Current Status Analysis and Countermeasure Research on Intellectual Property-Intensive Industries—A Case Study of Guangdong' s Biopharmaceutical Industry

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Abstract

Due to the considerable economic and social benefits of the biopharmaceutical industry, it has become a sunrise industry prioritized for development by many countries. To promote the development of biopharmaceutical-related industries, countries such as the United States, Japan, and India have regarded the biotechnology industry as a means to enhance their national competitiveness, and have formulated corresponding laws and regulations to standardize the development of the biopharmaceutical industry and protect biopharmaceutical intellectual property. This paper first conducts multi-angle data analysis from a macro perspective, including analysis of the development trends of intellectual property in the global and China' s biopharmaceutical industries. It then takes Guangdong Province' s biopharmaceutical industry as a case study, analyzes data on its intellectual property intensity indicators, and compares these with indicator data such as industrial economy and patent status from other provinces. Finally, it proposes countermeasures and recommendations to effectively enhance Guangdong Province's biopharmaceutical industry development and intellectual property utilization, thereby strengthening industrial competitiveness.

Full Text

Preamble

Analysis and Strategic Recommendations for Intellectual Property-Intensive Industries: A Case Study of Guangdong' s Biopharmaceutical Sector

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Abstract: The biopharmaceutical industry has emerged as a sunrise industry in many nations due to its substantial economic and social benefits. Countries including the United States, Japan, and India have prioritized biotechnology as a means to enhance national competitiveness, establishing comprehensive legal frameworks to regulate industry development and protect intellectual property rights. This study conducts a multi-dimensional macro-level data analysis of global and domestic biopharmaceutical IP development trends, then examines Guangdong Province' s biopharmaceutical sector through the lens of IP intensity indicators. Comparative analysis with other provinces evaluates industrial economic performance and patent metrics. Finally, the paper proposes effective strategies to enhance Guangdong' s biopharmaceutical industry development, optimize IP utilization, and strengthen industrial competitiveness.

Keywords: intellectual property-intensive industry; Guangdong biopharmaceutical industry; industrial analysis; patent analysis

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1 Background Analysis of Domestic and International Biopharmaceutical IP-Intensive Industries

Knowledge-intensive industries (also termed technology-intensive industries) are characterized by their disproportionate reliance on technological and intellectual factors compared to other production inputs. These industries represent a rapidly growing strategic emerging sector with three primary characteristics: concentrated industrial typology, geographic clustering with snowball attraction effects, and rapid knowledge innovation and diffusion that drives regional industrial upgrading and transformation while further promoting industrialized innovation [1]. "Intellectual property-intensive industries" are defined as industries where per-employee IP ownership exceeds the average across all economic sectors [2]. Based on IP type classifications, these industries can be categorized into patent-intensive, trademark-intensive, copyright-intensive, geographical indication-intensive, and other IP-intensive sectors.

1.1 International Overview of Biopharmaceutical IP-Intensive Industries

The biopharmaceutical industry represents a high-tech, high-investment, high-risk, and high-return knowledge-intensive sector with significantly greater dependence on IP protection than other industries. Drug research and development involves complex, lengthy processes with increasingly stringent safety requirements, driving up capital investment. New drug development carries substantial risk and high attrition rates; a single drug' s journey from basic research to market approval spans many years with considerable risk. Project failure can result in irrecoverable losses reaching hundreds of millions in R&D investment, yet successful market launch yields enormous economic returns. Patent protection grants companies pricing power and exclusive market access, typically recovering investment within 2-3 years and generating profit returns exceeding tenfold [3].

As of December 2015, 4,055 biologics were in clinical development through to market launch stages, compared with 5,748 chemical drugs, yielding a biologics-to-chemicals ratio of 2:3 and demonstrating a clear upward trend in biologics R&D. Sixty-two percent of biologic drugs remain in clinical phases, with nearly 400 in Phase III trials and approximately 200 biologics potentially receiving approval globally within two years. The antibody drug pipeline comprises 623 candidates, with 78 already marketed globally and nearly 85% still in clinical development. Thirteen antibody drugs are in NDA stages, with approval expected

in the near term. Sales of the top five antibody drugs alone are projected to reach $41.9 billion by 2020 [4].

