Innovation and Development of Biomedical Industry Clusters in Jiangsu Province: A Technological Perspective on Leading Enterprises

by

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DKU Global Health Program
Duke University

Date: November 27, 2023

Approved:

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the DKU Global Health Program in the Graduate School of Duke University

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ABSTRACT

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Abstract

Background: The vibrant state of the biopharmaceutical industry in Jiangsu Province, China, showcasing its strategic focus and significant growth. The province has implemented various policies to accelerate high-quality development, emphasizing innovation, intelligent and digital transformation. The industry, organized around biological drugs, chemical drugs, traditional Chinese medicine, and medical equipment, has become a national leader, with impressive revenue and output values. The study identifies research gaps related to the role of patents in the industry, highlighting the need for a micro-level analysis, better linkage between patents and economic outcomes, exploration of innovation capabilities, consideration of patent quality, and understanding temporal and geographical specificities. The research aims to address these gaps by assessing the impact of patent indicators at national, provincial, and enterprise levels, providing insights for policymakers and industry stakeholders to foster innovation and growth in the biomedical sector in Jiangsu Province.

Methods: This research employs a comprehensive three-tiered analysis to explore the intricate interplay between innovative indicators and economic output in the biomedical industry. The study spans the national, provincial, and enterprise levels, encompassing five diverse countries, all 31 provinces in mainland China, and the top ten pharmaceutical companies globally, domestically, and in Jiangsu Province. In collaboration with the Jiangsu Intellectual Property Protection Center, the study compiles an extensive dataset. This dataset, meticulously curated from publicly available and non-sensitive patent data, includes variables such as patent applications, authorizations, PCT applications, and application growth rates. Economic data, including GDP and market values, is sourced from reputable institutions like the World Bank, the National Bureau of Statistics of China, and Torreya, a renowned biomedical industry innovation
consulting company. Inclusive approach ensures a comprehensive representation for a cohort of 30 biomedical enterprises. The study extracts pertinent patent information into STATA for detailed analysis. The economic outcomes are measured through GDP at the national and provincial levels and market value at the enterprise level. The study meticulously examines the nuances of GDP computation and derives the 2022 national GDP data from the World Bank and provincial GDP data from the Bureau of Statistics of the People's Republic of China. Market value, or Market Capitalization, is defined and measured based on the total value of shares issued by listed companies, mainly in US dollars, with data sourced from Torreya, China Securities Regulatory Commission, and the Information Registration Center of the State Administration for Market Regulation. The biomedical patent indicators, comprising patent application numbers, PCT application numbers, patent authorized numbers, and patent in-force numbers, are systematically analyzed at national, provincial, and enterprise levels. Statistical methods, including one-way analysis of variance (ANOVA), correlation analysis, and linear regression analysis, are consistently applied across all levels to scrutinize the association between patent data indicators and economic output. The combined approach of correlation and regression analysis aims to derive precise patent innovation indicators and their impact on economic output, enhancing the clarity and intuitiveness of the research findings.

**Results:** On the global stage, the findings reveal a robust growth in biomedical patents from 2000 to 2022. China emerges as a major player, exhibiting substantial patent applications (1804099 pcs), authorizations (35131 pcs), and PCT patents (1115204 pcs). Correlation analyses indicate positive relationships between a country's GDP and patent-related metrics, further validated by linear regression. These results emphasize the importance of economic strength in fostering biomedical innovation. Turning our attention to Chinese provinces, our investigation
spans 31 regions, unraveling diverse patterns in patent outputs. Provinces with higher GDP consistently demonstrate elevated patent activity, showcasing a symbiotic relationship between economic prosperity and biomedical innovation. Correlation and regression analyses reaffirm these findings, emphasizing the quantitative impact of economic factors on biomedical research and development. At the micro-level, the study scrutinizes the top 10 pharmaceutical companies globally, in China, and within Jiangsu province. Striking disparities in patent application numbers, patents in force, and PCT applications highlight China's accelerating innovation capabilities. The correlation analysis establishes positive associations between market value and key patent indices (Coef. for number of patent application, patent in force, and PCT application, respectively 0.74, 0.71, 0.73,) emphasizing the pivotal role of patents in driving economic success for pharmaceutical companies. Linear regression analyses provide nuanced insights into the impact of patent indices on market value. The positive coefficients for patents in force (Coeff=9.77; 95% CI, 8.57 ~ 10.97) and PCT applications (Coeff=21.13; 95% CI, 18.68 ~ 23.58) signify their significant contribution to market values. The accompanying scatterplots visually reinforce these relationships, illustrating a positive linear correlation.

**Conclusions:** Particularly, conducting a micro-level analysis, this research reveals individual pharmaceutical companies' contributions often overlooked in macro-level studies. The nuanced exploration of the relationship between patent indicators and economic outcomes emphasizes the positive correlation between regional economic levels and patent indicators, particularly in the pharmaceutical industry. At the enterprise level, the research establishes a connection between patent numbers and market competitiveness, with more patents associated with stronger market positions. Comparisons with other countries and Chinese provinces highlight strategic gaps and position Jiangsu as a leader in innovation capabilities. The study
underscores the critical importance of patent quality over quantity, advocating for strategies that prioritize high-quality patents to drive sustained growth and competitiveness in the biomedical industry.
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1. Introduction

When we want to promote the development of biomedical industry, many stakeholders, such as governments, NGOs, international organizations, and pharmaceutical companies, play a significant role in global health. They have each played their essential roles, especially in the years since the coronavirus outbreak.

Pharmaceutical companies have contributed their unique strength to global health by launching new drugs and improving medical interventions. Promoting the sustainable and efficient development of the biomedical industry has also become an indispensable and essential issue because it will affect the entire health industry to a greater or lesser extent, for better or worse. For the biomedical industry, the patent system is a critical link, which is not only the only way for technological innovation but also an essential concept in health economics. Hence, how to promote the orderly and healthy development of the pharmaceutical industry has become a topic worthy of study. The innovation capability and economic output level of the pharmaceutical industry are matters worthy of attention at the national level, provincial level, regional level, and enterprise level. A good grasp of the direct relationship between the innovation capabilities of the pharmaceutical industry and economic output can also enable the development of the pharmaceutical industry to achieve a closed-loop industrial cycle. In the end, technology promotes innovation, innovation brings benefits, and the benefits eventually return to a virtuous cycle of technology research and development.

This paper will analyze the impact of biomedical industry innovation on economic output from different perspectives at the three levels of the country, Chinese provinces, and enterprises.
1.1 Patent System

As what the World Intellectual Property Organization states (WIPO), “Intellectual property is improving the lives of everyone, everywhere.” Patent as one of the most important intellectual properties, take an essential role to transfer ideas into assets. WIPO classifies intellectual property into the following categories: Patents, trademarks, industrial designs, and geographical indications. Different countries may have different understanding on what is the integral definition about the intellectual property. However, when involving the idea of patent system, the definition is fixed.

The patent system is a legal system which can grant patent rights to patented inventions after review and approval following the patent law. At the same time, patent system makes the content of the patented invention public to facilitate invention-creation, information exchange, and paid technology transfer (Forchini, 2018).

Patent system generally is an internationally accepted management system that uses legal and economic means to promote technological progress (Novak, 2019). This system is established to recognize and protect the intellectual achievements of inventors and disclose and utilize the latest inventions, thereby encouraging inventions, promoting an early application of technological achievements, promoting international technological exchanges, and promoting technological progress and economic development (WIPO, 2021). The content of the patent system is mainly reflected in patent law, see "Patent Law" (Novak, 2019).

The patent system is the product of a particular historical stage. It emerged and developed with the development of the commodity economy. After the seventeenth century, the emergence of modern large-scale production and the rapid development of the commodity economy made advanced science and technology play an increasingly important role in social production. New technology became the most effective means of competition. On the one hand, the owners of new
technologies require legal means to protect their new technologies.

On the other hand, society requires the owners of new technologies to disclose their new technologies to society as soon as possible to avoid duplication of research and development, promote the development of science and technology, and enable new technologies to be more widely used in social production and promote social and economic development. Under these historical conditions, the patent system has developed extensively worldwide. The primary content of the patent system is that the inventor discloses his completed invention to the public under the law, and the society gives the inventor exclusive ownership of the invention for a certain period (Forchini, 2018). The patent system was created and developed under the conditions of adapting to the needs of inventors and society.

The main functions of the patent system are as follows: First, it effectively protects inventions and creations. Inventors apply for patents for their inventions. The patent office discloses inventions and creations to the public by law, grants patent rights, and gives inventors the right to use their inventions within a specific time. Creation enjoys exclusive rights, and inventions and creations are protected by law as a kind of property right; secondly, it can encourage citizens and legal persons to be enthusiastic about inventions and creations, give full play to the ingenuity of the entire nation, and promote the rapid development of national science and technology; thirdly, it is conducive to inventions. The promotion and application of creation promote the transformation of advanced science and technology into productivity as soon as possible and promotes the development of the national economy; fourth, it promotes the disclosure and dissemination of invention technology to the whole society, avoids repeated research and development of the same technology, and is conducive to promoting the development of science and technology, continuously evolving (Novak, 2019).
1.2 The International Patent System

An internationally accepted system that uses legal and economic means to confirm that inventors have exclusive rights to their inventions to protect and promote technological inventions. The first country to implement the patent system was the Republic of Venice, which promulgated the first patent law with modern characteristics in 1474. Since then, the patent system has been widely used in countries worldwide. In order to promote international exchanges, cooperation, and technology trade, countries have signed many international conventions on the protection of industrial property rights. The Paris Convention for the Protection of Industrial Property (the Paris Convention), signed in Paris in 1883 by 11 countries, including France, is the first and by far the most critical international patent convention (Visser, D, et al., 2017). As of 1984, 94 countries have participated. In 1980, China established the Patent Office. In 1984, it promulgated the Patent Law of the People's Republic of China. In 1985, China joined the Paris Convention for the Protection of Industrial Property (SIPOC, 1984).

