

# Enterprise-Led High-Value Patents Call for Patient Capital: A Data-Driven Empirical Analysis

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**Abstract:** High-value patents serve as a key indicator of regional innovation capability. However, existing research lacks systematic exploration of the structural characteristics and dynamic evolution of enterprise-led high-value patents. This study identifies and evaluates such patents from the perspective of regional innovation networks, providing a basis for optimizing innovation resource allocation, promoting cross-regional collaboration, and formulating intellectual property strategies in the Sichuan-Chongqing region. Focusing on enterprises in the Sichuan-Chongqing region and utilizing authoritative patent data, this study employs social network analysis to examine the development paths and network characteristics of enterprise-led high-value patents from multiple dimensions. High-value patent activities show an evolutionary trend from “policy-driven scale expansion” to “market-oriented quality optimization”, with an average growth cycle of 9.17 years. The cooperation network presents a “core-periphery” structure, with Sichuan and Chongqing as the hub, eastern coastal areas as the key region, and preliminary inter-provincial collaboration in western China. The technological layout constructs a collaborative innovation system centered on “computing” and “telecommunications”, evolving toward intelligent integration. The enterprise coupling network is characterized by the coexistence of leading enterprise guidance, industrial focus, and diversified collaboration.

**Keywords:** High-value patents, innovation network, ITGInsight, enterprise-led.

## 1. Introduction

As a core strategic resource in today’s innovation ecosystem [1], high-value patents have evolved beyond the traditional legal exclusivity associated with patents. They have gradually developed into a multifaceted value entity that integrates legal, market, and technological dimensions [2]. They serve not only as a vital vehicle for breakthroughs in key core technologies but have also become a key indicator for measuring the innovation performance of nations, regions, and even cities [3]. Therefore, an in-depth exploration of the mechanisms underlying the creation, utilization, and protection of high-value patents in enterprises holds both theoretical significance and practical urgency. As the most dynamic agents of innovation and the core units of market value creation [4], enterprises play a leading role in the formation of high-value patents. Enterprise-led high-value patents are, in essence, strategic actions that integrate internal and external resources to build sustainable competitive advantages [5]. Their impact extends far beyond the enterprises themselves; through knowledge spillovers and industrial chain synergy networks, they profoundly shape and enhance the overall resilience, dynamic adaptability, and long-term security of regional innovation ecosystems [6, 7]. Consequently, a systematic analysis of the structural characteristics, innovation trends, and evolutionary pathways of high-value patents held by enterprises serves as a crucial entry point for understanding the mechanisms underlying the formation and advancement of regional innovation capabilities. As a key hub for major national regional development strategies, the Sichuan-Chongqing region boasts a comprehensive industrial system and a rapidly growing concentration of innovation resources. It bears the strategic mission of leading high-quality development in the western region and contributing to the nation’s overall coordinated development. Currently, the region is at a critical juncture in its transformation from a traditional manufacturing hub to a

science and technology innovation community with nationwide influence. The increasingly vibrant innovation activities within the region, coupled with the complex synergistic and competitive relationships among multiple stakeholders, provide a highly representative real-world context and a rich sample set for observing the generation mechanisms, spatial distribution, and evolutionary trajectories of high-value patents held by enterprises. A systematic analysis of the development trends of high-value patents held by enterprises in this region will not only help reveal the intrinsic logic and structural characteristics of innovation-driven development in a typical western region but also provide important theoretical references and practical insights for a deeper understanding of the organizational models and evolutionary dynamics of cross-administrative-region collaborative innovation. However, despite the region’s growing innovative vitality, existing academic research still suffers from significant limitations in perspective and a lack of analytical depth. Most existing studies focus on meso-level aspects such as macro-policy evaluation, industrial planning and layout, or R&D intensity, while empirical research that adopts a micro-level perspective centered on “enterprise actors”—using “high-value patents” as the direct unit of observation and analysis—to systematically characterize the structural characteristics, spatial patterns, and dynamic evolution of their innovation cooperation networks remains relatively scarce. High-value patents are not isolated technological achievements; they are, in essence, a structured mapping and explicit manifestation of knowledge flows, resource allocation, and strategic collaborative relationships among innovation actors. The aforementioned gaps in existing research not only hinder a deep understanding of the micro-level mechanisms underlying regional innovation capacity but also affect the precision and effectiveness of relevant innovation policies and intellectual property strategies.

Given the aforementioned background and gaps in existing

research, this paper adopts a firm-level perspective and uses the Sichuan-Chongqing region as an empirical case study to construct a multidimensional analytical framework that integrates temporal evolution, spatial networks, and technological themes. This study aims to systematically address the following four interrelated core questions: (1) What are the overall characteristics and regular patterns of high-value patents led by firms in the Sichuan-Chongqing region in terms of their temporal evolution trends and spatial distribution? (2) What are the characteristics of the growth cycles of enterprise-led high-value patents in the Sichuan-Chongqing region? (3) What are the topological structures, core-periphery attributes, and geospatial manifestations of their patent collaboration networks? (4) What trends do the thematic distribution patterns and evolutionary trajectories of key technologies reveal, and how do these reflect the region's choices regarding innovation pathways and technological deployment strategies?

Through a systematic examination of the aforementioned issues, this paper aims to provide an accurate portrayal of the development landscape and evolutionary trajectory of high-value patents held by enterprises in the Sichuan-Chongqing region, thereby offering empirical evidence and decision-making support for optimizing the allocation of regional innovation resources, deepening cross-regional collaborative innovation, and formulating targeted industrial and intellectual property policies.

## 2. Literature Review

### 2.1. Research on High-Value Patents

#### 2.1.1. Definition and Characteristics of High-Value Patents

As a key indicator of a nation's innovation capacity and the core competitiveness of its industries, high-value patents have always been a central topic in the field of innovation management research. Although there is a consensus on their strategic significance, the academic community has yet to establish a unified and operational definition of their essence and measurement methods; however, the development of relevant theories has clearly evolved from single-attribute assessments toward multidimensional, systematic identification frameworks.