Given its substantial economic and social benefits, the biopharmaceutical industry has become a priority sunrise industry for many nations. Countries such as the United States, Japan, and India have leveraged biotechnology to enhance national competitiveness while establishing corresponding laws and regulations to govern industry development and safeguard IP rights. National macro-level policies and planning provide fiscal support and legal protection for IP, creating favorable development environments for biopharmaceutical knowledge-intensive industries. Additionally, extensive cultivation of innovative talent and collaborative R&D partnerships among research institutions ensure sustained innovation and the formation of industrial scale clusters.

1.2 Domestic Patent Overview of Biopharmaceutical IP-Intensive Industries

According to the "China Patent-Intensive Industries Main Statistical Data Report (2015)" released by the National Intellectual Property Administration, China' s patent-intensive industries demonstrate strong economic driving force and market competitiveness. From 2010-2014, the added value of China' s patent-intensive industries totaled 26.7 trillion yuan, accounting for 11.0% of GDP with an average annual real growth rate of 16.6%—more than double the 同期 GDP growth rate of 8%. Employment in patent-intensive industries represented only 3.4% of total social employment yet created over 10% of national GDP. New product sales revenue accounted for 20.7% of main business revenue, and export delivery value represented 19.3% of total sales output value—2.5 times and 2.2 times higher than non-patent-intensive industries, respectively. R&D investment intensity (ratio of internal R&D expenditure to main business revenue) reached 1.3%, 2.6 times that of non-patent-intensive industries [5].

China' s biopharmaceutical patent publication growth rate significantly exceeds global averages, with China becoming the world' s third-largest pharmaceutical market after the United States and Japan by 2010 [6]. Recent years have seen vigorous support for biopharmaceutical industry development, particularly through the National Major New Drug Innovation Program, which has effectively guided and promoted industrial innovation. Overall, China' s biopharmaceutical patent publications showed annual increases from 2009-2013, as shown in [Figure 1: see original paper], indicating continuously improving innovation capabilities and substantially heightened emphasis on patent protection [7].

[Figure 1: see original paper] Patent Publications and Growth Rate in China' s Biopharmaceutical Sector, 2009-2013 [7]

In terms of technology composition, medical devices rank first in patent publications, followed by traditional Chinese medicine, chemical pharmaceuticals, and biopharmaceuticals—differing from global biopharmaceutical technology structures. This reflects traditional Chinese medicine' s status as a product of China'

s traditional medical culture, with some formulations demonstrating efficacy through millennia of use and maintaining broad, stable market presence, thus motivating active R&D investment. Conversely, China' s chemical pharmaceutical sector consists primarily of generic drugs with lower patent publication volumes, while biopharmaceuticals face greater R&D difficulty and higher entry barriers, remaining in initial development stages with fewer patent publications. However, biopharmaceuticals offer higher added value than chemical drugs, warranting encouragement for stronger pharmaceutical companies and more innovative biotechnology firms to increase R&D investment.

[Figure 2: see original paper] Patent Publications in Six Biopharmaceutical Subsectors in China, 2009-2013 [7]

1.3 Regional Distribution of Domestic Biopharmaceutical Industry

According to National Bureau of Statistics data, by the end of 2014, China' s pharmaceutical manufacturing sector total assets reached 1.848 trillion yuan. In 2014, pharmaceutical manufacturing achieved sales revenue of 2.335033 trillion yuan, representing an increase of 1.93305 trillion yuan compared with 2005 at the end of the 10th Five-Year Plan period, with a compound annual growth rate of 21.59%, as shown in [Figure 3: see original paper].