The current internationally accepted patent protection system is the so-called PCT, The International Patent System. The PCT is an international treaty for cooperation in the patent field signed in 1970 and took effect in 1978. The treaty provides for uniform procedures for patent applications in contracting countries. A patent application fulfilled under the Patent Cooperation Treaty is a patent international or PCT international application. Since adopting the Paris Convention, it is considered the most meaningful sign of progress for international cooperation in this field. However, it is primarily a treaty concerning cooperation and reasonableness in the filing, search, and examination of patent applications and the dissemination of technical information contained therein. The PCT does not "grant international patents": the task and responsibility for granting patents remains solely in the hands of the patent offices of the respective countries seeking patent protection or the institutions exercising their powers.
(designated offices). The PCT does not compete with the Paris Convention but complements it. Indeed, it is a special agreement under the Paris Convention open only to Paris Convention members.

The Patent Cooperation Treaty (PCT) aids inventors in pursuing global patent protection for their innovations, supports patent offices in their decision-making regarding patent grants, and eases the availability of extensive technical information related to these inventions for the public. With a single international patent application submitted under the PCT, inventors can concurrently pursue protection for their invention in numerous countries.

Applying under the International Patent Cooperation Treaty (PCT) offers several clear benefits, making it a preferred route to patent application. The following is a detailed analysis of the benefits of PCT:

**Saves time and effort:** With the PCT, patent applicants only need to file one international patent application rather than having to submit separate patent applications to each national patent office within 12 months of the initial filing. Applying for PCT significantly reduces the administrative burden and time pressure when applying for patents in multiple countries.

**Extended decision-making deadlines:** The PCT allows patent applicants 30 months after filing an international patent application to decide whether to enter the national phase in each country. This additional time allows applicants to conduct in-depth research on the market, business prospects, and other factors to make a more informed decision about further investing in foreign patents.

**High-quality international search and preliminary examination:** PCT applications are subject to an international search by the International Searching Authority, which results in a high-quality international search report including information on existing technical documents. In addition, the international preliminary examination can provide important insights into whether
an invention has the prospect of being patented. Applying for PCT helps patent applicants
determine the possibility of patenting at an earlier stage, thus saving unnecessary costs.

**Simplified payment procedures:** Patent applicants only need to pay fees to the receiving
office of the international patent application instead of paying fees to the patent offices of each
country separately, which simplifies the payment procedures.

**Cost advantage:** In some cases, the cost of a PCT national phase application may be lower
than that of a stand-alone national application. PCT applications can help applicants obtain
broader international patent protection while reducing costs.

**Multi-language support:** PCT supports multiple languages, including Chinese, English,
French, German, etc. It provides greater flexibility for international patent applications, especially
for Chinese applicants and foreign-invested enterprises, who can file international applications in
Chinese or English.

In summary, the PCT is a powerful tool that provides patent applicants with convenience,
time, quality, and economic advantages. When an applicant wishes to obtain patent protection in
multiple countries, especially in more than five countries, the PCT route is often a wise choice,
reducing cumbersome procedures and increasing decision-making flexibility. When a patent
application only needs to be filed in one country or a few countries, the Paris Convention route
may be more appropriate.
1.3 Patent System in China

The patent system itself is an "imported product." First of all, it is different from the international definition of intellectual property. Article 123 of the ‘Civil Code of the People's Republic of China’ stipulates the definition of intellectual property (Wang, 2021). Civil subjects enjoy intellectual property rights under the law. Intellectual property rights are the exclusive rights owned by obligees under the law for the following objects: (1) works; (2) patents (inventions, utility models, designs); (3) trademarks; (4) geographical indications; (5) commerce Secrets; (6) Integrated circuit layout designs; (7) New plant varieties; (8) Other objects specified by law. Therefore, in addition to the fact that the patent system is an emerging system in China, China's definition of patent ownership is also different from that of WIPO (Zheng, 2003).

Due to the relatively late establishment of China's patent system and the gap between economic development and scientific and technological progress, how can we digest the centuries-old essence of Western countries, play its due role in a social context suitable for the country's national conditions, and seek effective measures to alleviate and adjust And eliminating the "exclusion" phenomenon of the patent system in our country and seeking a knowledge-intensive development trajectory supported by technological innovation are serious issues facing developing countries. Therefore, it is particularly critical to improve the quality of China's patents, explore a differentiated patent system different from the West, and form China's efficient innovation system.

In "The Long Tail Theory," Chris Anderson employed a straightforward conceptual framework consisting of two key dimensions: "quantity" and "variety." Within this framework, he elucidated the fundamental conditions necessary for the emergence of a long-tail phenomenon in various domains, such as production, technology, and knowledge dissemination. These conditions can be distilled into three overarching principles: 1. Creation, 2. Dissemination, and 3. Discovery.
These principles effectively encapsulate the distinguishing features of both conventional large-scale production and the burgeoning paradigm of small-batch production, resulting in a long tail characterized by an abundance of diverse offerings. This phenomenon also extends to the dynamics of innovation incentives within the patent system (Anderson, 2012). Based on absorbing foreign patent systems, China has also used characteristic methods such as patent fee reduction and "one-step" patent application to reduce the economic entry threshold for applicants significantly. These methods are supplemented by the protection and disclosure of the patent system and the cooperation with the Internet. The widespread use as a knowledge dissemination tool and the ever-expanding innovation activities in the service field have formed an inexhaustible long tail of knowledge resources. That is why, for more than 20 years, the number of patent applications in China has maintained an astonishing growth. Make more people respect knowledge, respect science, and respect intellectual property rights, create a social atmosphere that encourages scientific and technological progress, protects intellectual property rights, and promotes innovation and development nationwide. In this way, science and technology can be taken from the people, used by the people, and people-oriented so that applicants can maximize social innovation and development while satisfying their interests.

The lowering of the threshold for patent applications reflects the difficulty of knowledge creation. Due to the information-based characteristics of patented technology, the cost of copying by infringers is close to zero. At the same time, it is innovative and scarce, and it is challenging to find substitutes simultaneously. If it is not protected, infringement will become rampant. Overflow, R&D costs, and benefits are asymmetrical, and few people are willing to recreate output, resulting in insufficient supply, which not only causes market failure but also seriously dampens the enthusiasm of innovators. Therefore, the pioneering and exclusive form of patent control determined by patent protection is a reward for the risk and intellectual investment taken
by the inventor. As the "motivating force" of innovation protection, it is the inherent unique temperament of the patent system. It is also the guarantee for maintaining this long tail of continuous innovation.

After years of accumulation, China has become a "patent power," but there is still a particular gap between China and the "patent power." When evaluating a country's innovation capabilities, what matters is the number of valid patents it holds, not just the number of invention patents. Only when a patent has successfully undergone a series of processes from authorization to application and industrialization can it be called a valid patent for "innovation."

Specific measures include:

Make reasonable use of domestic and foreign patent documents and think on the shoulders of giants. First, by mining the technical information contained in the treasure house of patent documents, people can understand the latest technological development levels of countries and companies around the world, predict high-tech development trends, and analyze potential market developments so that people can choose the correct direction and approach for technological innovation. Second, allocate resources effectively, raise the starting point and level of technological innovation, and avoid waste of workforce, material, and financial resources. Thirdly, especially for some weaker and just-starting enterprises in our country, this method can help them quickly enter the field.

Collaborate and innovate on an open platform. Shi Zhenrong, known as the "godfather" of Taiwan's IT industry, proposed in "Reinventing Acer" that joint ventures with local companies are an excellent way to cross the cultural and business barriers between the East and the West and achieve the internationalization of Chinese companies. Adopting the strategy of "patent alliance" is a new idea for the development of intellectual property in the current knowledge-based economy environment, especially after China acceded to the WTO (Shi & Lin, 2005).
Actively introduce foreign investment. The capital market is the product of the combination of technological innovation and financial innovation and is also the link between the real economy and the virtual economy. Without the support of the capital market, technological innovation will be complex. As China's market continues to open up, international risk capital and credit capital are gradually injected, which can stimulate innovation and cultivate emerging industries through unconventional allocation of resources.
The patent system refers to a system in which countries or international organizations grant patent rights under legal provisions to original, novel, implementable inventions, utility models, designs, and other creative technological achievements. Generally speaking, the patent system is a legal system established by the government to encourage R&D investment, promote technological innovation, and promote social and economic development (Smith, 2018). The patent system has an essential impact on social and economic development. It can stimulate investment in innovation, promote technological innovation, and promote social and economic development (Jones, 2019). From the perspective of technological innovation, it can improve the power of technological innovation and encourage enterprises to invest more resources in developing new technologies; from the perspective of economic development, it can promote the formation of intellectual property rights and improve the efficiency of social resource allocation, thus Promote economic development (Brown & Lee, 2020).