Early research tended to identify high-value patents based on a single attribute or characteristic. For example, Schettino et al. [8] focused on legal risk, arguing that litigated patents possess greater value due to the critical technical significance and strength of their exclusive rights as evidenced in disputes. As understanding deepened, scholars generally recognized that high-value patents are essentially a composite of multiple values, and research perspectives consequently expanded toward a more systematic and multidimensional approach. This theoretical evolution has unfolded primarily along three interrelated pathways: First is the pathway of value-dimensional integration. This pathway emphasizes that high-value patents represent a convergence of multiple intrinsic values. Representative studies, such as those by Fischer et al. [9], explicitly propose that high-value patents are a fusion of legal, competitive, strategic, and scientific value, marking a shift in value perception from the assessment of single attributes toward a structured integration. Second is the approach that focuses on deepening the economic and strategic attributes. While acknowledging the multidimensional nature of patents, this approach emphasizes

the analysis of their core economic and strategic functions. Some scholars highlight their market value, such as Hu Zewen et al. [10], who define a patent as one capable of generating significant economic returns or potential returns for the patent holder. They stress that a patent must possess market, strategic, and legal value, and be economically "beneficial" and "useful." Other studies focus on their role in driving innovation and strategic positioning. For instance, scholars such as Cui Weijun et al. [11] advocate for a multidimensional approach, defining high-value patents as high-quality patents filed with original innovation at their core, basic research as a strategy, and high-quality development as a strategic orientation, characterized by high technological, market, strategic, and economic value. Scholars such as Kelly et al. [12] link high-value patents to major breakthroughs at the technological frontier and their role in laying the groundwork for subsequent innovation. Furthermore, the research by Chen Yu et al. [13] elevates the perspective to the level of international competition, pointing out that high-value patents should possess a high degree of innovation or technological sophistication, be capable of driving scientific and technological progress, possess significant economic value, and be effectively protected internationally; they are often regarded as "core patents" or "strategic patents." Third is the full-chain systematic analysis approach. This approach aims to establish a holistic analytical framework that encompasses the entire process of creation, protection, utilization, and management. The "four-in-one" analytical concept proposed by Liu Qin et al. [14] systematically elucidates the full-chain attributes of high-value patents—from high-level technological R&D, high-quality patent application and grant, high-return commercialization and utilization, to industry leadership from a high starting point—and reflects a strong emphasis on comprehensiveness and systematicity.

Although existing research has reached a basic consensus on the multidimensional and multifaceted nature of high-value patents—encompassing technological, legal, market, strategic, and globalization aspects—this indicates that the theoretical framework in this field is maturing. However, this complexity also poses a core challenge in translating theory into practice: namely, how to accurately and efficiently identify high-value patents from a vast pool of patents in specific contexts.

#### 2.1.2. Research on Methods for Identifying High-Value Patents

As a consensus has emerged regarding the multidimensional and multifaceted nature of high-value patents, research on identification methods has evolved in diverse directions, shifting from single indicators to comprehensive models and from static evaluation to dynamic prediction. Current mainstream identification paradigms primarily include indicator-based approaches, machine learning methods, network analysis, and hybrid methods. These approaches differ significantly in their theoretical foundations, technical approaches, and application logic, collectively forming the core methodological framework of this field.

As a traditional mainstream paradigm, the indicator-based approach centers on constructing a systematic evaluation framework that encompasses multidimensional attributes such as technology, law, and market dynamics, with the aim of structurally measuring patent value. For instance, Liu Peipei et al. [15] further developed an evaluation system

based on four dimensions—technology, law, market competitiveness, and social benefits—and created a corresponding patent competitiveness assessment software system, thereby bridging the gap between theoretical models and practical applications. However, in recent years, the rise of machine learning methods has signaled a shift in identification research from reliance on expert experience and rule-based design toward data-driven predictive models. This approach trains on historical data to automatically screen for potential high-value targets within vast patent datasets. For instance, Wang Sipai et al. [16] utilized random forest algorithms based on patent indicator features to identify high-value patents during the patent application formation stage. Park et al. [17] defined highly cited patents in the information and communications technology (ICT) field as valuable patents and identified cutting-edge technologies based on citation coupling networks. Compared to the aforementioned methods based on patent attributes, network analysis provides an identification approach from a relational perspective. This approach places patents within an innovation network composed of relationships such as citations and collaborations, and identifies key patents by analyzing topological properties such as node centrality and structural holes. For example, Guo Jianming et al. [18] constructed a comprehensive patent citation network and designed an evaluation index for patent node importance to identify significant patents within the patent network. To integrate the depth of quantitative analysis with qualitative judgment, some studies have adopted hybrid methods. For instance, Xu Zhenliang et al. [19] established a four-dimensional evaluation system integrating “economic, technical, legal, and strategic” dimensions, comprehensively employing the Analytic Hierarchy Process (AHP) and the Delphi method for indicator weighting, and conducted empirical screening using specific industrial patent data as samples, demonstrating the potential applicability of method integration in specific fields.

Existing identification methods tend to focus primarily on the static attributes of patents or simple binary reference relationships, and thus fail to provide an in-depth examination of the complex, dynamic collaborative networks among the innovators behind these patents. At the same time, existing research has not situated patents within regional or industrial innovation ecosystems, making it difficult to systematically reveal their structural value as knowledge hubs and vehicles for collaboration.

## 2.2. Research on the Patent Cooperation Treaty

Patent collaboration networks are structured systems of connections formed through joint patent applications by innovators. As key vehicles for knowledge flow and resource integration, they have become an important paradigm in innovation network research. Such networks are characterized by dynamic evolution and adaptive adjustment, with their structures exhibiting a trend toward increasing complexity and sophistication over time. Existing research has established multi-level analytical frameworks based on different spatial scales and observational perspectives of these networks.

At the macro level, research primarily focuses on the overall morphology of network structures at the global or national scale and their impact on innovation competitiveness. For example, Yang Yong et al. [20] constructed a global urban innovation network based on multinational patent data,

highlighting the spatial characteristics and evolutionary trends of the network’s overall structure, thereby providing a systematic description at the macro level.

At the meso level, scholars focus more on innovation collaboration and spatial organization among regions or urban agglomerations within a country. For instance, Feng Xinghua et al. [21] systematically analyzed the structure of innovation networks within and between 19 urban agglomerations in China from 2010 to 2020 using patent transfer data, emphasizing the overall identification of regional collaboration patterns. Nie Jingxin [22], however, narrowed the research scale further to a single city. Taking Beijing as a case study, he combined polycentric theory with spatial analysis methods to deeply reveal the spatial differentiation mechanisms and evolutionary pathways of innovation activities, demonstrating the extension of meso-level research into micro-level spatial mechanisms.

At the industrial and technological sector level, research aims to reveal the structural characteristics and evolutionary patterns of cooperation networks within specific industries. For example, Wang Q. X [23], focusing on China’s advanced non-ferrous metals industry, constructed a two-layer network of patent collaboration and knowledge integration, meticulously depicting the topological structure and temporal evolution of the collaborative network in this field. Although such studies provide relatively comprehensive structural descriptions, they generally fail to further elucidate the specific transmission pathways through which network structural characteristics influence corporate innovation performance or patent value, thus suffering from the limitation of “emphasizing structural depiction while neglecting mechanistic explanation.”