[Figure 3: see original paper] Main Business Revenue and Growth Rate of China' s Pharmaceutical Manufacturing Enterprises, 2005-2014 (Data source: China Statistical Yearbook)

Recent development has initially formed a spatial industrial pattern with the Yangtze River Delta and Bohai Rim region as core areas, while the Pearl River Delta and Northeast China have rapidly developed as major eastern and central regions. Additionally, Henan, Hunan, and Hubei in central China, as well as Sichuan and Chongqing in western China, have established solid industrial foundations. The Yangtze River Delta hosts the largest number of multinational biopharmaceutical enterprises, with high innovation capacity and international exchange levels, gradually forming a Shanghai-centered biopharmaceutical industry cluster. The Bohai Rim region boasts abundant human resources, rich clinical and educational resources, with provinces and municipalities surrounding Beijing forming innovation-capable industrial clusters. The Pearl River Delta features a mature market economy system, well-developed pharmaceutical distribution networks, proximity to Hong Kong and Macau, strong external radiation capacity, active private capital, and substantial market potential, forming commercial network-intensive biopharmaceutical industry clusters around Guangzhou, Shenzhen, and Zhuhai. Moreover, the Chengdu-Chongqing economic circle demonstrates active innovation in biomedical engineering, serving as an important biopharmaceutical achievement transformation base in western China.

Comparison of Biopharmaceutical Manufacturing Data for Major Provinces and Municipalities: Number of Enterprises, Main Business Revenue (billion yuan),

Total Assets (billion yuan) (Data source: China Statistical Yearbook 2015 and provincial/municipal statistical yearbooks)

2 Industrial Development Background and Comparative Analysis

2.1 Industrial Development Background

Guangdong's biopharmaceutical industry originated in the mid-1980s, with over 30 years of development history. In recent years, Guangdong' s modern biopharmaceutical industry has developed rapidly, emerging as a strategically important sector with substantial growth potential. Guangzhou serves as a national pharmaceutical export base and national bioindustry base city, functioning as the medical and pharmaceutical distribution center for South China. The city has formed three advantageous industrial clusters in biopharmaceuticals, biomanufacturing, and health services, alongside distinctive biotech service sectors. With a strong pharmaceutical culture, Guangzhou represents one of China' s most concentrated regions for biopharmaceutical health industries, featuring solid foundations, rapid development, and strong market radiation, gradually entering a track of clustered, rapid growth. Consequently, as a knowledge-intensive industry, biopharmaceuticals play a crucial role in Guangdong' s and the nation' s biopharmaceutical economy.

As a major biopharmaceutical province, Guangdong has established a complete industrial chain and robust industrial foundation, with biopharmaceutical output value accounting for approximately one-tenth of the national total in 2015 [8]. Guangdong's IP-intensive industries possess strong economic and industrial foundations, with GDP reaching 7.281255 trillion yuan in 2015, ranking first nationally for economic aggregate, wherein tertiary industry GDP exceeded 50% for the first time. As a strategically cultivated emerging industry in Guangdong, biopharmaceuticals enjoy substantial advantages in policy support, funding, and talent investment [9].

Guangdong's biopharmaceutical industrial system has become increasingly complete, initially forming a modern biomedical industry system covering R&D, manufacturing, and sales across pharmaceuticals, medical devices, and reagents. The province holds competitive advantages in modern Chinese medicine, chemical synthesis drugs, biopharmaceuticals, gene diagnostic reagents, and medical devices. Guangdong hosts numerous research institutions including the Guangzhou Institutes of Biomedicine and Health (Chinese Academy of Sciences), Sun Yat-sen University, Jinan University, and Southern Medical University, with four state-level and fifteen provincial-level key laboratories established, such as the Guangzhou National Biopharmaceutical Industry Base, Shenzhen National Biotechnology and Pharmaceutical Industry Base, and Foshan High-tech Industrial Development Zone Medical Health Industrial Park [10]. Guang-

dong has essentially established a biopharmaceutical industrial structure supported by four major sectors: chemical drugs (primarily pharmaceutical preparations), Chinese patent medicines, medical devices, and biotechnology, with particular strength in biopharmaceuticals, gene diagnostic reagents, modern Chinese medicine, and medical devices.

