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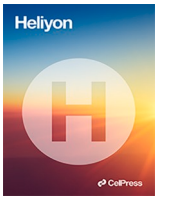

Review article

Can antitrust policy promote enterprise innovation? Evidence from Zhongguancun science and Technology Park

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ABSTRACT

Emerging countries usually rely on the innovation of enterprises within the regional innovation ecosystem to enhance the national innovation level. However, existing literature lacks insight into how antitrust policies might influence innovation within them. We estimate the impact of the implementation of the Anti-Monopoly Law on enterprise innovation within Zhongguancun Science and Technology Park, China's prominentregional innovation ecosystem. Using a cross-industry difference-in-difference design, we show that greater exposure to competition shock materially boosted enterprise innovation. Antitrust policy promotes enterprise innovation by increasing the R&D investment, human capital, and export. The promotion effect of antitrust is relatively strong in the sample of electronic information industry, firms with low levels of financing constraints, and those that undertake open innovation. Our findings elucidate the nexus between competition and innovation in regional innovation ecosystems and underscore the pivotal role of antitrust policies in the development of Zhongguancun Science and Technology Park.

1. Introduction

Innovation is the engine that continues to drive economic development. China, and perhaps all countries in the world, is confronted with the issue of how to promote enterprise innovation to drive economic growth. As the founder of innovation theory, Schumpeter[[1]] pointed out that innovation stems from entrepreneurial spirit. However, different economic systems bring about different incentive structures, thereby influencing the direction and efficiency of entrepreneurial spirit allocation. Therefore, tracing back to its roots, the economic system is likely to be a fundamental factor influencing innovation[[2]]. Since Adam Smith, most economists generally agree that competition contributes to enhancing social welfare, but is fostering competition truly the primary driver of innovation? Existing literature does not provide a consistent answer.

Antitrust seems to play two diametrically opposite roles in corporate innovation. Some literature argues that antitrust policies hinder innovation. Schumpeter [1] argued that a monopolistic market structure can encourage enterprise innovation by increasing post-innovation rents. The core of competition policy, Competition Law, which aims to promote competition, negatively impacts enterprise innovation because of increasing costs of market innovation [3], reducing post-innovation rental income, and weakening

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innovation incentives [4]. Countervailing arguments, however, doubt the argument that antitrust will discourage enterprise innovation. They believe that antitrust policies can promote enterprise innovation. Arrow [5] emphasized that competitive market institutions provide greater economic incentives to innovators. Owing to its destructive nature, innovation will accelerate the obsolescence and depreciation of the original technology. Incumbent enterprises have the motivation and ability to leverage market positions and patent advantages to conduct competition-damaging behaviors, hindering the birth of new technologies by small- and medium-sized enterprises or new entrants. At this time, anti-monopoly policies can change the innovation incentive structure [6], effectively prohibit monopolistic behaviors that damage innovation [7], and promote enterprise innovation [8]. These views are supported by empirical evidence. Dutz and Hayri [9] found that the effectiveness of antitrust and competition policy enforcement has a reliable, independent, and robust role in promoting economic growth. Buccirossi et al. [8] constructed a competition policy indicator using data of 12 OECD countries from 1995 to 2005 for 22 industries and found that competition policy is positively correlated with the total factor productivity. Gutiérrez and Philippon [10] provide similar evidence in their research. Similar evidence exists at the micro level. Levine et al. [11] used the data of more than 1.4 million enterprises across 68 countries from 1991 to 2015 and found that stricter competition laws can positively affect the number of self-created patents, the number of patent indexes, and the explorative nature of those patents. Specifically, when it comes to the stages and types of innovation, similar evidence has been found. Kwon & Marco's [12] research suggests that antitrust regulation of patent consolidation can have a positive impact on competitors' follow-on innovation. Callander & Matouschek [13] found that a strict antitrust policy can encourage entrepreneurial firms to enhance the novelty of innovation. Furthermore, diverging from both of the aforementioned perspectives, some studies argue that the innovation effects of antitrust are highly contingent on industry contexts. Aghion et al. [14] incorporated inter-industry innovation levels into their analytical framework and found an inverted U-shaped relationship between competition and innovation. The overall effect of this relationship depends on the magnitude of the offsetting effects of escaping competition and the Schumpeterian effect. Existing literature, grounded in different stages and scenarios, has explored the impact of antitrust policies on innovation. However, it overlooks a crucial question: whether antitrust policies affect the development of regional innovation ecosystems. Cultivating regional innovation ecosystems is a vital pathway for driving economic growth in both developed countries, such as the United States, and developing countries, such as China.