In summary, existing research has yielded substantial findings regarding the topological characteristics, spatial patterns, and evolutionary dynamics of patent collaboration networks, establishing a multi-scale analytical framework that spans from the macro to the micro level and from the overall context to specific sectors. However, most of these studies treat network analysis as an independent descriptive tool, failing to systematically translate the structural attributes it reveals into actionable evaluation metrics that can be organically integrated into the framework for identifying and evaluating high-value patents. This theoretical gap provides a significant research opportunity for this paper to integrate the perspectives of network analysis and corporate actors, systematically examining the structural roles and evolutionary dynamics of high-value patents within regional innovation networks.

## 3. Research Methods and Data Sources

### 3.1. Research Methods

This study utilizes the ITGInsight patent data analysis platform and employs social network analysis methods to analyze high-value patent data generated by enterprises in the Sichuan-Chongqing region. This method is suitable for revealing the collaborative structures among innovation actors—such as enterprises, universities, and research institutions—and identifying key nodes within the network. Based on this, this study constructs a patent collaboration network. In this network, nodes represent enterprise innovation entities, and links represent collaborative relationships involving jointly filed patents. The following core metrics are used to analyze the network structure and

node importance.

**Degree Centrality:** Measures the number of other nodes directly connected to a node, identifying the most active collaborators in the network. It does not consider a node's influence on other nodes but focuses solely on the node's own connectivity.

**Proximity Centrality:** Measures the sum of the distances between a node and all other nodes, focusing on a node's ability to remain independent of other nodes. Proximity centrality is the only reverse indicator; that is, the higher a node's proximity centrality, the greater the distance between it and other nodes, and thus the less likely it is to be a core node in the network. Proximity centrality is calculated as follows:

$$C_i = \sum_{j=1}^n d_{ij} \quad (1)$$

In the formula,  $C_i$  represents the betweenness centrality of node  $i$ , and  $d_{ij}$  represents the shortest-path distance from node  $i$  to node  $j$ , where  $i \neq j$ .

Betweenness centrality measures the extent to which a node lies between two other nodes, focusing on the node's ability to control the two end nodes. Betweenness centrality is calculated as follows:

$$M_i = \sum_j \sum_k \frac{F_{jk(i)}}{F_{jk}} \quad (2)$$

In the formula,  $M_i$  represents the intermediate centrality of node  $i$ ;  $F_{jk(i)}$  represents the number of shortest paths between nodes  $k$  and  $j$  that pass through node  $i$ ; and  $F_{jk}$  represents the total number of shortest paths between nodes  $k$  and  $j$ , where  $k \neq j \neq i$  and  $j < k$ .

## 3.2. Data Sources

The data for this study is sourced from the WisdomIP patent database. This database is characterized by its extensive coverage, detailed fields, and timely updates, providing reliable data support for the identification and analysis of high-value patents.

To precisely identify the research subject—"high-value patents led by enterprises in the Sichuan-Chongqing region"—this study designed a multi-dimensional screening strategy, with the search period ending on September 24, 2025. The screening criteria are as follows: (1) The administrative region of the patent holder is restricted to the Sichuan-Chongqing region, specifically the entire province of Sichuan and the administrative region of Chongqing. (2) The patent holder is restricted to enterprises that are the first current applicant. In patentometrics, the first applicant is typically recognized as the primary contributor of R&D funding, the entity with actual control over technology ownership, and the main driver of commercialization. By excluding patents where enterprises serve only as secondary collaborators, this study aims to eliminate non-core innovation activities and more accurately depict enterprise-led technological evolution pathways and innovation landscapes. (3) The analysis focuses on valid and granted invention patents whose technical fields fall within the national strategic emerging industries as defined by the China National Intellectual Property Administration. (4) Given that strategic emerging industries are characterized by high R&D intensity and significant technological spillovers, the distribution of their technological value exhibits a distinct power-law pattern, wherein a very small number of core patents drive the technological evolution of the entire industry. Drawing on the

research of Harhoff et al. [24] and Albert et al. [25], this study adopts a more robust outlier filtering mechanism, setting the citation threshold for high-value patents at 25 citations. It should be noted that, given the significant time lag in patent citations, this criterion effectively identifies high-impact patents that have already entered the technological maturity phase during the sample period and have generated significant technological diffusion and recognition within the industry. While this screening strategy may exclude some potential high-value patents that have just entered the application window, it maximally eliminates the interference of "filler" patents, ensuring that the analysis sample possesses a high degree of certainty and industry recognition at both the market and technological levels.

After filtering the data according to the above criteria, it was imported into the ITGInsight analysis platform for cleaning and consolidation, ultimately yielding 3,659 high-value patent samples. To analyze the distribution characteristics of high-value patent grant dates, this paper also processed and statistically analyzed data on the number of high-value patents granted to enterprises in the Sichuan-Chongqing region using SPSS 27.0 software. The specific steps included: (1) Year-code conversion: To standardize the measurement criteria for the time dimension, the year of grant  $X$  was encoded, with 2025 coded as 1, 2024 as 2, and so on. This established the year-code as the core analytical variable, with the conversion formula: Year of Grant  $X = 2025 - \text{Code} + 1$ ; (2) Setting of weight variable  $w$ : The number of high-value patent grants in each year was used as the weight variable to reflect the intensity of the impact of patent output scale in different years on temporal distribution characteristics and the average growth cycle; (3) Analysis of the average growth cycle of high-value patents: Import the data organized in the previous two steps into SPSS 27.0 software, enable the weighted cases function to ensure that statistical results reflect the weighting effect of patent counts; and calculate the weighted mean (defined in this study as the average growth cycle of high-value patents, i.e., the time interval from patent grant to the first instance where the number of citations reaches 25), weighted standard deviation, weighted skewness, weighted kurtosis, and other indicators; test the normality of the distribution of grant dates; and quantify the distribution pattern.

## 4. Data Analysis

### 4.1. Overall Analysis of High-Value Patents Led by Enterprises in the Sichuan-Chongqing Region

#### 4.1.1. Characteristics of the Number of High-Value Patents Granted to Enterprises in the Sichuan-Chongqing Region

A time-series comparison of the number of high-value patent applications and grants filed by enterprises in the Sichuan-Chongqing region reveals a highly synchronized dynamic evolution between the two (Figure 1). Overall, the trends in the number of grants and applications remain highly consistent. From 2005 to 2013, the number of high-value patent applications filed by enterprises in the Sichuan-Chongqing region rose rapidly from 11 in 2005 to 382 in 2013. From 2014 to 2016, the number of applications fluctuated slightly downward. From 2007 to 2016, the number of grants grew in tandem from 2 to 380. Subsequently, starting in 2016, both the number of applications and the number of grants

showed a significant downward trend.