In recent years, knowledge-intensive clusters centered on Guangzhou Science City and Guangzhou Bio-Island have driven Guangdong' s biopharmaceutical development. Patent application data reveals that from 1985-2004, biopharmaceutical patent applications remained low but showed substantial growth, indicating an exploratory phase with immature biotechnology. In recent years, patent applications have increased annually, maintaining stable growth rates and demonstrating that enhanced government attention and investment have matured Guangdong' s biopharmaceutical industry and elevated its biotechnological capabilities.

[Figure 4: see original paper] Patent Applications in Guangdong' s Biopharmaceutical Sector (Data source: Chinese Academy of Sciences Patent Online Analysis System; 2016 patent data not fully disclosed)

2.2 Comparison Between Guangdong and Other Provinces

This study selected representative provinces from the Yangtze River Delta, Bohai Rim, and Sichuan-Chongqing regions for comparative analysis. Given that pharmaceutical manufacturing constitutes a pillar industry within biopharmaceuticals, it serves as the primary analytical focus. The comparative framework is illustrated below.

[Figure 5: see original paper] Framework for Comparative Analysis of Biopharmaceutical IP-Intensive Industries

(1) Industrial Scale Analysis

Industrial scale refers to the output or operational scale of an industry, here specifically denoting the operational scale of the biopharmaceutical sector. Development status is reflected through three dimensions: number of enterprises, employment, and total assets. Economic performance is measured through industrial output value, main business revenue, and total profits. Output value reflects value creation capacity, while revenue and profit indicate market development degree.

[Figure 6: see original paper] Comparison of Pharmaceutical Manufacturing Scale Data for Guangdong, Shandong, Jiangsu, and Sichuan, 2011-2015 (Data source: Provincial statistical yearbooks of Guangdong, Shandong, Jiangsu, and Sichuan)

Due to China' s 2011 pharmaceutical reforms, all four provinces experienced varying reductions in pharmaceutical manufacturing enterprises, with Guangdong most severely impacted at a 20.1% decrease. Over the subsequent four

years, Shandong' s enterprises grew at an average rate of 8%, while Guangdong and Jiangsu showed similar modest growth rates of 5.4% and 5.6%, respectively.

Regarding employment, Shandong' s workforce substantially exceeded Jiangsu' s by an average of 20,000 employees, with notable growth in 2012. Jiangsu maintained steady growth at a stable 5% annual increase. Guangdong experienced a post-reform decline in 2011 but rebounded in 2012, though subsequent growth slowed. Sichuan proved least affected by reforms, with employment increasing 19% in 2011. Among the remaining provinces, only Guangdong and Shandong achieved growth rates exceeding 10%, at 12.85% and 14.91%, respectively.

Shandong' s pharmaceutical manufacturing development and asset accumulation significantly outpaced other provinces, maintaining over 20% annual growth throughout the five-year period. The gap with Guangdong widened from 39.02 billion yuan in 2010 to 117.789 billion yuan in 2014. Guangdong and Jiangsu showed similar asset value trends, with decelerating growth from 2010-2013 before Jiangsu' s growth accelerated in 2014. Sichuan' s pharmaceutical manufacturing assets also demonstrated healthy upward trends, albeit with greater growth rate volatility.

In terms of output value, Shandong ranked first in both total volume and growth rate, with peaks approaching 35%. Jiangsu' s output value growth exceeded 20% from 2011-2013, showing signs of gradual deceleration. These two provinces' output values significantly outranked the other two by a substantial margin. Guangdong maintained relatively stable growth, while Sichuan experienced a major decline in 2012, with growth plummeting from 46% to -1.8% before recovering in subsequent years.

Shandong and Jiangsu became the only two provinces with pharmaceutical manufacturing main business revenue exceeding 300 billion yuan, while Guangdong and Sichuan only surpassed the 100 billion yuan threshold in 2013 and 2014, respectively. Growth rate curves roughly mirrored industrial output value trends.

Among the four provinces, Shandong reported the highest profits, supported by strong operating revenue, with Jiangsu following closely. However, in terms of five-year average profit margins, Guangdong led at 12%, followed by Shandong (11%), Jiangsu (10%), and Sichuan (9.7%). Regarding growth rate patterns, Jiangsu' s 2012 total profit growth rate exceeded Shandong' s, diverging from industrial output and main business revenue curves.