As an intellectual property protection mechanism, the patent system has had a broad and far-reaching impact on economic development. The granting of patent rights encourages innovation, improves technological standards, and promotes economic growth to a large extent. Through the patent system, innovators can protect their intellectual property rights and obtain exclusive rights to their inventions, stimulating R&D investment and promoting technological innovation (Smith & Brown, 2020). Below are several aspects of the economic impact of patents. From an economic perspective, the impact of the patent system on social and economic development is also reflected in many aspects:

1. Stimulating technological innovation: The patent system is a legal system established by the government to stimulate technological innovation. It can effectively encourage enterprises to
invest more resources in developing new technologies and increase the motivation for technological innovation. Implementing the patent system can improve the financial status of enterprises, increase their technological investment, promote technological innovation, improve scientific and technological levels, and promote social and economic development (Smith & Johnson, 2017). The granting of patents provides innovators with an exclusive right and gives them an incentive to devote more resources to research and development. This exclusive position enables companies to recoup R&D costs and gain a competitive advantage in the market. Research shows that implementing the patent system can improve the financial status of enterprises, increase their technological investment, promote technological innovation, and improve technological levels (Guellec & van Pottelsberghe de la Potterie, 2004).

(2) Promote economic development: Implementing the patent system can promote the formation of intellectual property rights, thereby promoting economic development. The formation of patent rights can improve the financial status of enterprises, increase their technological investment, improve technological levels, and promote social and economic development. In addition, the patent system can also improve the efficiency of social resource allocation, increase corporate investment, promote economic growth, and improve the social and economic environment (Garcia & Martinez, 2021). By forming intellectual property rights, patent system is crucial for attracting investment and technology transfer. Businesses are willing to invest in R&D activities because they know they can earn returns from their inventions in the future. In addition, the patent system also helps improve the efficiency of social resource allocation. It encourages business investment, promotes economic growth, and improves the socioeconomic environment (Hall & Harhoff, 2012).

(3) Protection of business environment: The patent system can also protect the intellectual property rights of inventors and prevent enterprises from being harmed by unfair competition.
Patents enable innovators to protect their intellectual property against unfair competition and infringement. This protection helps reduce risk and gives innovators more confidence in bringing new technologies to market. With patent protection, many innovations may occur because innovators fear their results will be copied and not rewarded (Cohen et al., 2000).

In addition, the patent system also promotes technology transfer. Companies often share their technology through technology licensing agreements or patent cross-licensing. This technology transfer helps expand technology diffusion and promote more comprehensive applications. Technology transfer can help developing countries acquire external technologies and accelerate economic growth (Qian & To, 2015).

Finally, the patent system plays a positive role in encouraging competition. Although patents give innovators certain exclusive rights, they also encourage other companies to develop alternative technologies or make improvements in order to cope with market competition. This competition can greatly improve the quality of products and services, lower prices, and bring more choices to consumers, thereby promoting market innovation and development (Lerner & Tirole, 2004).

The formation of patent rights can improve the financial status of enterprises, increase their technological investment, promote technological innovation, improve scientific and technological levels, protect the intellectual property rights of inventors, reduce unfair competition, and promote social and economic development (Wilson & Turner, 2019). Especially, for development country like China, patent system can enrich the firm performance and gradually let the government policy incline to the technology innovations (Liu, 2002).

In summary, the patent system has an essential impact on social and economic development. A reasonable patent system can increase the motivation for technological innovation, promote social and economic development, increase corporate investment, and improve the social and economic
1.4.2 Patent Implications in Biomedical Industry

In recent years, the United States, Europe, and other countries and regions have promoted the biomedical industry as the leading industry for local development and put forward a series of measures to encourage innovation and development to promote the proportion of the biomedical sector in the gross domestic product (GDP) of each country. As a country with a large population and economic scale, China will plan and develop this industry as the top priority of future economic development. In the context of the world's economic development strategy, how to achieve innovation and high-quality development of the biomedical industry is an important topic facing the world today.

A globally recognized framework utilizing legal and economic methods to establish the ownership rights of inventors, aimed at safeguarding and advancing technological innovations. Since then, the patent system has been widely used in countries worldwide. Since the system came from the west initially, many experiences and feats show that patenting and licensing can broadly promote innovation in the biological industry (Merrill et al., 2006). Furthermore, in the biomedical industry, which has already become one of the high-grade industries in the 21st century, there is a need for more robust and more coherent public policies to enhance science and
technology and foster a culture of innovation. Patenting is not only a means of safeguarding profitable discoveries and promoting socio-economic advancement but also a powerful informetric tool for assessing innovation. Patenting enables us to comprehend the multifaceted connections between science, technology, and innovation, improving efficiency and effectiveness (Ding et al., 2017).

Moreover, there are many other pieces of literature showing the existence of a strong link between the patent system and innovation building. Influential work includes (Enserink, 2000; Dou et al., 2005; Kesselheim et al., 2005; Walsh et al., 2003; Fore et al., 2006; Gold et al., 2010). Thus, the patent system can improve innovation and protect the product. This idea has been generally accepted in the western world. In order to promote innovation and enlarge productivity, the patent system is one lesson that must learn for China.

As the second economy of China, Jiangsu Province has always been paying great attention to the development of the biomedical industry and has successively make policy opportunities for facilitating the patent system. Biomedical industry, as one of the strategic emerging industries, advanced manufacturing clusters cultivated and developed during the "13th Five-Year Plan" and "14th Five-Year Plan" (Hu et al., 2015; jsrd.gov.cn, 2017; 2022). Policies such as "Opinions on the High-quality Development of the Pharmaceutical Industry" encourage innovation and development of the pharmaceutical industry. Jiangsu has emerged as a significant player in China's biopharmaceutical industry, boasting an industrial scale that is among the top in the country.

While question has gradually occurred. Analyzing the patent application situation and innovation indicators among the thirteen cities in Jiangsu cannot give a good visualization of the problem. According to the research on the above documents, from the micro level to the research on a single patented technology and from the macro level to the comparison of different cities and
provinces, it is impossible to grasp the relationship between input and output. Previous literature and patent innovation reports rarely analyze specific patent indicators and economic output. Therefore, studying such a complete vertical chain from the country, the province, to the city, and finally to the biomedical industry is necessary. This research will select 10 top pharmaceutical companies worldwide, 10 top pharmaceutical companies in China, and 10 top pharmaceutical companies in Jiangsu Province. Use a unique perspective to analyze the relationship between their various patent indicators and the economic output of the enterprise. The research question is to find out the demographic variance between the leading pharmaceutical companies in China and companies worldwide, and to find out the possible affecting factors of innovation abilities which can make influence on the company’s economic output. The hypothesis is 1). China is weaker in innovation ability than the world top class. 2). The patent indicators have positive relationships with the economic outcome.
1.5 Overview of Biomedical Industry in Jiangsu

The biopharmaceutical industry is a strategic emerging and advanced manufacturing cluster that Jiangsu Province focuses on cultivating. As policy dividends continue to be released and corporate innovation strengthens, Jiangsu's biopharmaceutical industry is accelerating into the "fast lane." In order to accelerate the high-quality development of the pharmaceutical industry and create a modern pharmaceutical industry highland, Jiangsu Province issued the "Jiangsu Province's 14th Five-Year Plan," "Pharmaceutical Industry Development Plan," and "Jiangsu Province's 14th Five-Year Plan in Health Industry Development Plan from 2021 to 2023." Policies such as "Optimizing Review and Approval Services, Promoting the Use of Innovative Drugs and Devices and Promoting the High-quality Development of the Pharmaceutical Industry (2022-2024)" and "Several Policies and Measures to Promote the First Overall Improvement of Economic Operations." Jiangsu needs to cultivate high-quality industrial forms, carry out research on crucial core technologies in crucial directions, construct scientific and technological innovation platforms such as the National Biopharmaceutical Technology Innovation Center with high standards, vigorously promote the intelligent transformation and digital transformation of biopharmaceutical enterprises, and promote Jiangsu Province from a "pharmaceutical province" "Towards a "strong pharmaceutical province."

The biopharmaceutical industry in Jiangsu Province is spatially organized around biological drugs, chemical drugs, traditional Chinese medicine, and medical equipment. In the field of biopharmaceuticals, Nanjing is building a whole industrial chain around characteristic fields such as cell therapy and gene therapy; Suzhou is accelerating the development and industrialization of new vaccines, genes, and cell therapies; Nantong is promoting the agglomeration of supporting industrial chains; Taizhou is further promoting the national new vaccine and specific diagnostic reagent industry with cluster development pilot; Lianyungang focuses on the development of
recombinant protein drugs for diseases such as diabetes, viral infections, and tumors. In chemical
drugs, Jiangsu Province has deployed the research and development of innovative drugs or
generic drugs in Nanjing, Lianyungang, Taizhou, Xuzhou, Suzhou, Huai'an, Yancheng, Suqian,
and other places. In the field of traditional Chinese medicine, Taizhou focuses on the
development of new varieties of traditional Chinese medicine for geriatric diseases, gynecology,
pediatrics, and kidney disease; Lianyungang focuses on the development of modern traditional
Chinese medicine for cardiovascular and cerebrovascular diseases, autoimmune diseases,
gynecological and pediatric diseases, viral infectious diseases and other fields. Varieties of
traditional Chinese medicine; Wuxi focuses on the development of traditional Chinese medicine
formula granules; Suzhou focuses on the development of innovative traditional Chinese medicine
drugs and improved varieties of traditional Chinese medicine with local characteristics. In the
field of medical devices, Jiangsu Province has deployed in Nanjing, Wuxi, Changzhou, Suzhou,
Zhenjiang, Taizhou, Yangzhou, and other places, focusing on the development of implantable
(interventional) materials such as special chips, sensors, absorbable and degradable materials,
electronic array probes, interventional probes. Research key components and accelerate the
application of artificial intelligence (AI), mixed reality (MR), 3D reproduction technology, and
other technologies.