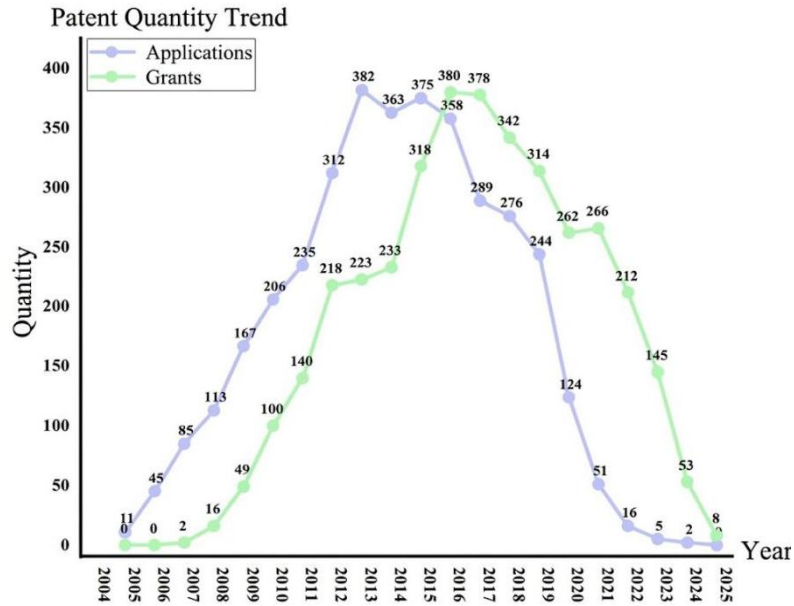


Figure 1. Trend Chart of Annual Patent Applications and Grants in the Sichuan-Chongqing Region

To investigate this driving force, this study conducted a growth cycle analysis based on the dates of high-value patents granted to enterprises in three categories: the Sichuan-Chongqing region as a whole, Sichuan Province, and Chongqing Municipality. As shown in Table 1, the average growth cycle for high-value patents held by enterprises in the Sichuan-Chongqing region is 9.17 years. Based on the average growth cycle, the core year of patent grants falls around 2017. This indicates that patents filed around 2013, after a typical 3–4-year examination cycle, entered a systematic phase of high-value manifestation around 2017. This corresponds chronologically with the peak and subsequent decline in the application volume curve shown in Figure 1. Table 1 further shows that the distribution of this growth cycle is relatively flat (kurtosis = -0.695) and nearly symmetrical (skewness = 0.125). To some extent, this reflects the characteristics of innovation activities in the Sichuan-Chongqing region—a strategic hinterland of the nation—within technology-intensive, long-cycle, and high-investment industries such as artificial intelligence and core electronics industry. Continuous support from policy-driven and guiding capital has provided crucial backing for such innovation activities that require long-term R&D investment.

Within the region, Sichuan and Chongqing exhibit distinct characteristics. The average growth cycle for high-value patents in Sichuan is 9.31 years, slightly longer than the overall average; their distribution is the most even (kurtosis = -0.703) and nearly symmetrical (skewness = 0.066). This

characteristic aligns with the industrial structure of Sichuan’s high-value patents. Table 2 shows that Sichuan’s high-value patents are widely distributed across new-generation information technology sectors, including artificial intelligence, core electronics industries, and next-generation information network industries. These industries typically involve high technical complexity and long R&D and industrialization cycles, which may result in a more gradual and sustained process of realizing patent value. In contrast, the average growth cycle for Chongqing’s high-value patents is 8.83 years, slightly shorter than the average for Sichuan and Chongqing combined; their distribution is right-skewed (skewness = 0.265) and relatively concentrated (kurtosis = -0.6175), indicating that its innovation activities respond more promptly to market demands. Table 2 shows that Chongqing has a higher proportion of patents in new-generation information technology fields such as artificial intelligence (15.4%) and emerging software and new information technology services (8.9%), while its share in sectors like new energy vehicle devices and parts manufacturing (10.4%) is also higher than that of Sichuan. These sectors feature rapid technological iteration and are closely linked to market demand, which may lead to earlier realization of patent value but may also imply relatively limited investment in basic research and frontier fields with longer technology cycles. Differences in the pace and patterns of innovation within the region collectively shape the overall innovation landscape of the Sichuan-Chongqing region.

Table 1. Regional Statistical Characteristics of High-value Patents

Statistical Indicator	Mean	Variance	Skewness	Kurtosis	Sample Size
Sichuan-Chongqing Region	9.17	13.417	0.125	-0.695	3659
Sichuan Region	9.31	13.421	0.066	-0.703	2565
Chongqing Region	8.83	13.259	0.265	-0.617	1094

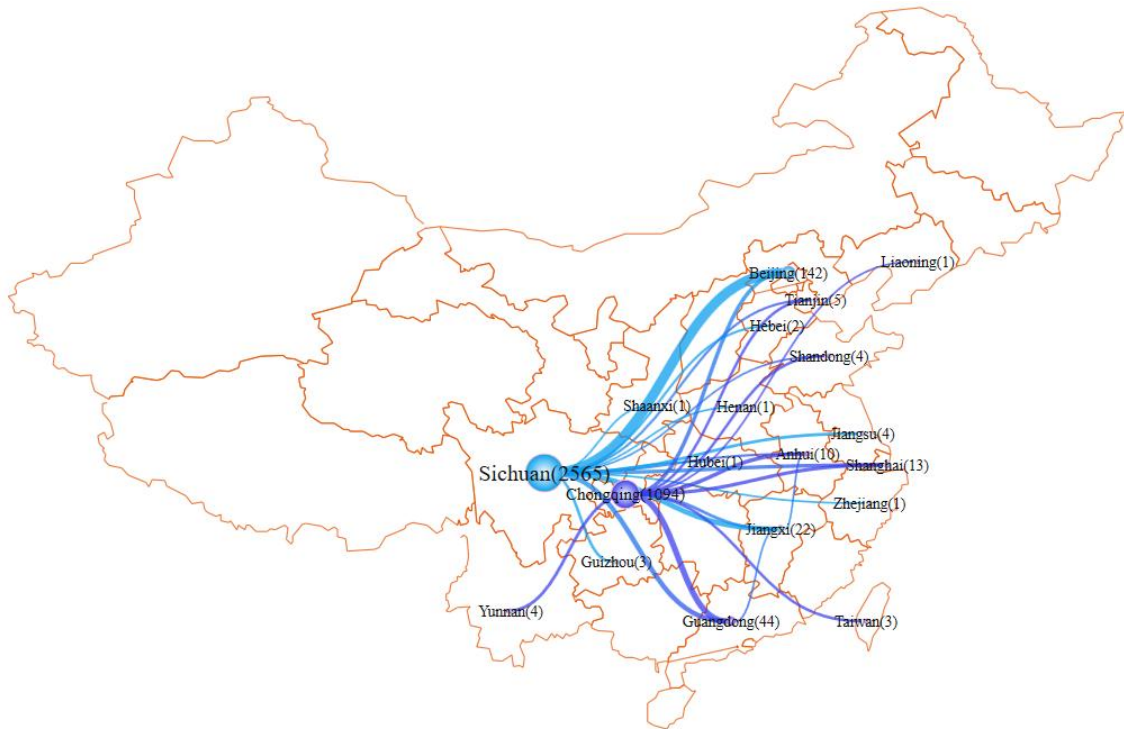
**Table 2.** Distribution Characteristics of Major Strategic Emerging Industries for High-value Patents of Enterprises in Sichuan-Chongqing Region