These comparisons reveal that despite having the fewest enterprises and employees among the four regions, Guangdong avoided ranking last in production value and main business revenue while achieving the highest average profit margin. This indicates Guangdong' s biopharmaceutical workforce and enterprises exhibit higher quality, achieving greater output with fewer inputs. Guangdong' s products demonstrate higher innovation and exclusivity, yielding superior profit margins.

(2) Industrial Economic Indicators Analysis

a. Capital-Output Ratio

The capital-output ratio measures capital input required per unit of output in an economic system; a lower ratio indicates greater output from relatively less capital. Technology typically plays a capital-saving role—higher technology yields more output from identical capital inputs. The calculation can be simplified as: Capital-Output Ratio = Fixed Asset Stock / Industrial Output Value.

[Figure 7: see original paper] Capital-Output Ratios for Pharmaceutical Manufacturing in Guangdong, Shandong, Jiangsu, and Sichuan (Data source: Calculated from provincial statistical yearbooks, 2011-2015)

Sichuan exhibited the highest capital-output ratio, followed by Shandong, Guangdong, and Jiangsu. Since lower ratios indicate superior performance (more output from less capital), the actual technological ranking from highest to lowest is: Jiangsu, Guangdong, Shandong, and Sichuan.

b. Per Capita Main Business Revenue (10,000 yuan)

[Figure 8: see original paper] Comparison of Per Capita Main Business Revenue in Pharmaceutical Manufacturing for Guangdong, Shandong, Jiangsu, and Sichuan (Data source: Calculated from provincial statistical yearbooks, 2011-2015)

Jiangsu and Shandong demonstrated higher levels and faster growth in per capita revenue, while Guangdong only surpassed the 1 million yuan per capita threshold in 2013. All four provinces showed slowly rising trends, with Sichuan experiencing a minor decline between 2011-2012.

c. Output Value Profit-Tax Rate

The output value profit-tax rate represents the percentage of total realized profits and taxes (including total profits, product sales taxes and surcharges, and payable value-added tax) relative to total industrial output value. Higher rates indicate greater profitability. The formula is: Output Value Profit-Tax Rate (%) = (Total Profits and Taxes / Industrial Output Value) × 100%.

Output Value Profit-Tax Rates for Three Provinces

Guangdong' s average output value profit-tax rate was 17.51%, compared with Shandong' s 15.80% and Jiangsu' s 16.24%, indicating Guangdong' s enterprises possess the strongest profit-generating capability among the three provinces, followed by Jiangsu and then Shandong. Sichuan data was unavailable due to missing pharmaceutical manufacturing profit-tax totals.

d. Capital Profit-Tax Rate

This indicator measures the ratio of total realized profits and taxes to average total assets (net fixed assets plus current assets) over a given period, reflecting profit-tax generation per unit of capital (typically per 10,000 yuan). It serves as a primary metric for evaluating capital utilization efficiency and investment effectiveness, with rates above 15% considered excellent. The formula is: Capital

Profit-Tax Rate (%) = Cumulative Total Profits and Taxes / (Net Fixed Assets + Current Assets) × 100%.

Capital Profit-Tax Rates for Three Provinces

All three provinces exceeded the 15% threshold, indicating sound economic performance. Numerically, Jiangsu ranked highest, followed by Shandong and Guangdong. Trend-wise, Guangdong experienced gradual decline from 2011, Shandong remained stable between 25-26%, and Jiangsu showed slowly increasing rates. This suggests Jiangsu' s pharmaceutical manufacturing achieves the best capital investment outcomes with improving conversion efficiency, while Guangdong' s capital utilization effectiveness, though still strong, is declining.

These analyses indicate Guangdong possesses strong technological innovation capability and high industry technical standards, resulting in excellent profitability and profit margins. However, Guangdong' s relatively stable development trajectory requires "catalysts"to accelerate effective R&D and achievement transformation.