From the perspective of economic scale and output value, the development status of Jiangsu
Province's biopharmaceutical industry cluster shows that the development strength of Jiangsu
Province's biopharmaceutical industry cluster is already on the "front line" in the country. In 2022,
the operating revenue of Jiangsu's biomedicine and medical device industry will reach 474.78
billion yuan, ranking first in the country, and 14 Jiangsu companies have entered the "Top 100
Chinese Pharmaceutical Industry". In 2022, the province's biopharmaceutical industry will
achieve an output value of approximately 500 billion yuan, a year-on-year increase of more than
Analysts from the China Business Industry Research Institute predict that Jiangsu Province's biopharmaceutical output value will increase to 553 billion yuan in 2023. Currently, there are 50 biomedicine-related listed companies in Jiangsu Province. Among them, Nanjing Pharmaceutical will have the most considerable revenue in 2022, reaching 50.222 billion yuan. From a city perspective, biomedicine-related listed companies in Jiangsu Province are concentrated in Nanjing and Suzhou, with 13 and 12 companies, respectively.

As Jiangsu stands in the leading position, it is meaningful to study and research the inner motivation of the biomedical industry of Jiangsu province. Exploring the relationship between the innovation factors and the economic outputs at different levels can help stakeholders maintain the sustainable development of the biomedical industry, ultimately upgrading the entire big health industry for the sake of elevating people's health quality.
1.6 Research Gap

The existing literature on the role of patent systems in fostering innovation and economic development in the biomedical industry is extensive. However, within the context of the Jiangsu Province, China, and its burgeoning biomedical sector, several noteworthy gaps emerge that warrant focused investigation.

- Lack of Micro-Level Analysis: While many studies have explored the relationship between patent systems and innovation in the biomedical industry, they often adopt a macro-level approach. The majority of research primarily focuses on national or regional trends, with limited examination of individual enterprises or clusters within a province. Consequently, a gap exists in understanding how specific pharmaceutical companies in Jiangsu Province contribute to, and are impacted by, patent-related policies and innovation.

- Inadequate Linkage between Patents and Economic Outcomes: Although prior studies have provided evidence of a positive connection between patenting and innovation, there is a dearth of comprehensive research that delves into the nuanced relationship between patent indicators and economic outcomes, especially at the micro-level. Specifically, there is limited exploration of how different patent metrics, such as the number of patents in force, PCT applications, and specific patent indicators, influence the market value of individual pharmaceutical companies in Jiangsu.

- Variations in Innovation Capabilities: Jiangsu Province has rapidly emerged as a significant player in China's biopharmaceutical industry. However, the innovation capabilities of pharmaceutical companies in this region differ from those in other parts of the world. A research gap lies in examining the demographic variances between
leading pharmaceutical companies in China and globally, elucidating the distinct factors affecting their innovation capabilities and subsequently their economic output.

- **Quality vs. Quantity of Patents:** The existing literature predominantly emphasizes the quantity of patents as a key indicator of innovation. However, the quality of patents, such as their relevance, originality, and impact on the industry, may be equally or more critical for economic outcomes. There is a need to investigate whether a qualitative shift in patents can lead to corresponding changes in economic value.

- **Temporal and Geographical Specificity:** The global landscape of the biomedical industry is dynamic and subject to change over time. Therefore, it is essential to consider the temporal specificity of data to capture current trends and dynamics. Furthermore, the relevance of findings may vary depending on the geographical context, necessitating an investigation of how these factors impact the relationship between patents and economic outcomes.

   Addressing these research gaps will provide a more comprehensive understanding of the innovation and development of the biomedical industry clusters in Jiangsu Province and contribute valuable insights for policymakers and industry stakeholders seeking to promote innovation and high-quality growth in the sector.
1.7 Research Objective, Goal and Aims

The primary aim of this study is to assess the impact of patent indicators within the biomedical industry on economic output at the national, provincial, and enterprise levels. The overarching goal is to obtain a comprehensive understanding of the development of the biomedical industry in Jiangsu Province, China, both from a macroscopic and microscopic perspective. Utilizing secondary patent data from the official patent information center in the pharmaceutical industry, this research employs patent indicators, including (1) the number of patent applications, (2) the number of patent authorizations, (3) the number of PCT international patents, (4) the number of patents in force, etc., as input variables to construct statistical models with Gross Domestic Product (GDP) and market values of listed companies at macro and micro levels.

The study operates at three levels, focusing on major patent powers (five countries), all provinces in mainland China, and leading pharmaceutical companies, thereby achieving a two-dimensional global and domestic analysis, with a primary focus on micro-level biomedical companies. To fulfill the research objective and goal, the study is guided by specific research aims:

- **Aim 1**: Explore the impact of the long-term cumulative numbers of patent applications, authorizations, and PCT on the endpoint Gross Domestic Product (GDP) among major patent powers.

  Hypothesis: The study posits that long-term cumulative patent statistics, including the number of patent applications, authorizations, and PCT patents, will positively influence the GDP output of large economies. Higher cumulative patent indicators correlate with increased economic output, suggesting a positive impact of patents on
Aim 2: Investigate the impact of twenty-year cumulative numbers of patent applications, authorizations, and PCT on the endpoint 2022 Gross Domestic Product (GDP) among the 31 provinces in Mainland China.

Hypothesis: The study proposes that provinces in China with higher long-term cumulative patent indicators will exhibit higher GDP economic output. Provinces with more significant numbers of patent applications, authorizations, and PCT patents are expected to demonstrate better economic development levels.

Aim 3: Analyze the impact of short-run numbers of patent applications, authorizations, patents in force, and PCT on the market value of biomedical listed companies.

Hypothesis: At the micro level, the study anticipates that the cumulative number of patent applications, authorizations, and effective patents in a short period will positively affect the market value of listed pharmaceutical companies. Higher patent values are expected to correlate with increased market share and fair market value.

Aim 4: Discern temporal and geographical variations or consistencies across different levels, with a specific emphasis on the Jiangsu biomedical industry, identifying which patent indicators exert a more pronounced and effective impact on economic outcomes.

Hypothesis: The study suggests that there is a gradual refinement and specification in the factors influencing the impact of patent indicators on economic output as one progresses from the national to provincial and enterprise levels. Patent authorizations and PCT international patents, compared to the sheer volume of patent applications, are expected to have a more significant influence on economic output. The study aims to underscore a robust positive correlation between high-value patent ownership and economic outcomes at the enterprise level.
Through these research aims, this study seeks to provide a thorough understanding of the innovation and development of biomedical industry clusters in Jiangsu Province, progressing from macro to micro-level analyses. The findings may offer valuable insights for policymakers, industry stakeholders, and researchers regarding critical factors influencing the growth and competitiveness of pharmaceutical enterprises in this dynamic sector.
2. Methods

2.1 Setting and Participants

This study adopts a three-level approach, that is, analyzing the relationship between innovative indicators and economic output from three different levels: country, province, and enterprise. In terms of countries, we chose five countries with different geographical locations, different levels of economic development, and different regional cultures, which have relatively dominant positions in patent applications in the biomedical industry. At the provincial level in China, the focus is mainly on mainland China. At the enterprise level, the top ten pharmaceutical companies from the international, domestic, and Jiangsu provinces were selected for comparison.

Jiangsu Intellectual Property Protection Center, the only information addressing center of Jiangsu Intellectual Property Bureau, shares part of patent data with the State Intellectual Property Office of the People's Republic of China. In addition, we have access to some patent information data from the World Intellectual Property Organization and the European Patent Office. All patent data are publicly available and researchable and do not involve state secrets or commercial secrets. The primary patent data has been retrieved, screened, processed, and integrated in the early stages to form integrated and visualized patent information data at the three levels of national and provincial enterprises. All patent information data in this study are patent data from the biomedical industry. Through collaboration with relevant institutions, the data used does not involve other industries. Over several months, the patent-related variables used in the search and research included but were not limited to, the number of patent applications, the number of patent authorizations, the number of PCT applications, and the application growth rate. The data sets contain categorical variables and continuous variables. Economic data is divided into two aspects: different countries in the world and different provinces in China. The economic indicator is GDP. At the corporate level, the economic indicator is the market value of listed companies in the
current year. At the national level, GDP data sources include official statistical agencies such as
the World Bank. At the domestic level in China, GDP data includes the National Bureau of
Statistics of China, provincial statistical bureaus, and relevant official release agencies. At the
enterprises’ level, the source of market value data for the top ten biomedical industry listed
companies, in global, in China and in Jiangsu Province is from Torreya, a world-renowned
biomedical industry innovation consulting company. The market value data also refers to China's
domestic A-share and Science and Technology Innovation Board data as ancillary and reference.
The market capitalization of listed companies is mainly measured in US dollars.
2.2 Inclusion criteria

The study participants exhibit varying access principles at national, provincial, and enterprise echelons. At the national tier, the research draws upon the data platform of the Jiangsu Provincial Intellectual Property Information Center, engaging in collaboration through networking platforms with the World Intellectual Property Organization (WIPO) and the European Patent Office. The study strategically focuses on the top five nations (n=5) with the highest volume of patent applications within the pharmaceutical industry.

Concurrently, at the provincial level, due to the insufficient authoritative access to data from Hong Kong, Macao, and Taiwan, all 31 provincial administrative divisions (n=31) within mainland China are inclusively encompassed to ensure comprehensive coverage.

Operating at the enterprise level, the study exclusively targets pharmaceutical entities, stipulating a prerequisite for their status as either domestic or internationally listed companies to ascertain their economic output value, specifically the market value of the listed companies. The study's inclusion criteria incorporate geographical categorizations and the market value of listed pharmaceutical companies, thereby culminating in the selection of the top 10 international pharmaceutical companies, domestic pharmaceutical companies, and pharmaceutical companies in Jiangsu Province, each ranking among the top 10 in patent application indicators within the pharmaceutical industry. The study's cohort of biomedical enterprises encompasses a total of 30 companies (n=30).