Global efforts to strengthen antitrust policies have intensified. Since 2021, the United States has successively reviewed and passed the "End Platform Monopoly Act," "American Innovation and Choice Online Act," and "Open Application Market Act." Similarly, in 2022, the European Parliament passed the Digital Services Act and the Digital Markets Act. China officially implemented the Anti-Monopoly Law of the People's Republic of China (hereinafter referred to as the Anti-Monopoly Law) in 2008. After more than ten years of institutional innovation and improved law enforcement, in 2018, China emerged as one of the three largest antitrust jurisdictions in the world, alongside the United States and the European Union. In 2022, China passed the "Anti-Monopoly Law of the People's Republic of China (2022 Amendment)." These bills share common elements aimed at bolstering anti-monopoly regulations and intensifying competition, particularly in the digital field.

Theoretical gaps, practical needs, and economic growth concerns further drive our analyses of the innovation effects of antitrust policy. Differences in development stages and scenarios may allow an antitrust policy to have differentiated results on corporate innovation. Using data from transition countries, Dutz and Vagliasindi [9] found that the effective implementation of competition policy (including the antitrust laws) is positively and statistically significantly related to the expansion of efficient private enterprises. Then, as an emerging country, how will the implementation of China's antitrust policies affect enterprise innovation in the regional innovation ecosystem? Kong and Xu et al. [15] found that the enactment of the Chinese Anti-Monopoly Law increased the total factor productivity of firms with larger market power, and one of the possible channels behind the effects is the increase in innovation output. Because this study focuses on the total factor productivity of enterprises, it does not reveal how anti-monopoly policies can promote the innovation output of enterprises, nor does it disclose whether they can promote enterprise innovation within the regional innovation ecosystem. Can Science and Technology Parks, which are established as regional innovation ecosystems under the leadership of the Chinese government, benefit from antitrust policies to foster their innovation development? If it does, it implies that anti-monopoly policies are conducive to the development of Science and Technology Parks. It indicates that emerging countries should adjust their systems to promote competition while developing Science and Technology parks. However, the existing literature does not provide a definitive answer. Furthermore,in the digital economy era, the stifling acquisitions by tech giants have seriously harmed overall societal innovation, making the regulation of digital technology monopolies a focus of research in both theoretical and academic circles. Despite the new characteristics of digital monopoly behavior, both digital and traditional monopoly regulatory policies emphasize the need to increase competition. So, will antitrust policies that promote competition have an innovation-promoting effect on digital enterprises? Therefore, our study focuses on Science and Technology Parks in China, aiming to reveal the impact and mechanism of antitrust policies on regional innovation ecosystems. Additionally, we attempt to explore whether antitrust policies have an innovation-promoting effect on enterprises with a high digital intensity.

Beijing Zhongguancun is an excellent research sample. Zhongguancun is China's first state-level high-tech industrial development zone. In 2009, the State Council of the People's Republic of China clarified that the goal of Zhongguancun Science and Technology Park is to become a scientific and technological innovation center with global influence. Currently, Zhongguancun has emerged as a banner of innovation and development in China, ranking fourth in the global innovation ecosystem.

Thus, we explore what impact the Anti-Monopoly Law has had on enterprise innovation in the Zhongguancun Science and Technology Park. We regard the implementation of the Anti-Monopoly Law in China in 2008 as a quasi-natural experiment. Inspired by the unbalanced impact of competition on innovation, we utilize the differences in the impact of the Anti-Monopoly Law on industries with different market concentrations to construct a difference-in-difference methodology, and then systematically evaluate its effect and internal mechanism. We found that compared with industries with low market concentration, the implementation of the Anti-

Monopoly Law can better promote enterprise innovation in industries with high market concentration. After a series of empirical tests, the results are robust. The innovation promotion effect of the Anti-Monopoly Law is relatively strong in the electronic information industry, firms with low financing constraints, and those that conduct open innovation. R&D investment, exports, and human capital are the intermediary mechanisms through which the Anti-Monopoly Law affects enterprise innovation.

Our contributions to the existing literature are as follows. First, this study adds to the debate about the effect of competition on innovation. We use a unique enterprise dataset, mainly small- and medium-sized nonlisted enterprises, covering the manufacturing and service industries, to comprehensively identify the causal effect of the implementation of the Anti-Monopoly Law in 2008 on enterprise innovation. The study is consistent with that by Kong et al. [15], who used listed enterprise data and found that the enactment of the Anti-Monopoly Law increases the total factor productivity of firms with larger market power in China. Unlike them, we use the data of unlisted small- and medium-sized enterprises and focus on enterprise innovation. More importantly, we reveal the underlying mechanisms by which antitrust policies affect firm innovation.

