patent family layout strategies in the solar energy field.

3.1 Current Status of Patent Families in the Solar Energy Field

Given that the incoPat database contains patent information from 112 countries, organizations, and regions worldwide and is updated four times per week, it provides relatively comprehensive data coverage. Therefore, this study selects the incoPat database as the data source for solar energy patents.

Using the search formula TIAB=(solar OR "solar energy" OR "solar power") and selecting all years, we retrieved 637,653 published patent application records

(search date: December 4, 2018). To further refine the search results and ensure accuracy, we selected all data from the most dominant classification in the results, namely the IPC main group "F24J2," which includes all patents related to the utilization of solar heat, devices for generating mechanical power from solar energy, and semiconductor devices for converting solar energy into electrical energy. This yielded 96,851 records for analysis.

Statistical analysis shows that, based on patent publication numbers, the top five countries/organizations/regions in terms of patent application volume are China, Japan, the United States, Germany, and the European Union, as shown in Figure 1 [Figure 1: see original paper]. These top-ranking countries and regions are all at the forefront of solar energy industry development, and the volume of patent applications can to some extent reflect the level of technological development of a country or region.

Figure 1. Top 5 countries/organizations/regions by patent application volume in the solar energy field

Statistical analysis of the 96,851 patent application records reveals that patents with a family size of 1 account for the highest proportion, with the number of applications showing an overall downward trend as patent family size increases, as shown in Figure 2 [Figure 2: see original paper].

Figure 2. Trend of patent family size in the solar energy field

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3.2 Overall Relationship Between Patent Families and Patent Value in the Solar Energy Field

The role of patent families as an indicator of patent value has been confirmed in numerous studies. For the solar energy field selected in this study, we retrieved and cleaned data from the incoPat database, obtaining 96,851 published patent application records. Among these, 9,539 had the legal status of "abandoned," 18,946 were "terminated," 4,840 were "withdrawn," and 1,178 were "rejected." In the high-value patent category, there were 51 litigated patents, 6 standard-essential patents, and 6,403 transferred patents after data cleaning. To verify whether a significant relationship exists between patent families and patent value in the solar energy field, we grouped 33,325 low-value patents into one group and 6,460 high-value patents into another. Before conducting the test, we first performed a normality test on the data. After running SPSS, the P-values for both groups were less than 0.05, indicating that neither followed a normal distribution. Therefore, we chose to use independent samples non-parametric tests. The test results are shown in Table 1 .

Table 1 shows that the difference in patent family size between high-value and low-value patents was statistically significant, with a two-sided $P=0.004<0.05$, meeting the $\alpha=0.05$ threshold. Therefore, we conclude that in the solar energy field, patent family size shows significant differences between high-value and

low-value patents, and patent family size can be used as an evaluation indicator for patent value.

3.3 Detailed Analysis of the Relationship Between Patent Family Size and Patent Value

To further explore the relationship between patent family size and patent value, this study groups the selected high-value and low-value patent sets according to patent family size, treating high-value and low-value patents as separate wholes and drawing bar charts of the proportion of patents in each group, as shown in Figure 3 [Figure 3: see original paper].

Figure 3. Bar distribution of patent quantity proportions by patent family size

Combined with the data table, Figure 3 clearly shows that when patent family size is less than 12, the differences in patent quantity proportions between the high-value and low-value patent groups are significant, after which they tend to converge. To more clearly observe the changing differences in patent family quantity proportions between high-value and low-value patent sets, this study separately plotted sample data with patent family sizes greater than 3 to observe the trend, as shown in Figure 4 [Figure 4: see original paper].

Figure 4. Line distribution of patent quantity proportions for patent families larger than 3

Figure 4 clearly shows that as patent family size continues to increase, particularly after patent family size exceeds 12, the overall difference in patent family quantity proportions between high-value and low-value patents becomes smaller and gradually converges. To clearly determine how the contribution of patent family size to patent value changes, intuitive observation alone is insufficient; precise data support is also needed. To further test the significance of these differences, based on the above observations, we conducted non-parametric tests on the differences in patent quantity proportions between different groups starting from patent family size 12. The test results are shown in Table 2 .

From the highlighted data in Table 2, we can conclude that when patent family size exceeds 16, the P-value is greater than 0.05, and the difference in patent family quantity proportions between high-value and low-value patents is no longer significant and lacks statistical meaning. Therefore, we can conclude that in the solar energy field, the relationship between patent family size and patent value is non-linear. When patent family size is less than 16, increases in patent family size contribute significantly to patent value. However, as patent family size continues to expand, the difference in patent family quantity proportions between high-value and low-value patents is no longer significant, and the contribution of increased patent family size to patent value diminishes markedly.

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4. Conclusions and Recommendations

This paper addresses the currently unclear issue of how changes in patent family size contribute to patent value through empirical research. We use litigated patents, transferred patents, and standard-essential patents as subsets of high-value patents, and patents with legal statuses of abandoned, terminated, rejected, and withdrawn as subsets of low-value patents. Using the solar energy field as a case study, we selected relevant patent data from the incoPat database as our dataset. First, we conducted independent samples non-parametric tests on the patent data, proving that patent family size can serve as a patent value assessment indicator in the solar energy field. We then grouped the retrieved patent data according to patent family size and conducted separate tests, concluding that in the solar energy field, when patent family size is less than 16, increases in patent family size contribute significantly to patent value. However, as patent family size continues to expand, the difference in patent family quantity proportions between high-value and low-value patents is no longer significant, and the contribution of increased patent family size to patent value diminishes markedly.

The reasons for this result are analyzed as follows: (1) Patent family application fees are relatively high. While these costs are bearable for large enterprises, small businesses and individual inventors lack sufficient funds to support applications in numerous countries or multiple applications for the same patent in the same country. Therefore, for many high-value patents, applicants selectively file only in key countries, as clearly shown in Figure 1, where the top-ranking countries in solar energy industry development also hold the most patents. (2) Different countries focus on developing different technology fields. In the solar energy field selected for this study, the current leaders are primarily the United States, Japan, China, and European countries. For many technologies, filing only in countries with economies of scale and large markets is sufficient; there is no need to file in smaller or less developed countries, which would only increase costs unnecessarily.

This research has important implications for patent applications in the solar energy field. Before filing, applicants need to make reasonable estimates of patent value to guide their decisions, achieving the dual goals of reducing application costs while protecting inventions and safeguarding their rights. Additionally, this study is significant for researchers in patent value assessment, as it demonstrates that the relationship between patent family size and patent value is not entirely linear. When patent family size exceeds a certain threshold, further increases contribute only marginally to patent value.

This study has certain limitations. First, we selected only a single research field for empirical analysis, while different technology fields have different key development countries. Future research could consider selecting multiple fields for comparative analysis. Furthermore, due to differences in national policies, patent application patterns also vary. Subsequent studies could incorporate

factors such as national policies and government decisions to further improve this research.

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Author Contributions

Long Yixuan: Data collection, experimental design, paper writing and revision
Wang Xiaomei: Research topic proposal, paper revision

Note: Figure translations are in progress. See original paper for figures.