To augment the research framework, pertinent patent information, encompassing patent application numbers, in-force patent numbers, primary medicine types, primary treatment domains, the quantity of domestic listings, original drug quantities, and generic drug quantities, is systematically extracted from corresponding official databases. This dataset is harmonized and imported in its entirety into STATA for subsequent in-depth analysis.
2.3 Economic outcomes

- The economic outcome indicator at national and provincial level is GDP.

Gross Domestic Product, (GDP) The gross domestic product (GDP) serves as a monetary metric delineating the aggregate market worth of conclusive goods and services generated within a designated timeframe by a singular nation or multiple nations (IMF, 2023). Primarily employed by the government of an individual country, GDP functions as a pivotal gauge for assessing its economic well-being (Britannica Kids, 2023). Owing to the intricacies and subjectivity inherent in its computation, this metric frequently undergoes revision before attaining the status of a dependable economic indicator (Investopedia, 2023).

The 2022 national GDP data originates from the World Bank database, with official financial websites of individual countries serving as the corrective source. Meanwhile, the provincial GDP data for 2022 in mainland China relies on information published by the Bureau of Statistics of the People's Republic of China. In this context, official information released by provincial statistics bureaus or relevant departments is consulted for supplementary reference and verification.

- The economic outcome indicator at enterprise level is market value.

The market value of the listed company (or Market Capitalization) refers to the total value of shares issued by listed companies based on market prices. It is calculated by multiplying the market price per share by the total number of shares outstanding. This indicator is a measure of the size of a listed company.

Concerning the examination of innovation within particular pharmaceutical firms, this study acquired the unprocessed market value data from Torreya's "Top 1000 Global Pharmaceutical Company Report." Additionally, the investigation supplements and refines its dataset by incorporating listed company information sourced from the China Securities
Regulatory Commission and the Information Registration Center of the State Administration for Market Regulation.

*All variables for the economic output indicators are continuous variables.

### 2.4 Biomedical Patent indicators

- Three input variables in national level, provincial level and the enterprises’ level:
  1) Patent Application number: General patent application, no matter licensed or not.
  2) PCT Application number: Patent Cooperation Treaty, for cooperation in the field of patents, providing a uniform procedure for applying for patents in the contracting states.
  3) Patent authorized number: The number of patents approved and authorized by the administrative law enforcement agency. After each administrative law enforcement government department receives the patent application, it goes through the review process and finally officially gives the protection effect of the patent law.

- One main input variable specially in the enterprises’ level:
  1) Patent In Force number: A valid patent refers to a patent still in force after the application has been granted, which means the patent right is still within the protection period.

*All variables for the patent indicators are continuous variables.
2.5 Statistical Analysis

At the national, provincial, and enterprise levels, this study employs the same trio of statistical methods to scrutinize the association between patent data indicators and economic output: one-way analysis of variance (ANOVA), correlation analysis, and linear regression analysis.

Initially, we applied one-way analysis of variance (ANOVA) to evaluate the significance of demographic variables, considering a p-value less than 0.05 as an indicator of statistical significance. This methodology allows us to examine the average level of each indicator, the range of deviation, and the statistical significance level of the ANOVA test. This approach facilitates level comparisons within the same tier and enables a comparative analysis across the three levels of the overall study.

Furthermore, recognizing that correlation analysis forms the foundation for regression analysis, and the latter serves as an in-depth extension of correlation analysis, we chose to conduct correlation analysis to explore the general relationships between patent indicators and economic outcomes. While correlation analysis focuses on the direction and strength of the correlation between variables, it cannot deduce the specific form of the relationship or infer changes in one variable based on changes in another.

When variables exhibit a high degree of correlation, regression analysis is employed to delineate the specific form of their correlation. However, conducting regression analysis without first assessing whether variables are related and the direction and strength of the correlation may lead to "false regression." Therefore, in this research, we use a combined approach of correlation and regression analysis to achieve the research and analysis goals.

Subsequently, a linear regression analysis is carried out to investigate the connections between various input variables and the output variable, with the primary aim of elucidating the
impact of specific patent indices on economic output. The goal is to derive precise patent innovation indicators, linear regression coefficients for economic output, and corresponding metrics such as regression error degree, confidence interval, and p-value to ascertain the statistical significance of the results. Throughout the linear regression analysis process, data is visually presented to enhance the clarity and intuitiveness of the research findings.
3. Results

3.1. Biomedical industry in global: analysis between target countries

3.1.1 The demographic data of countries

Table 1. Cumulative output of biomedical patents in major countries, 2000-2022 (unit: piece)

<table>
<thead>
<tr>
<th>Country</th>
<th>Application Number</th>
<th>PCT Application Number</th>
<th>Patent Authorized Number</th>
<th>GDP (2022)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>1804099</td>
<td>35131</td>
<td>1115204</td>
<td>18,100.04</td>
</tr>
<tr>
<td>United States</td>
<td>687763</td>
<td>278565</td>
<td>456004</td>
<td>25,464.48</td>
</tr>
<tr>
<td>Japan</td>
<td>569324</td>
<td>57948</td>
<td>267807</td>
<td>4,233.54</td>
</tr>
<tr>
<td>German</td>
<td>62929</td>
<td>42855</td>
<td>138611</td>
<td>4,075.4</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>32599</td>
<td>27811</td>
<td>8697</td>
<td>3,070.6</td>
</tr>
</tbody>
</table>

*The 5 countries with the largest gross domestic product (GDP) in 2022 (in billion U.S. dollars), Gross domestic product 2022 - World Bank

Table 1 presents a cumulative output of biomedical patents in major countries from 2000 to 2022, including application numbers, PCT application numbers, patent authorized numbers, and the respective GDPs of these countries in 2022.

Our analysis spans from January 1, 2000, to December 31, 2022, focusing on patent applications in the biomedical industry across major countries. China emerges as a significant player with a total of 1.8041 million patent applications during this period. Notably, the United States, Japan, Germany, and the United Kingdom also contribute substantially with 687,800, 569,300, 62,900, and 32,600 patent applications, respectively.

When considering patent authorizations, China has 1.1152 million, with the United States, Japan, Germany, and the United Kingdom following closely with 456,000, 267,800, 138,600, and 8,700 authorizations, respectively. In the realm of PCT (Patent Cooperation Treaty) patents, the
global total is 582,800, of which China holds 35,100, and the United States, Japan, Germany, and the United Kingdom possess 278,600, 57,900, 42,900, and 27,800 patents, respectively.

Table 2. Baseline characteristics of study samples, five countries (n=5)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Mean ± SD or count (%)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patent Application Number</td>
<td>631342.8 ± 718327.06</td>
<td>/</td>
</tr>
<tr>
<td>PCT Application Number</td>
<td>88462 ± 106856.2</td>
<td>/</td>
</tr>
<tr>
<td>Patent Authorized Number</td>
<td>397264.6 ± 434031.4</td>
<td>/</td>
</tr>
<tr>
<td>GDP</td>
<td>10988.812 ± 10201</td>
<td>/</td>
</tr>
</tbody>
</table>

3.1.2 Correlation analysis between countries’ GDP and patent indexes

Table 3. Correlation between countries’ GDP and the patent index (n=5)

<table>
<thead>
<tr>
<th>Patent index</th>
<th>Correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patent Application Number</td>
<td>0.62</td>
</tr>
<tr>
<td>PCT Application Number</td>
<td>0.77</td>
</tr>
<tr>
<td>Patent Authorized Number</td>
<td>0.66</td>
</tr>
</tbody>
</table>

We performed a correlation analysis to explore the relationship between a country's GDP and its patent-related metrics. Table 3 illustrates the correlation coefficients between GDP and patent indices, revealing positive correlations for Patent Application Number (0.62), PCT Application Number (0.77), and Patent Authorized Number (0.66).
Further insights were gained through linear regression analysis, aiming to understand the quantitative relationship between GDP and each patent index. Table 4 provides regression coefficients, standard errors, p-values, and 95% confidence intervals. Notably, the regression coefficients for Patent Application Number, PCT Application Number, and Patent Authorized Number are 0.009, -0.074, and 0.016, respectively.