Second, our research reveals the key role of anti-monopoly policies in the development of regional innovation ecosystems, specifically in enhancing the innovation level of Zhongguancun Science and Technology Park. To elevate innovation levels, governments in China and many other countries are striving to promote the development of regional innovation ecosystems. As the most typical regional innovation ecosystem in China, our empirical study results indicate that antitrust policies can have a positive impact on it. Our research provides new insights for countries aiming to foster the development of regional innovation ecosystems.

Third, our research provides a new perspective on the potential future economic outcomes of digital monopoly regulatory policies. On the one hand, both digital and traditional monopoly regulatory policies emphasize increasing competition. On the other hand, the electronic information industry is the core of the digital industry. When we divide the sample into two categories, namely, electronic and non-electronic information industry, the promotion effect of anti-monopoly policy on innovation is significantly positive in the electronic information industry. This study allows us to draw on historical experience to gain insight into the possible economic effects of digital monopoly regulatory policies.

This study is presented as follows: Section 2 elaborates on the institutional background. We present the data and methodology used in the study in Section 3. Section 4 presents the effect of the Anti-Monopoly Law on enterprise innovation and Section 5 explores its possible channels. Section 6 concludes.

2. Institutional background, theory and hypotheses

2.1. Institutional background

A gradual market-oriented reform was launched in China after the Third Plenary Session of the Eleventh Central Committee, and China's anti-monopoly regulation policy underwent a process from its inception to maturity, evolving from an immature and fragmented state to a mature and systematic one. Throughout this historical process, the evolution of anti-monopoly regulatory policies can be fairly classified into three stages. The first stage was the emergence of anti-monopoly regulatory policies (1978–1992), which were mostly scattered in notices and regulations, focusing on introducing elements of competing and strengthening the concept of protecting competition. In the second stage, anti-monopoly regulatory policies entered the legal system (1993–2006). In 1993, the Anti-Unfair Competition Law of the People's Republic of China was promulgated and implemented, with many of its provisions involving the regulation of monopoly behavior. In this stage, the law was an important component of China's anti-monopoly policy, contributing significantly to protecting fair competition and improving market-oriented mechanisms. However, unlike the Anti-Monopoly Law, which specifically regulates monopolistic behavior, the Anti-Unfair Competition Law focuses more on maintaining the micro- and static economic order through partial and individual corrections and post-event regulation and has little effect on the maintenance of the macro and dynamic order. Subsequently, to meet the need for competition protection in the reform process, the state has successively promulgated a series of anti-monopoly laws and regulations, such as the Price Law and the Bidding Law. The third stage is the establishment and improvement of the anti-monopoly regulatory policy legal system (from 2007 to present). After 13 years of preparation, the Anti-Monopoly Law was legislated in 2007 and enforced on August 1, 2008, marking the formal establishment of China's basic anti-monopoly legal system. Based on the EU competition law, it has a basic system similar to that of other countries in the world. China's "Anti-Monopoly Law" system mainly covers the three major anti-monopoly cornerstones: prohibiting monopoly agreements, prohibiting the abuse of market dominance, and controlling the concentration of operators. According to the real situation, a part of administrative monopoly regulation is added, and a series of regulations on anti-monopoly and intellectual property rights are implemented simultaneously. Other systems are attached or derived systems of these basic systems.

Compared with the original anti-monopoly regulation laws, the Anti-Monopoly Law is more systematic and authoritative. The first is to regulate all kinds of monopolistic behaviors carefully and comprehensively. The second is the extension of the scope of the jurisdiction. The Anti-Monopoly Law has extraterritorial jurisdiction, surpassing that of the Anti-Unfair Competition Law and the Price Law. The third is to expand the objects of regulation. The regulated objects of the Anti-Monopoly Law include industry associations not covered by the Anti-Unfair Competition Law and the Price Law. Considering the competition and cooperation relationship between the Anti-Unfair Competition Law and the Anti-Monopoly Law, the 2017 revised version of the Anti-Unfair Competition Law deleted the monopoly provisions already regulated by the Anti-Monopoly Law. This adjustment aimed to harmonize the Anti-Unfair Competition Law, with its mission of maintaining honesty and business ethics, with the Anti-Monopoly Law, with its mission of maintaining efficiency, freedom, fairness, and economic vitality. In 2022, the amendment to the Anti-Monopoly Law was passed, with a clear goal of encouraging innovation.