Rank	Sichuan Province	Prop. (%)	Chongqing Municipality	Prop. (%)
1	Artificial Intelligence	9.9	Artificial Intelligence	15.4
2	Core Electronics Industry	7.5	New Energy Vehicle Devices & Parts Manufacturing	10.4
3	Next-Generation Info Network Industry	7.3	Emerging Software & New IT Services	8.9
4	Internet, Cloud Computing & Big Data Services	6.5	Intelligent Mfg Equipment Industry	8.5
5	Advanced Petrochemical New Materials	6.5	Core Electronics Industry	6.1
6	Emerging Software & New Info Tech Services	5.7	Next-Gen Info Network Industry	5.5
7	Intelligent Manufacturing Equipment Industry	5.5	Advanced Environmental Protection Industry	4.6
8	Advanced Steel Materials	3.9	Advanced Petrochemical Materials	4.5
9	Smart Power Grid Industry	3.9	Internet, Cloud & Big Data Services	3.9
10	Digital Cultural Creative Activities	3.4	Biomedical Engineering Industry	3.9

**4.1.2. Characteristics of the Interprovincial Cooperation Network for High-Value Patents Led by Enterprises in the Sichuan-Chongqing Region**

Figure 2 shows that the interprovincial collaboration networks for high-value patents held by enterprises in the Sichuan-Chongqing region as primary rights holders exhibit a distinct “core-ring” spatial structure. This structure reveals the collaborative patterns and spatial orientation of the region as it integrates into the national innovation system. The core ring is characterized by “local collaboration dominance,” with Sichuan and Chongqing forming the most strongly connected core nodes in the network. The high concentration of collaborative patents within the region indicates that a close-knit collaborative innovation community for high-value patents has already taken shape. The secondary layer, meanwhile, exhibits a pronounced “eastern coastal

orientation.” Collaboration with eastern innovation hubs such as Beijing (142 patents), Guangdong (44 patents), and Shanghai (13 patents) is particularly prominent, serving as a key channel linking the region to external high-end innovation resources. This reflects the efficient flow of innovation factors under market mechanisms as they seek top-tier research resources and market opportunities. In contrast, the network demonstrates weakness in “regional outreach.” Although the region borders geographically adjacent provinces such as Guizhou (3 patents) and Yunnan (4 patents), the actual number of collaborative patents is limited. This indicates that the current external collaboration network for high-value patents in the Sichuan-Chongqing region is more focused on vertical connections with national innovation hubs, while its capacity for horizontal outreach and driving force within the western region still needs to be strengthened.



**Figure 2.** Inter-Provincial Collaboration Network of Enterprise-Led High-value Patents in the Sichuan-Chongqing Region

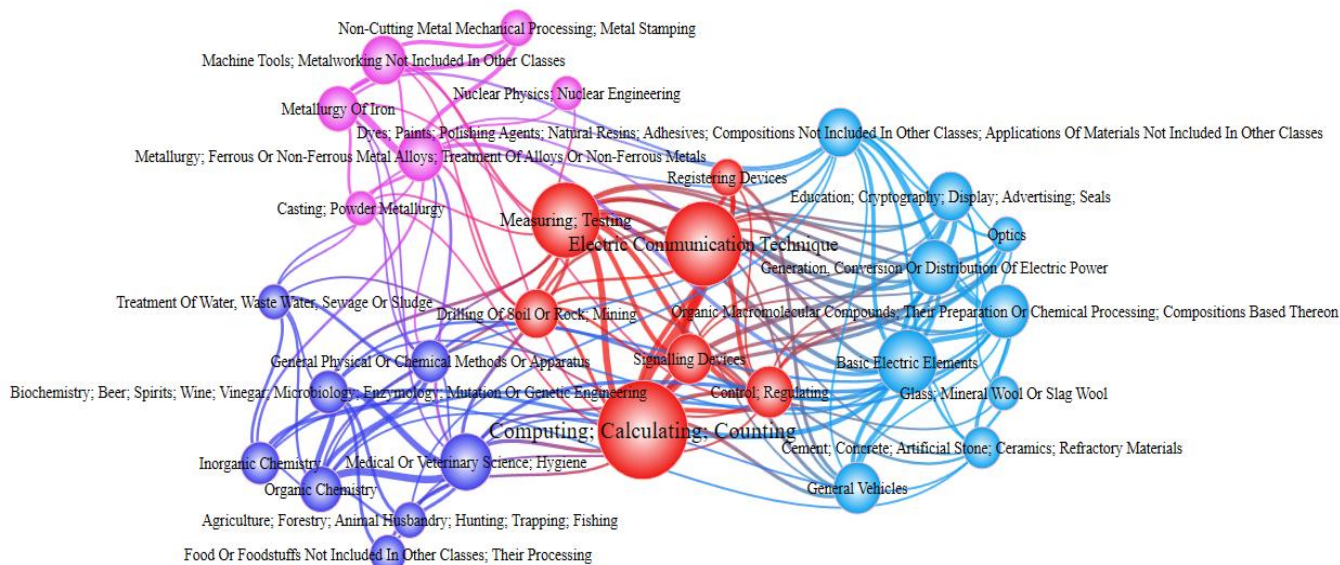
**4.1.3. Distribution Characteristics of High-Value Patent Technologies Dominated by Enterprises**

Co-occurrence networks and quantitative statistics based on the International Patent Classification (IPC) (Figure 3, Table 3) reveal that the high-value patent technology portfolio of enterprises in the Sichuan-Chongqing region exhibits a

systematic pattern. The number of patents in the two major fields of “Computing; Calculating; Counting” (781) and “Electric communication technique” (499) significantly leads the others, together forming the technological core of the region’s high-value patents and reflecting the concentrated allocation of innovation resources in the digital economy and

telecommunications sectors. Surrounding this core, key supporting and extending technical sectors have emerged, including “Measuring; Testing” (362 patents), “Basic electric elements” (235 patents), “Medical or veterinary science; Hygiene” (159 patents), and “Generation, conversion, or distribution of electric power” (145 patents). The high-

intensity co-occurrence of these technologies indicates that the region’s industries are driving the synergistic upgrading of industrial structures and iterative innovation through the deep integration of electronic information technology with fields such as intelligent detection, precision control, and advanced materials.