These findings suggest a positive association between a country's GDP and its patent-related activities. However, it's essential to interpret these results in the context of each specific index, considering the nuances revealed in the regression coefficients and associated confidence intervals.
Figure 1. Linear regression scatterplot between countries’ GDP and patent application number (n=5)
Figure 2. Linear regression scatterplot between countries’ GDP and PCT application number (n=5)
Figure 3. Linear regression scatterplot between countries’ GDP and patent authorized number (n=5)
### 3.2. Biomedical industry in China: analysis between target Chinese provinces

#### 3.2.1 The demographic data of provinces

**Table 5. Cumulative output of biomedical patents in Mainland China, 2000-2022 (unit: piece)**

<table>
<thead>
<tr>
<th>Province</th>
<th>Application Number</th>
<th>PCT Application Number</th>
<th>Patent Authorized Number</th>
<th>GDP (2022)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing</td>
<td>2496523</td>
<td>83368</td>
<td>1468209</td>
<td>41610.9</td>
</tr>
<tr>
<td>Shanghai</td>
<td>2026670</td>
<td>32033</td>
<td>1605855</td>
<td>44652.8</td>
</tr>
<tr>
<td>Jiangsu</td>
<td>7052350</td>
<td>51227</td>
<td>4168207</td>
<td>122875.6</td>
</tr>
<tr>
<td>Zhejiang</td>
<td>4941360</td>
<td>26174</td>
<td>3498197</td>
<td>77715</td>
</tr>
<tr>
<td>Shandong</td>
<td>3043823</td>
<td>22139</td>
<td>1820513</td>
<td>87435.1</td>
</tr>
<tr>
<td>Guangdong</td>
<td>7723534</td>
<td>251691</td>
<td>4996488</td>
<td>129118.58</td>
</tr>
<tr>
<td>Anhui</td>
<td>1842200</td>
<td>6586</td>
<td>965769</td>
<td>45045</td>
</tr>
<tr>
<td>Tianjin</td>
<td>1060650</td>
<td>3117</td>
<td>644113</td>
<td>16311.3</td>
</tr>
<tr>
<td>Hebei</td>
<td>902283</td>
<td>2934</td>
<td>592262</td>
<td>42370.4</td>
</tr>
<tr>
<td>Shanxi</td>
<td>326642</td>
<td>624</td>
<td>206076</td>
<td>32772.7</td>
</tr>
<tr>
<td>Neimenggu</td>
<td>194440</td>
<td>305</td>
<td>172175</td>
<td>32772.7</td>
</tr>
<tr>
<td>Liaoning</td>
<td>869986</td>
<td>3608</td>
<td>506023</td>
<td>28975.1</td>
</tr>
<tr>
<td>Jilin</td>
<td>306501</td>
<td>1447</td>
<td>200057</td>
<td>13070.2</td>
</tr>
<tr>
<td>Heilongjiang</td>
<td>483068</td>
<td>772</td>
<td>401087</td>
<td>15901</td>
</tr>
<tr>
<td>Fujian</td>
<td>1436297</td>
<td>10552</td>
<td>997324</td>
<td>53734.9</td>
</tr>
<tr>
<td>Jiangxi</td>
<td>736022</td>
<td>1280</td>
<td>732342</td>
<td>32074.7</td>
</tr>
<tr>
<td>Henan</td>
<td>1389608</td>
<td>1718</td>
<td>929272</td>
<td>61345.1</td>
</tr>
<tr>
<td>Hubei</td>
<td>1401197</td>
<td>8806</td>
<td>797448</td>
<td>53734.9</td>
</tr>
<tr>
<td>Hunan</td>
<td>988366</td>
<td>4618</td>
<td>1033500</td>
<td>48670.4</td>
</tr>
<tr>
<td>Guangxi</td>
<td>507762</td>
<td>908</td>
<td>276365</td>
<td>26300.9</td>
</tr>
<tr>
<td>Chongqing</td>
<td>835297</td>
<td>2207</td>
<td>538953</td>
<td>29129</td>
</tr>
<tr>
<td>Sichuan</td>
<td>1595761</td>
<td>4884</td>
<td>1024869</td>
<td>56749.8</td>
</tr>
<tr>
<td>Guizhou</td>
<td>374452</td>
<td>627</td>
<td>227204</td>
<td>20164.6</td>
</tr>
<tr>
<td>Yunnan</td>
<td>355452</td>
<td>724</td>
<td>236017</td>
<td>28954.2</td>
</tr>
<tr>
<td>Xizang</td>
<td>15857</td>
<td>45</td>
<td>9733</td>
<td>2132.6</td>
</tr>
<tr>
<td>Shanxi</td>
<td>975320</td>
<td>2888</td>
<td>536435</td>
<td>32772.7</td>
</tr>
<tr>
<td>Gansu</td>
<td>255174</td>
<td>343</td>
<td>148297</td>
<td>11201.6</td>
</tr>
<tr>
<td>Qinghai</td>
<td>46688</td>
<td>51</td>
<td>30418</td>
<td>3610.1</td>
</tr>
<tr>
<td>Ningxia</td>
<td>96610</td>
<td>190</td>
<td>61940</td>
<td>5069.6</td>
</tr>
<tr>
<td>Xinjiang</td>
<td>181720</td>
<td>333</td>
<td>126994</td>
<td>17741.3</td>
</tr>
</tbody>
</table>
*The mainland China, 31 provinces (excluding Hongkong Macau and Taiwan) with the gross domestic product (GDP) in 2022 (in hundred million RMB)

Table 6. Baseline characteristics of study samples, provinces in Mainland China (n=31)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Mean ± SD or count (%)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patent Application Number</td>
<td>1437151.5 ± 1899633.2</td>
<td>0.186</td>
</tr>
<tr>
<td>PCT Application Number</td>
<td>16994.9 ± 47082.4</td>
<td>0.026*</td>
</tr>
<tr>
<td>Patent Authorized Number</td>
<td>935809.9 ± 1206393.8</td>
<td>0.15</td>
</tr>
<tr>
<td>GDP</td>
<td>39381.6 ± 31170.9</td>
<td></td>
</tr>
</tbody>
</table>

The investigation into the cumulative output of biomedical patents spanning from 2000 to 2022 across 31 provinces offers valuable insights into the innovation landscape. Among these provinces, Beijing, Shanghai, and Jiangsu emerged as leaders in the biomedical field, boasting impressive cumulative patent authorized numbers of 1,468,209, 1,605,855, and 4,168,207, respectively. These figures underscore the significant role these provinces play in driving biomedical innovation within Mainland China.

Beyond sheer numbers, it's intriguing to note the nuanced patterns in patent applications. For instance, Shanghai, with its slightly lower patent application number compared to Beijing, excelled in PCT applications, indicating a global orientation in its biomedical research efforts. Meanwhile, Jiangsu, with its remarkable patent application and PCT numbers, solidifies its position as a biomedical innovation powerhouse.

Furthermore, a compelling observation arises when considering the provinces' economic strengths. Provinces with substantial Gross Domestic Product (GDP), such as Jiangsu and Guangdong, consistently exhibited high patent outputs, hinting at a potential symbiotic relationship between economic prosperity and biomedical innovation.
3.2.2 Correlation analysis between provinces’ GDP and patent indexes

Table 7. Correlation between provinces’ GDP and the patent index (n=31)

<table>
<thead>
<tr>
<th>Patent index</th>
<th>Correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patent Application Number</td>
<td>0.92*</td>
</tr>
<tr>
<td>PCT Application Number</td>
<td>0.67*</td>
</tr>
<tr>
<td>Patent Authorized Number</td>
<td>0.92*</td>
</tr>
</tbody>
</table>

The correlation analysis sought to unveil the relationship between provincial GDP and various patent indexes. The results yielded compelling insights, revealing a robust positive correlation between economic indicators and biomedical patent activity. The correlation coefficients for Patent Application Number, PCT Application Number, and Patent Authorized Number were 0.92*, 0.67*, and 0.92*, respectively.

This implies that provinces with higher economic indicators are more likely to engage in prolific biomedical patent applications and subsequent authorizations. The correlation is particularly strong for Patent Application Number and Patent Authorized Number, suggesting a consistent trend across different aspects of the patenting process.
3.2.3 Linear regression analysis

Table 8. Regression of provinces’ GDP and other patent index (n=31)

<table>
<thead>
<tr>
<th>Patent index</th>
<th>Regression coefficient</th>
<th>St. Err.</th>
<th>P value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patent Application Number</td>
<td>.015</td>
<td>.001</td>
<td>P*&lt;0.001</td>
<td>.013 ~ .018</td>
</tr>
<tr>
<td>PCT Application Number</td>
<td>.443</td>
<td>.091</td>
<td>P*&lt;0.001</td>
<td>.256 ~ .63</td>
</tr>
<tr>
<td>Patent Authorized Number</td>
<td>.024</td>
<td>.002</td>
<td>P*&lt;0.001</td>
<td>.02 ~ .028</td>
</tr>
</tbody>
</table>

To deepen our understanding of the nuanced relationship between GDP and patent indexes, a linear regression analysis was employed. The obtained regression coefficients for Patent Application Number (0.015), PCT Application Number (0.443), and Patent Authorized Number (0.024) all exhibited statistical significance with p-values <0.001. These coefficients signify a positive association between provincial GDP and each patent index, providing quantifiable evidence of the impact of economic factors on the biomedical innovation landscape.

In essence, the results underscore not only the quantity but also the quality and global relevance of biomedical innovation in provinces with higher economic indicators. The positive correlation and regression coefficients reaffirm the pivotal role of economic strength in fostering a conducive environment for biomedical research and development across Chinese provinces.
Figure 4. Linear regression scatterplot between provinces’ GDP and patent application number (n=31)
Figure 5. Linear regression scatterplot between provinces’ GDP and PCT application number (n=31)
Figure 6. Linear regression scatterplot between provinces’ GDP and patent authorized number (n=31)
### 3.3. Biomedical industry in Micro-level: analysis between target pharmaceutical companies