2.2. Theory and hypotheses

2.2.1. Antitrust and enterprise innovation

Based on existing literature, the economic logic supporting the notion that the Anti-Monopoly Law can promote enterprise innovation is as follows. First, by restricting economic monopoly behavior, the implementation of the Anti-Monopoly Law increases the degree of competition and compels entrepreneurs to allocate resources to innovation activities [16] to carry out risky innovation projects, to win more customers in the selection mechanism of survival of the fittest [17] to gain long-term competitive advantages and innovative rents. Second, the Anti-Monopoly Law's regulation of administrative monopoly can strengthen the incentive for innovation. On the one hand, it can restrain the barrier effect of administrative monopoly on fair competition, unify the domestic market, accelerate the dynamic cycle of factors and products, and then improve the allocation efficiency of innovation resources of enterprises, and help them capture the benefits of economies of scale and scope through of innovation advantages. The abundant technological opportunities and application scenarios provided by the integrated market extend the market selection of the enterprise, which can promote the speed of new technology optimization, iteration, growth, and maturity. On the other hand, breaking the administrative monopoly will dismantle the rent-seeking channels, reducing the unproductive allocation of innovation resources [18]. Simultaneously, entrepreneurial spirit will be guided towards the benign path of technological innovation. Third, the Anti-Monopoly Law's regulation on the abuse of intellectual property rights can positively promote enterprise innovation. Increasing the effective protection of intellectual property does not mean tolerating the abuse of intellectual property. Especially in the era of knowledge and digital economy, the abuse of intellectual property rights will greatly reduce the profit space and flexibility of competitors [19], hinder the process of knowledge interaction and technology accumulation in technological innovation, and have a negative impact on enterprise innovation. Using the Anti-monopoly Law to regulate the abuse of intellectual property to stimulate the innovation competition of the new innovators under the protection of intellectual property rights is a common choice for existing market economies.

Although theoretically, the implementation of the Anti-Monopoly Law can have a positive effect on enterprise innovation, Levine et al. [11]have verified that the Anti-Monopoly Law can promote micro-enterprise innovation. However, the Anti-Monopoly Law is not uniformly effective in promoting innovation across all industries but rather has industry-specific contexts. Compared with industries with low market concentration, enterprises in industries with high market concentration can benefit more from the implementation of the Anti-Monopoly Law. Its logic is as follows. First, the differences in the initial competition structure within the industry have unbalanced impact effects even if competition of the same intensity is increased [14]. Different from the industries with relatively fierce competition and low market concentration, the competition intensity in the industries with high market concentration is relatively low, which makes the enterprises in the industry suffer greater competition shock, and the resulting competition treatment effect and selection effect also have stronger promotion effect on enterprise innovation. Second, competition required for innovation is not static perfect competition advocated by mainstream economics, but dynamic imperfect competition for innovation in pursuit of monopoly profits, and more emphasis is placed on the protection of the competition process rather than the competition structure [20]. A perfectly competitive market structure, in which excess monopoly profits cannot be obtained through innovation, does not effectively unleash entrepreneurship and lacks the resource base needed for innovation. On the contrary, in industries with moderate industrial concentration, the Anti-Monopoly Law to curb the abuse of all kinds of monopoly behaviors is more beneficial to enterprise innovation.

H1. The implementation of the Anti-Monopoly Law has a greater effect on promoting enterprise innovation in industries with high market concentration than in those with low market concentration.

2.2.2. Antitrust, R&D investment and corporate innovation

The increase in competition intensity resulting from the implementation of antitrust laws generates a promotion effect on R&D investment, thereby promoting enterprise innovation.

Firstly, in industries with high market concentration, the predatory risks and anticipated profit damages resulting from competitive shocks are higher than in industries with low market concentration. Therefore, companies in such industries have a greater incentive to engage in research and development (R&D) investment to increase the success rate of innovation and escape competition. R&D investment also has economies of scale and spillover effects, and expanding the scale of R&D is beneficial for companies to improve R&D efficiency, enhance their ability to absorb and reconfigure innovation resources both internally and externally, and increase the likelihood of innovation success.