**Figure 3.** Co-occurrence Graph of IPC

**Table 3.** Statistical Table of Top 10 Frequency Rankings for IPC Classification Numbers

Rank	IPC Classification Code	Frequency
1	Computing; Calculating; Counting	781
2	Electric communication technique	499
3	Measuring; Testing	362
4	Basic electric elements	235
5	Medical or veterinary science; Hygiene	159
6	Generation, conversion, or distribution of electric power	145
7	Organic macromolecular compounds; their preparation or chemical processing; compositions based thereon	133
8	Control; Regulating	119
9	General vehicles	118
10	Metallurgy; ferrous or non-ferrous metal alloys; treatment of alloys or non-ferrous metals	112

#### 4.1.4. Overall Structure of the Innovation Network

The joint application coupling network constructed based on the top 30 companies by number of high-value patents (Figure 4) reveals that the innovation network of enterprises in the Sichuan-Chongqing region exhibits the following characteristics:

First, the structural composition is hub-centric. Leading enterprises such as BOE Technology Group (and its Chengdu subsidiary, 91), Sichuan Changhong Electric (83), Chongqing Changan Automobile (81), and Huawei Technologies Co., Ltd. (Chengdu) (68) stand out in terms of node size, serving as core hubs within the network. These companies dominate regional industries with competitive advantages, such as electronic information, smart home appliances, and

automobile manufacturing, and play a pivotal role in resource integration and innovation leadership within enterprise-led high-value patent collaboration networks. Second, industrial linkages reflect strategic synergy. The technological strategies and patent collaborations of core enterprises are closely aligned with the industrial clusters prioritized for development in the Chengdu-Chongqing region, such as semiconductors and electronic information (BOE, VeriSilicon), smart home appliances (Changhong), and smart connected vehicles (Changan). Patent co-application networks extend along these industrial lines, indicating that enterprises’ high-value patent strategies are deeply integrated with regional industrial strategies, aiming to strengthen core technological barriers and competitiveness. Third, the organizational structure exhibits an open ecosystem. In addition to local leading enterprises, the network has attracted cross-regional technology firms such as Tencent Technology (Shenzhen) Co., Ltd., as well as specialized research institutions like the Chongqing Research Institute of China Coal Technology & Engineering Group. At the same time, a group of small and medium-sized innovative entities, such as Haofengguang Energy Storage Technology (Chongqing) Co., Ltd., are deeply embedded within the network, forming a symbiotic innovation landscape characterized by “leadership from large enterprises and collaboration among diverse entities.” This promotes the penetration and transformation of high-value patents across all links of the industrial chain.

In summary, the Sichuan-Chongqing region has preliminarily established a high-value patent cooperation system centered on leading enterprises, structured around advantageous industries, and integrating diverse entities. This reflects a self-organizing order within the regional innovation resource system, shaped through specialized division of labor and collaborative evolution under market-driven mechanisms.

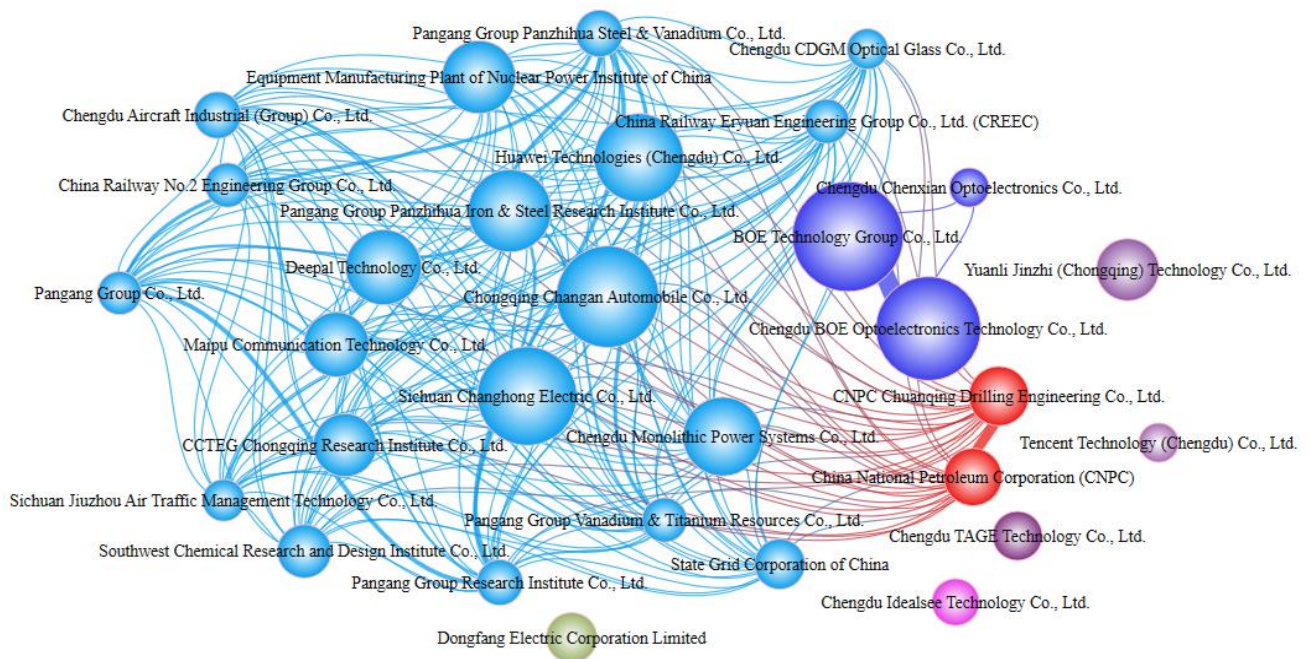


Figure 4. Coupling Network Graph of Applicants for Enterprise-Led High-Value Patents

## 4.2. Analysis of the Distribution and Evolution of High-Value Patent Themes Led by Enterprises

### 4.2.1. Cluster Analysis of Patent Themes

Based on the cluster analysis of high-frequency keywords (Figure 5), high-value patents led by enterprises in the Sichuan-Chongqing region are concentrated in five core thematic areas:

The largest cluster, with the most frequent keyword “Preparation Method,” has the highest frequency at 461 and is the largest node in the entire diagram. This cluster covers the full chain of technologies, including material synthesis, device manufacturing, and process optimization, with associated keywords such as stability, low cost, and high efficiency. As the core vehicle of technological innovation, patents in this cluster focus on technology implementation and industrialization, centering on performance enhancement, cost control, and application optimization. This reflects the emphasis placed on the practicality of technical solutions and market competitiveness in patent innovation.