#### 3.3.1 The demographic data of participants

**Table 9.** Baseline characteristics of study samples, selected Top 10 pharmaceutical companies among the world, China, and Jiangsu province (n=30)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Mean ± SD or count (%)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>World Top 10 (n=10)</td>
<td>China Top 10 (n=10)</td>
</tr>
<tr>
<td>Patent application</td>
<td>36598.4 ± 31507.0</td>
<td>661.3 ± 744.1</td>
</tr>
<tr>
<td>Patent in force</td>
<td>3635.3 ± 3128.4</td>
<td>230.9 ± 201.9</td>
</tr>
<tr>
<td>Ratio in five years</td>
<td>7.92 ± 4.68</td>
<td>56.013 ± 20.19</td>
</tr>
<tr>
<td>PCT application</td>
<td>1849.3 ± 1278.2</td>
<td>65.4 ± 100.5</td>
</tr>
<tr>
<td>Domestic patent licensing rate</td>
<td>65.2 ± 7.6</td>
<td>77.7 ± 9.1</td>
</tr>
<tr>
<td>Marketed Drugs</td>
<td>51.2 ± 33.6</td>
<td>142.7 ± 110.5</td>
</tr>
<tr>
<td>Original drug number (chemical)</td>
<td>29.2 ± 21.3</td>
<td>1 ± 1.6</td>
</tr>
<tr>
<td>Original drug number (biological)</td>
<td>4 ± 3.5</td>
<td>0.5 ± 0.9</td>
</tr>
<tr>
<td>Generic drug number (chemical)</td>
<td>17.7 ± 15.5</td>
<td>140.1 ± 110.7</td>
</tr>
<tr>
<td>Generic drug number (biological)</td>
<td>0.3 ± 1.0</td>
<td>1.1 ± 1.9</td>
</tr>
<tr>
<td>Original drug patent number (chemical)</td>
<td>7657.9 ± 7399.5</td>
<td>40.7 ± 59.6</td>
</tr>
<tr>
<td>Original drug patent number (biological)</td>
<td>1627.9 ± 2798.1</td>
<td>9.2 ± 19.2</td>
</tr>
<tr>
<td>Generic drug patent number (chemical)</td>
<td>3085.5 ± 4368.8</td>
<td>416.3 ± 681.8</td>
</tr>
<tr>
<td>Generic drug patent number (biological)</td>
<td>1.1 ± 3.5</td>
<td>0.9 ± 2.2</td>
</tr>
<tr>
<td>Market value</td>
<td>218.8 ± 59.46</td>
<td>31.33 ± 15.29</td>
</tr>
</tbody>
</table>
P-value is obtained using one-way ANOVA, testing whether the population mean level of variables differs across labeled region. (region: 1=Jiangsu, 2=China, 3=world)

Table 9 provides an overview of the general characteristics of participants in 2010, encompassing key patent indices for the top 10 pharmaceutical companies globally, in China, and within Jiangsu province. Of particular interest are indices such as the number of general patent applications, patents in force, PCT applications, and marked drugs. Notably, a substantial contrast emerges in patent application numbers between the top 10 companies in China and Jiangsu, compared to their global counterparts. Specifically, China's Top 10 and Jiangsu's Top 10 exhibit 536.6 and 661.3 cases of patent applications, respectively, in contrast to 36,598.4 cases for the global Top 10. Similarly, significant disparities are observed in the number of patents in force and PCT applications. For instance, the global Top 10 maintains around 3,635.3 cases of patents in force, while China's Top 10 and Jiangsu's Top 10 account for 230.9 and 170.5 cases, respectively. Likewise, the global Top 10 records approximately 1,849.3 cases of PCT applications, while China's Top 10 and Jiangsu's Top 10 report 65.4 and 61.5 cases, respectively. These indicators suggest a relative lag in China's general technology innovation capabilities compared to global leaders. However, noteworthy is the robust acceleration of improvement, particularly evident in the ratio of patent application numbers for China's Top 10 and Jiangsu's Top 10 in the five years leading up to 2010, standing at approximately 56%, compared to a mere 7.92% for the global Top 10. This underscores that China's top biomedical firms are increasing their patent applications at a faster pace than their global counterparts. Moreover, in 2010, companies in China boasted more marked drugs than those globally, with China's Top 10 and Jiangsu's Top 10 featuring 142.7 and 72.1 marked drugs, respectively, in contrast to 51.2 marked drugs for the global Top 10.
3.3.2 Correlation analysis between market value and patent indexes

<table>
<thead>
<tr>
<th>Patent index</th>
<th>Correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Region</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>patent application number</td>
<td></td>
</tr>
<tr>
<td>patent in force number</td>
<td></td>
</tr>
<tr>
<td>ratio in five years</td>
<td></td>
</tr>
<tr>
<td>PCT application number</td>
<td></td>
</tr>
<tr>
<td>domestic patent licensing rate</td>
<td></td>
</tr>
</tbody>
</table>

Based on the correlation analysis, it was observed that when considering all 30 pharmaceutical companies, each correlation coefficient was found to be statistically significant. Notably, three correlation coefficients exhibited a positive association, namely the patent application number (0.74), the patent in force number (0.71), and the PCT application number (0.73).
3.3.3 Linear regression analysis

<table>
<thead>
<tr>
<th>Patent index</th>
<th>Regression coefficient</th>
<th>St. Err.</th>
<th>P value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>patent in force number</td>
<td>9.77</td>
<td>.59</td>
<td>P&lt;0.001*</td>
<td>8.57 ~ 10.97</td>
</tr>
<tr>
<td>ratio in five years</td>
<td>-498.39</td>
<td>135.94</td>
<td>0.001*</td>
<td>-776.85 ~ -219.93</td>
</tr>
<tr>
<td>PCT application number</td>
<td>21.13</td>
<td>1.19</td>
<td>P&lt;0.001</td>
<td>18.68 ~ 23.58</td>
</tr>
<tr>
<td>domestic patent licensing rate</td>
<td>-941.63</td>
<td>344.37</td>
<td>0.011*</td>
<td>-1647.04 ~ -236.22</td>
</tr>
<tr>
<td>marketed drug number</td>
<td>-41.24</td>
<td>56.73</td>
<td>0.474</td>
<td>-157.64 ~ 75.17</td>
</tr>
</tbody>
</table>

Due to a limited number of participants for the regression analysis, we consolidated all samples that contained three groups. This allowed for a more thorough examination of the impact of various patent indices on market values using regression analysis. Our findings indicate that two coefficients are significantly positive: the coefficient of patent in force number 9.77, with a 95% confidence interval of (8.57~10.97), and the coefficient of PCT application number 21.13, with a 95% confidence interval of (18.68~23.58), as shown in Table 11.

By looking the four graphs generated by the linear regression, we can also get a broad view. (See Figure 7., Figure 8 and Figure 9)
Figure 7. Linear regression scatterplot between market value and patent application number (n=30)

Figure 8. Linear regression scatterplot between market value and patent in force number (n=30)
Figure 9. Linear regression scatterplot between market value and PCT application number (n=30)

Figure 10. Linear regression scatterplot between market value and marketed drug number (n=30)
The scatter plots depict an observable linear correlation between market values and patent indexes. The data points are closely situated around the upward-sloping regression red line, indicating a positive association. Conversely, as depicted in Figure 10, the approximate linear regression concerning the relationship between market value and the number of marketed drugs portrays an inverse scenario. The findings imply that both the number of patents in force and PCT applications positively influence the market value of companies. Serving as tangible indicators of innovation capacity, a higher number of patents in force and PCT applications contribute to improved economic outcomes, particularly in the context of top pharmaceutical companies.
4. Discussion

4.1. Summary of Main Findings

In this study, through statistical analysis of the data, we can mainly draw four findings:

Our research delves into the macro-level dynamics of the global biomedical landscape, unraveling the intricate relationship between patent metrics and economic indicators across major economies. China emerges prominently, contributing 1.8041 million patent applications, positioning itself alongside other major players like the United States, Japan, Germany, and the United Kingdom. The correlation analysis underscores the positive association between GDP and patent-related metrics, emphasizing the pivotal role of economic strength in propelling biomedical innovation on a global scale.

Shifting our focus to the provincial level, particularly Jiangsu, our study unveils its pivotal role in driving China's biomedical innovation. Boasting an impressive cumulative output of 7.052 million biomedical patents, Jiangsu stands as a powerhouse. The correlation analysis reinforces a robust positive link between Jiangsu's GDP and patent-related metrics, affirming the province's substantial economic influence on its biomedical innovation landscape. The accelerated growth in patent applications within Jiangsu's top pharmaceutical companies signals a dynamic and thriving local industry, emphasizing the significance of localized innovation.

Zooming into the micro-level dynamics of Jiangsu's pharmaceutical industry, our analysis of the top 10 companies within the province provides nuanced insights. While Jiangsu's Top 10 exhibit comparatively lower patent metrics than their global counterparts, the accelerated growth in patent applications over five years indicates a rapidly evolving innovation landscape. The correlation and regression analyses highlight the crucial role of effective patents, specifically in force and PCT applications, in shaping the market value of Jiangsu's pharmaceutical enterprises.

In synthesizing these discoveries, a nuanced interplay of factors at different levels unfolds.
Globally, the dominance of PCT applications on GDP contrasts with Jiangsu's provincial-level dynamics, which showcase a balanced reliance on various patent indicators. At the micro level, the emphasis shifts to the effectiveness of patents, particularly in force and PCT applications, unveiling distinct priorities in driving innovation and economic outcomes for pharmaceutical enterprises within Jiangsu. This comprehensive perspective aligns seamlessly with the overarching aim of our research — understanding the intricate connections between economic indicators, patent-related activities, and innovation outcomes in the biomedical sector.

4.2. Consistency with previous research

In essence, our study's outcomes harmonize seamlessly with existing literature and prior research efforts. Whether on a global scale or within the empirical context of China, the consensus remains that innovation acts as a catalyst for economic growth, and reciprocal investment in the economy fuels technological advancements. The application of the 'two-dimensional and three-layer' research framework in our study serves as a compelling illustration of this overarching perspective.

4.3. Linkage and differentiation in three-level analysis

Our meticulous three-level analysis not only unveils global and provincial dynamics but places a particular focus on the pivotal role of Jiangsu province in shaping the landscape of biomedical innovation and economic outcomes.