(3) Patent Analysis

This study employs the Chinese Academy of Sciences Patent Online Analysis System (http://patent.casip.ac.cn) as the retrieval database, with patent data sourced from the National Intellectual Property Administration. The retrieval strategy utilizes precise search methods, comprehensively matching exact IPC classification numbers and related IPC codes. Data collection extends through September 2016. The comprehensive search formula is:

PIC: (A61K31* OR A61K33* OR A61K35/00* OR A61K36/00* OR A61K38* OR A61K39* OR A61K48* OR A61P* OR C07G11/00* OR C07G13/00* OR C07G15/00* OR C07H21* OR C07K* OR C12M* OR C12N* OR C12P* OR C12Q* OR C12S* OR G01N27/327* OR G01N33*)

a. Overall Application and Grant Status

Patent application status was retrieved for the nation and for Guangdong, Shandong, Jiangsu, and Sichuan provinces, with results shown below.

Patent Application Data for the Nation and Four Provinces

All four provinces demonstrated upward trends. Jiangsu reported the most applications, Sichuan the fewest, with Jiangsu' s volume three times Sichuan' s. Before 2012, Guangdong exceeded Shandong, but Shandong surpassed Guangdong after 2012, though the difference remained modest. Growth rates were stable across Guangdong, Shandong, and Sichuan. Applications from the most recent six years accounted for 65.58% of Guangdong' s total, 68.98% of Shandong' s, 75.38% of Jiangsu' s, and 65.32% of Sichuan' s—exceeding 65% in all cases—indicating rapid recent growth in biopharmaceutical patent applications.

[Figure 9: see original paper] Comparison of Patent Types and Grant Rates

Across Four Provinces (Data source: Chinese Academy of Sciences Patent Online Analysis System)

Invention patents dominated across all regions, comprising 86.81% nationally and 82.19%, 87.74%, and 81.56% for Guangdong, Shandong, and Jiangsu, respectively. Grant volumes generally correlated with application volumes. Overall grant rates ranked as: Guangdong > Sichuan > Jiangsu > Shandong, indicating superior patent quality in Guangdong and Sichuan.

b. Patent Density Analysis

Patents are closely linked to innovation; the World Economic Forum' s Global Competitiveness Report incorporates innovation capacity as a key competitiveness metric. Macroscopically, innovation-driven technological advancement serves as a long-term economic growth driver, with patent-enabled technological progress better promoting industrial development [11].

Patent density serves as a crucial indicator for identifying IP-intensive industries, reflecting an industry' s patent concentration. The calculation formula is:

Patent Density = Patent Applications / Employment

Defining the average patent density across all industries as the threshold, industries exceeding this average are classified as patent-intensive. Calculations yield the following:

[Figure 10: see original paper] Comparison of Patent Density Across Four Provinces (Data source: Chinese Academy of Sciences Patent Online Analysis System and national/provincial statistical yearbooks)

Biopharmaceutical patent density significantly exceeds the all-industry average, clearly establishing it as a patent-intensive sector. All four provinces showed rising patent density trends, with Guangdong, Shandong, and Sichuan demonstrating steady growth. Jiangsu' s patent density surged due to explosive patent growth in 2012 and 2013.

c. Analysis of Major Applicants

Patent Application Data for Major Patentees in Four Provinces

The data reveals positive correlation between top applicants' volumes and provincial totals. Jiangsu' s Jiangnan University leads with 2,302 biopharmaceutical patent applications—double that of the second-ranked Nanjing Agricultural University and exceeding the combined total of Sichuan' s top ten institutions. Top ten applicants accounted for 24.91% of Guangdong' s total applications, compared with 23.70% for Shandong, 33.80% for Jiangsu, and 31.30% for Sichuan.

Institutional Nature of Patentees in Four Provinces

Analysis shows universities and research institutions dominate biopharmaceutical patent applications across all four provinces. Among top ten applicants, Guangdong' s universities/research institutes comprised 80%, while other

provinces reached 90%. Since patent applications reflect scientific and technological activity capacity and institutional strength, universities and research institutes prioritize patenting. Enterprises generally lag behind in research capacity, personnel, and funding reserves.