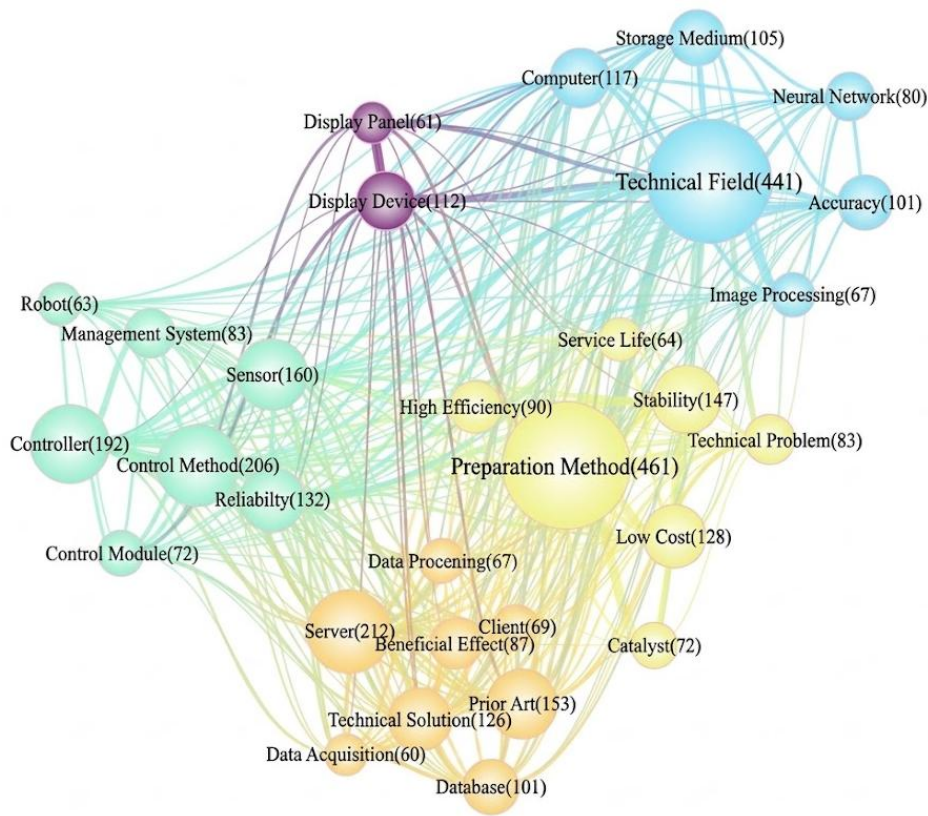
The second most frequent keyword in the cluster is “Technical Field,” with a frequency of 441. This cluster reflects the macro-level classification of patent technologies and market positioning, with associated keywords including computer, storage media, accuracy, and neural network. This cluster illustrates that the patent strategy of enterprises in Sichuan and Chongqing within the next-generation information technology sector uses computers as a general-purpose computing platform, deeply integrating artificial intelligence algorithms such as neural networks and image processing technologies with specialized hardware such as display devices. It focuses on high-accuracy intelligent interaction and data processing, covering full-chain innovation from hardware to algorithms and from foundational platforms to application scenarios.

The most frequent keyword in the third cluster is “Control Method” (192 occurrences), with related keywords including

controller, sensor, reliability, management system, and robot. As a key hardware component for automation and intelligence, controllers enable precise regulation of equipment and processes. With the development of IoT technology, the integration of controllers with sensors, smart devices, and robots has become a patent hotspot, with content covering sensitivity enhancement, energy consumption reduction, and multifunctional integration. This cluster highlights the central role of controllers and sensors in device interconnectivity and intelligent decision-making, with future technological trends pointing toward miniaturization, high precision, and low cost.

The fourth cluster’s most prominent keyword is “Server,” with the highest frequency at 212. Associated keywords include database and client. As the infrastructure for data centers, cloud computing, and the Internet of Things, patents related to servers focus on performance optimization, integrated control, and collaboration with smart devices, aiming to enhance the automation and intelligence of systems.

The fifth major cluster’s keyword is “Display Devices,” with a frequency of 112. This cluster is a core group in the specialized hardware sector; the associated keyword “Display panels” appears 61 times and serves as the core hardware medium for human-machine interaction and smart terminals. Related keywords intersect deeply with the “Technical Fields” cluster while simultaneously forming an independent technical cluster, covering the entire technology chain of display devices, including design, manufacturing, and performance optimization. This cluster reflects the patent strategies of enterprises in Sichuan and Chongqing, which center on technological innovation in display devices and display panels. By integrating technologies such as computing and data processing, these enterprises enhance display accuracy, interactive experiences, and system integration. They achieve technological breakthroughs for applications in consumer electronics and industrial displays, serving as a vital patent foundation for the region’s electronic information industry.



**Figure 5.** Co-occurrence Graph of Patent Subject Terms

#### 4.2.2. Analysis of the Evolutionary Path of Patent Subjects

An analysis of the evolution of high-frequency keywords (Figure 6) reveals that the focus of high-value patent technologies among enterprises in the Sichuan-Chongqing region has exhibited characteristics of phased evolution and cross-domain integration over time:

Phase I (approximately 2005–2008): Foundation-building period. Themes centered on keywords such as high performance, catalysts, stability, and low cost. R&D efforts focused on addressing fundamental reliability, stability, and cost issues through material and process optimization, laying the groundwork for subsequent application development. Phase Two (approx. 2009–2017): Digital Penetration Phase. Keywords such as servers, controller, sensor, database, and computer rapidly emerged and clustered together. Electronic

hardware and data elements were integrated into traditional fields, revealing a trend toward technological convergence. The industry began to focus on data interaction, platform services, and stability, and the innovation ecosystem gradually evolved toward digitalization and networking. Phase Three (approx. 2018–present): Intelligent Convergence Phase. The focus has clearly expanded toward intelligent sensing, intelligent computing, and scenario-based applications. The forefront of innovation is characterized by the deep integration of traditional processes with technologies such as the Internet of Things (IoT), intelligent control, and data analysis, with a commitment to achieving real-time monitoring, intelligent optimization, and automated control of processes. Technological development has entered the stage of in-depth “Intelligent+” applications.