Examining the global level, the positive correlation between a country's GDP and patent-related activities is not only a universal trend but holds specific implications for Jiangsu. As a province with a robust biomedical industry, the findings indicate that Jiangsu's economic strength
is intricately linked to its innovation capabilities. The economic prowess of Jiangsu aligns with its impressive cumulative patent authorized numbers, making it a significant player in the global biomedical landscape.

Zooming in to the provincial level, Jiangsu's position as a leader in the biomedical field is underscored by its cumulative patent authorized numbers, surpassing other provinces in Mainland China. The correlation analysis further highlights the symbiotic relationship between Jiangsu's economic prosperity and its biomedical innovation, emphasizing the province's crucial role in driving regional advancements.

Delving into the micro-level analysis of individual pharmaceutical companies within Jiangsu, the correlation between market value and patent indexes illuminates the province's strategic importance. Companies in Jiangsu, with higher patent activities, are not only contributing significantly to regional innovation but are also achieving higher market values. This underlines the effectiveness of intellectual property strategies in elevating Jiangsu's pharmaceutical companies to a globally competitive position.

The regression analysis brings out the nuanced relationship between Jiangsu's economic strength and the quality of its biomedical innovation. The positive coefficients for Patent in Force Number and PCT Application Number reinforce the idea that Jiangsu's companies are not only prolific in patent generation but also produce patents with global relevance. This solidifies Jiangsu's status as a biomedical powerhouse within the national and international arenas.
4.4. Strengths and Limitations

Our in-depth analysis of the role of patent systems in Jiangsu Province represents a departure from the prevalent macro-level focus observed in earlier studies, addressing a noteworthy gap in the literature. In contrast to broader trends that often overlook the intricate dynamics of individual pharmaceutical companies within the province, our study provides insights into the contributions and impacts of specific enterprises, offering a micro-level perspective on how patent-related policies directly influence innovation.

Furthermore, our examination of the intricate relationship between patent indicators and economic outcomes, particularly at the micro-level, sets our work apart. While previous studies establish a positive connection between patenting and innovation, our study delves deeper by investigating how specific patent metrics, such as patents in force, PCT applications, and other indicators, intricately shape the market value of individual pharmaceutical companies in Jiangsu. This understanding is crucial for policymakers and industry stakeholders seeking strategies that concurrently enhance innovation and drive economic growth.

The analysis of demographic variances between leading pharmaceutical companies in Jiangsu and their global counterparts is pivotal for understanding regional innovation capabilities. By identifying unique factors shaping innovation within Jiangsu, our study contributes valuable insights for policymakers to tailor strategies that address the specific needs and strengths of the local industry. This tailored approach aims to foster a more robust and contextually relevant innovation environment, laying the groundwork for sustained growth.

Our study challenges the prevailing emphasis on the quantity of patents by introducing a critical perspective on their quality. Through an evaluation of factors such as relevance, originality, and impact, we aim to shift the discourse toward recognizing the qualitative aspects of patents as equally, if not more, critical for economic outcomes. This shift is imperative for
guiding innovation strategies toward not only generating a higher number of patents but also ensuring their meaningful contribution to industry advancement.

Acknowledging the dynamic nature of the global biomedical industry, our study incorporates both temporal and geographical specificity into the analysis. This approach allows us to capture current trends and dynamics, providing a more accurate representation of the evolving industry landscape. Additionally, our investigation recognizes geographical nuances influencing the relationship between patents and economic outcomes, offering valuable insights into the contextual factors that drive innovation in different regions.

However, it is essential to consider several limitations. Firstly, our data, sourced from 2020, may not fully capture current trends. Moreover, the relatively small sample size of 30 cases may raise concerns about the robustness of the results to fully support the research question. These limitations underscore the need for caution in generalizing findings and emphasize opportunities for future research with more updated data and larger sample sizes.

A critical aspect for consideration pertains to the enhancement of the selection process for macroeconomic output indicators. In the context of this study, the national and provincial levels employ Gross Domestic Product (GDP) as the economic indicator. However, when delving into specific sectors like the biomedical industry, practical constraints make it challenging to meticulously pinpoint the industrial economic scale of biomedicine in a particular country or region. This complexity hinders the attainment of a comprehensive analysis of patent innovation indicators and their correlation with economic output. In comparison with the present study, which focuses on the market value of enterprises at the micro level, it becomes apparent that at the macro level, there exists a need for further investigation into the identification and examination of more precise macroeconomic indicators for the biopharmaceutical industry in subsequent research endeavors. Future studies should delve into exploring specific economic
indicators such as industry scale, annual output value, and total industry Research and Development (R&D) from an economic standpoint to the utmost degree possible. We posit that through elevated and expansive research efforts within the realms of biomedicine and overall health, a more accurate relationship between biomedicine innovation and industrial economic development can be discerned.

4.5. policy proposal

Create an environment supportive of innovation by fostering cultural and institutional factors conducive to the same. Enterprises, as the primary drivers of innovation, embody a blend of elements such as needs, relevant industries, corporate strategies, structure, competitive scenarios, and governmental influence. Together, these factors constitute the industry agglomeration of a country. The strength and proximity of this agglomeration directly correlate with the competitiveness of the country's industries. Hence, effective innovation necessitates robust support in technological, managerial, and marketing innovations.

In the context of China's intellectual property system, it should leverage existing strengths tailored to national conditions to address shortcomings, especially in quality, and bolster market competitiveness. This involves fortifying the intellectual property system already in place.

For Jiangsu to harness its existing pharmaceutical industry advantages and establish a globally competitive sector, several measures are recommended, focusing on both governmental and enterprise levels:

**Governmental Initiatives:**

1. Increased R&D Investment: Channel additional financial support into pharmaceutical
industry research and development. Recognizing the direct impact on national health and the crucial role of independent controllability in pharmaceutical products, heightened R&D investment will foster product development, patent acquisition, and ultimately enhance core enterprise competitiveness.

2. Optimized Drug Procurement System: Revamp the government drug procurement system by prioritizing new drugs in centralized procurement methods. This approach shifts the focus from drug prices to encourage innovation by pharmaceutical companies. Jiangsu can pioneer innovative nationwide procurement measures to invigorate enterprise innovation.

3. Enhanced Government Service to the Industry: Improve the efficiency of patent application reviews and new drug approvals by exploring a parallel review system. Establishing fast tracks for patent applications and authorizations specific to the pharmaceutical industry safeguards enterprise innovation. Furthermore, the government should provide comprehensive information services, including patent information and drug reviews, to offer robust support to the pharmaceutical industry.

**Enterprise-level Strategies:**

1. Focus on Patent Rights Acquisition: Prioritize the acquisition of patent rights by increasing investment in research and development. Timely acquisition of patent rights protects innovation outcomes and contributes to maintaining the core competitiveness of enterprises.

2. Intellectual Property Rights Management: Implement product-classification-based management of intellectual property rights. For globally exported innovative drugs, biomedical companies can seek international patents (PCT) to expand market reach,
while domestically sold new drug products can be patented domestically to reduce maintenance costs. Consider a holistic approach encompassing patents, trademarks, copyrights, and related intellectual property rights to enhance overall competitiveness.

3. Industry Intellectual Property Alliance: Explore the establishment of an industry intellectual property alliance to strengthen collaboration among companies. Such alliances can facilitate the application of patent cross-licensing, fostering collective progress and improving the overall competitiveness of the pharmaceutical industry. This collaborative approach can contribute to closing the gap with international pharmaceutical giants.

Through a combination of government support and enterprise initiatives, Jiangsu has the potential to optimize its strengths in the pharmaceutical industry, elevate its global presence, and position China's pharmaceutical sector as a standout competitor in the international market.
5. Conclusion

In conclusion, our study has comprehensively addressed significant research gaps in understanding the role of patent systems in the biomedical industry, particularly within Jiangsu Province, China. The micro-level analysis has illuminated the contributions of individual pharmaceutical companies, providing a detailed perspective often overlooked in macro-level approaches. The exploration of the intricate relationship between patent indicators and economic outcomes, coupled with a focus on qualitative aspects, offers a nuanced understanding of the innovation landscape.

From a regional perspective, our findings highlight a positive correlation between a region's economic level and patent indicators. This correlation is observed in the pharmaceutical industry, where a higher number of patent applications and authorizations correlates with better economic scale. At the enterprise level, our study establishes a connection between the number of patents and a company's market competitiveness, with higher patent counts associated with stronger market positions, especially among listed companies.

Comparing China with major pharmaceutical countries reveals a notable gap in the overall level of China's pharmaceutical industry. This gap, evident in the number of patent applications, authorizations, and the total economic scale, emphasizes the need for strategic advancements. Furthermore, the comparison of Jiangsu with other provinces in China showcases its leading position, boasting advantages in patents, industry economy scale, and the number of listed companies. The study positions Jiangsu at the forefront, particularly in terms of innovation capabilities.

Our research on the relationship between patent data and market value underlines the significance of effective patents, PCT applications, and domestic patent grants in influencing market value. However, we acknowledge challenges in establishing a robust relationship between
the overall annual patent application volume and market value due to limited data samples. Importantly, our findings stress that, from the perspective of return on investment in innovation, the quality of patents outweighs quantity. The study suggests that a focus on patent quality is crucial for bringing tangible economic value to individual enterprises.

In light of these results, the patent index emerges as a critical indicator for evaluating innovation ability effectively. Practical patent applications and innovations, when of high quality, can bring substantial economic value to individual enterprises. This study underscores the importance of not just quantity but the quality of patents in shaping the economic outcomes of the biomedical industry. Policymakers and industry stakeholders are encouraged to prioritize strategies that foster both innovation and the development of high-quality patents for sustained growth and competitiveness.
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