These findings demonstrate that biopharmaceuticals constitute a highly IP-intensive industry with active regional development efforts. Guangdong exhibits high IP achievement conversion rates and quality, with strong overall innovation capacity. However, Guangdong' s university and research institution application volumes lag behind other regions, indicating need for strengthened R&D and innovation capabilities.

Overall indicators show Guangdong' s biopharmaceutical industry maintains high IP density with substantial application volumes, strong profitability, and robust development momentum, indicating strong R&D capacity and industry-leading scientific and technological levels with steady growth. However, compared with other provinces, Guangdong' s employment and enterprise quantities remain relatively limited, constraining industry development to some extent.

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3 Countermeasures and Recommendations

(1) Guangdong' s biopharmaceutical industry has developed steadily in recent years, with gradual capital accumulation, stable growth in production value, and solid accumulation of fundamentals, alongside considerable profitability. The average profit margin of 12% ranks first among the four provinces, indicating strong R&D capabilities and profit-generating capacity, with certain products achieving substantial profits through core technologies. Guangdong' s pharmaceutical-related enterprises and employment have remained relatively stable with minimal fluctuation, reflecting continuously improving workforce quality and professional standards that enable higher returns despite limited personnel and enterprise numbers. However, since employment and enterprise quantities do not constitute advantages among the four major regions—and may even constrain industry development—Guangdong should accelerate biopharmaceutical industry development according to provincial characteristics and industry prospects. The province should improve mechanisms for attracting high-level talent, establish enterprise research capacity rating systems, actively attract high-level professionals, promote development of high-caliber enterprises, and enhance both the quantity and quality of personnel and enterprises to improve competitiveness in biopharmaceuticals.

(2) Despite steady progress, Guangdong' s biopharmaceutical industry faces notable concerns. While profitability remains high with strong profit-generating capacity, and the capital-output ratio ranks second among the four regions—achieving greater output with less capital input, indicating high overall technical standards and R&D capacity concentrated in high-

tech enterprises and leading research institutions—main business revenue growth has been relatively slow in recent years. The declining capital profit-tax rate suggests limited improvement in main business operations and decreasing capital utilization efficiency. This stems from lengthy R&D cycles and substantial investment in research expenses without corresponding output of major achievements. Therefore, Guangdong must actively promote R&D efforts, accelerate achievement transformation, and enhance main business competitiveness.

(3) Patent analysis reveals Guangdong ranks second in biopharmaceutical patent applications and first in grant rate, with patent density steadily ranking second. This demonstrates strong technological innovation capacity in recent years, with high patent quantity and quality. Patent density continues rising, with major applicants concentrated in Sun Yat-sen University, South China University of Technology, South China Agricultural University, Jinan University, BGI (Shenzhen), South China Sea Institute of Oceanology (Chinese Academy of Sciences), Southern Medical University, and Guangzhou Institutes of Biomedicine and Health (Chinese Academy of Sciences)—primarily research institutions. From the applicant perspective, Guangdong' s enterprises demonstrate strong R&D capacity, but university and research institution patent achievements lag behind Jiangsu' s. Therefore, Guangdong must increase investment in university and research institution R&D capacity, establish incentive systems, and substantially motivate researchers.

(4) Patent-intensive industries significantly drive economic growth. As biopharmaceuticals represent an IP- and patent-intensive industry, Guangdong should increase investment in relevant factors and continue introducing incentive and support policies to promote high-quality patent output. The province should increase funding for R&D and support for high-tech biopharmaceutical enterprises while introducing policies to incentivize industrial development. Guangzhou and Shenzhen have already established sound biopharmaceutical industrial parks and substantial industrial scale with distinctive competitive advantages. However, other Pearl River Delta cities such as Foshan, Zhuhai, Zhongshan, and Dongguan show less prominent advantages. Guangdong should continue providing funding and policy guidance for biopharmaceutical development in these cities while encouraging them to leverage Guangzhou and Shenzhen' s strengths for joint development or concentrate resources on cultivating distinctive biopharmaceutical industries. Through these measures, Guangdong can collectively promote the development of urban biopharmaceutical industry clusters.

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