“telecommunications” as its dual cores. This trajectory aligns with the global trend of information technology evolving from hardware to software and then to intelligent services, and it indicates that, as a strategic hinterland of the nation, the Sichuan-Chongqing region’s innovation activities are evolving from addressing foundational industrialization issues to driving the advanced forms of industrial intelligence. At the same time, the corporate coupling network exhibits characteristics of embedded collaboration among diverse entities, led by industry leaders such as BOE, Changhong, and Changan. This further reinforces the regional innovation ecosystem model characterized by “large-enterprise leadership, industrial clustering, and networked collaboration,” providing empirical evidence that large enterprises play a pivotal role in resource allocation and strategic direction within regional innovation.

In the existing literature on patent valuation, static indicators such as the number of granted patents and citation counts [26], or composite indices, are commonly used to measure patent value. Although these approaches take into account patent lifespans [27, 28] and regional industrial characteristics, they fail to reveal the intrinsic relationship between value and growth duration. This study innovatively defines and calculates the average growth cycle of high-value patents, integrating the temporal dimension into the value analysis framework. This extends the evaluation from a static cross-sectional assessment to a dynamic process-based evaluation, providing a new perspective for understanding the long-term technological capability development in late-developing regions; simultaneously, this study found that the collaboration network of high-value patents in the Sichuan-Chongqing region exhibits a distinct core-periphery structure, with an average growth cycle of approximately 9.17 years. This confirms that innovation in complex technologies and advanced manufacturing is characterized by long cycles, high investment, and high uncertainty, providing concrete empirical evidence on a specific time scale for theories such as patient capital; Furthermore, while traditional regional innovation research often focuses on static dimensions such as knowledge stock and network structure [29], this study, by comparing the differences in growth cycles between Sichuan and Chongqing, reveals the impact of industrial structure on the pace of regional innovation evolution and response strategies, thereby providing a theoretical basis for the design of differentiated innovation policies.

## 5.2. Policy Recommendations

Based on the above, this paper offers the following policy recommendations:

First, establish a patient capital investment mechanism tailored to the regional innovation stage. A patient capital support system featuring “stage-specific measures and differentiated guidance” should be developed. During the stages of innovation scale expansion and infrastructure development, policy-driven capital—such as government-guided funds and state-owned industrial funds—should serve as a “stabilizing force” and “architect,” thereby strengthening the institutional and material foundations of the regional innovation system; During the stages of innovation quality enhancement and industrial leadership, the focus should shift to guiding market-driven patient capital—such as venture capital and industrial capital—to participate deeply, thereby promoting the optimization and commercial application of high-value patent portfolios. By leveraging the resource

endowments and industrial division of labor between the Sichuan-Chongqing dual hubs, differentiated financing instruments should be collaboratively designed: Sichuan should prioritize the incubation of cutting-edge technologies, while Chongqing should focus on industrialization and scale expansion, thereby achieving precise policy alignment and dynamic optimization.

Second, establish a cross-regional collaborative R&D system for key core technologies. To advance the integrated innovation development of Chengdu and Chongqing, we must move beyond the logic of geographical proximity and shift toward institutional coordination and organizational innovation. Focusing on competitive fields such as “computing” and “telecommunications,” we should encourage leading enterprises to spearhead the formation of innovation consortia, collaborating with universities and research institutions to undertake major national science and technology projects. Through institutional arrangements such as establishing cross-administrative coordination bodies and jointly building and sharing physical R&D platforms, administrative barriers should be reduced to facilitate the effective spillover and two-way flow of innovation factors—including knowledge and talent—within the region and to neighboring areas in the west. This will drive the evolution of the regional innovation spatial structure from a “core-periphery” model to a “multi-centered, networked” one.

Third, strengthen enterprise-led innovation ecosystems. Leading enterprises should be supported in building innovation ecosystems characterized by “high-value patent portfolios combined with open application scenarios,” attracting small and medium-sized enterprises from across the industrial chain to participate in collaborative innovation and form industrial clusters rooted in key core technologies. Patient capital should be guided to adopt a strategic orientation of “investing early, investing for the long term, and investing in hard technology,” establishing long-term performance evaluation mechanisms focused on key core technology fields, de-emphasizing assessments of short-term financial returns, and thereby enabling long-term support for technological innovation.

Fourth, improve the linkage mechanism between intellectual property and capital exit. Promote the financialization and market-oriented operation of high-value patents, explore financial products such as patent pledge financing and securitization, and, relying on the intellectual property trading and operation platform jointly established by the Chengdu-Chongqing region, improve the service system for patent valuation, custody, and circulation. Establish diversified capital exit channels that align with the long-term cycles and high-risk nature of regional innovation. Encourage mergers and acquisitions within industrial chains, establish follow-on industrial funds, and support the IPO of hard technology companies, thereby fostering a virtuous financial ecosystem characterized by “bold investment, smooth exit, and reinvestment.”

## 6. Summary

Based on data from the strategic emerging industries in the Sichuan-Chongqing region, this paper examines the spatiotemporal evolution and collaborative network characteristics of high-value patents led by enterprises, and proposes four targeted management implications to provide a theoretical framework for fostering high-value patents in the region. Due to objective constraints, this study has the

following limitations:

(1) The trade-off between robustness and time lag in sample selection. This study primarily relies on the WisdomIP patent database, using citation frequency as the core indicator for identifying high-value patents. Although citation frequency is a credible measure of technological influence, patent citations inherently involve a time lag, resulting in the exclusion of some cutting-edge patents that have emerged in recent years but have not yet reached their peak of technological diffusion. Furthermore, the study did not fully integrate multi-source data such as corporate financials, technology contracts, and market share, leading to a certain degree of indirectness in the assessment of patent value. Future research could integrate industrial chain data, investment and financing information, and micro-level enterprise surveys to construct a more forward-looking and multidimensional patent value evaluation system.

(2) In-depth Deconstruction of Dynamic Evolution Mechanisms. While social network analysis has revealed the macro-structure of patent collaboration, the depth of analysis regarding the dynamic interaction logic among innovation actors, cross-regional knowledge spillover pathways, and the causal effects of policy interventions remains insufficient. Future research could incorporate Qualitative Comparative Analysis (QCA), empirical case studies, and dynamic network evolution models, combined with causal inference techniques, to deeply explore the complex driving mechanisms of co-created patent value within the three-way interplay of “government guidance—corporate strategy—technology portfolio.”

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