Secondly, the sustainability of R&D investment relies on substantial financial support, and financial constraints are the main factors inhibiting companies from conducting R&D investment [21] in industries with low market concentration. Companies in these industries are often small enterprises lacking sufficient financial strength, and they often rely on external financing to support their R&D and innovation activities [22]. In the real context of information asymmetry, the inherent characteristics of innovation activities easily result in high monitoring costs [23]. Coupled with the lack of sufficient collateral assets and specialized organizational structures among small enterprises, this exacerbates the problem of external financing constraints, while competition further intensifies this issue. This viewpoint is supported by empirical research. For example, Valta [24] found that competition reduces expected returns, increases cash flow risk, adds business risk [25], and compresses available investment opportunities for companies, thus increasing their default risk. This effect also jointly increases the debt cost for companies in competitive product markets by lowering the liquidation value of their assets, particularly for companies with weak financial strength. In contrast, companies in industries with high market concentration tend to have relatively stronger internal financial capabilities. Their accumulated asset stocks and collaborative records with external investors also help alleviate information asymmetry and negatively mediate the problems of insufficient external

financing and high financial costs caused by competitive shocks. This gives them a comparative advantage in expanding both the internal and external dimensions of R&D investment.

Lastly, in industries with higher market concentration, companies generally have larger scales. When the intensity of competition or potential competition increases, these companies can rely on their valuable and difficult-to-acquire stocks of human capital, knowledge, experience, and relationship capital as a resource foundation. This allows them to meet the diverse complementary asset and capability requirements for R&D investment, quickly respond to market expansion resulting from the implementation of antitrust laws, leverage abundant technological opportunities, and engage in R&D investment to enhance absorption and innovation capabilities. They can adopt a diversified innovation project investment strategy to diversify R&D investment risks, focus on developing products anchored to core technologies, and capture economies of scale and scope in R&D-product interaction. Moreover, they can leverage their relatively abundant production assets, mature operational capabilities, comprehensive coordination abilities, and extensive supply chain networks to achieve rapid productization, distribution, and value creation of R&D innovation, weakening the inhibitory effect of the non-exclusiveness of technological innovation [26] on R&D investment. The combination of these factors strengthens the motivation for R&D investment and provides positive feedback to technological innovation.

Based on this, we propose the following hypothesis.

H2a. The implementation of the Anti-Monopoly Law can promote enterprise innovation through R&D investment.

2.2.3. Antitrust, human capital and corporate innovation

High-quality human capital typically has better compatibility and suitability with advanced technologies, serving as the primary resource for enterprises to achieve long-term innovation advantages. The intrinsic learning and innovative capabilities of human capital are essential input elements for enterprise innovation. However, if human capital mobility within the industry is hindered, it leads to misalignment of human capital, where the search cost for high-quality human capital is high. If enterprises cannot continuously promote the upgrading of human capital quality and stimulate innovation vitality to create a favorable environment for proactive human capital upgrading, the diminishing marginal returns of innovation due to human capital depreciation [27,28] will become prominent, leading to low innovation efficiency. These factors collectively weaken the catalyzing effect of human capital on enterprise innovation.

The implementation of anti-monopoly laws can promote the optimization of human capital in high-concentration market industries, thereby promoting technological innovation. Firstly, it reduces the misalignment of high-quality human capital within the industry, continuously incentivizing enterprises to accumulate and upgrade high-quality human capital. The implementation of anti-monopoly laws generates a larger competitive impact on high-concentration market companies than on low-concentration market companies. On the one hand, the significant increase in competition generates a selection effect, facilitating the release of high-quality human capital held by low-efficiency enterprises within the industry, leading to the aggregation of high-quality human capital toward high-productivity enterprises [29]. This reduces the misalignment of human capital within the industry, accelerates the knowledge and technological spillover embedded in human capital, enriches the knowledge base, stimulates innovation and entrepreneurial vitality, and promotes enterprise innovation. On the other hand, based on the effect of escaping competition, high-concentration market companies are more inclined to continuously optimize their human capital structure to enhance the speed and quality of technological innovation search paths, improve the efficiency of innovative resource utilization, and select suitable technological opportunities in the complex technology market, harvesting the economic value of technological innovation and gaining long-term competitive advantages. This reinforcement of micro-level incentives is likely to prompt enterprises to increase business training and skills enhancement for internal staff, continuously promote the upgrading of human capital quality and the accumulation of existing stock, and reduce the negative impact of knowledge depreciation on enterprise innovation. At the same time, it is also more likely to accelerate the increase in the relative employment ratio of skilled talents, enrich the high-quality human capital pool within enterprises, and create a favorable environment to stimulate the innovative vitality of high-quality human capital.

Second, the regulation of intellectual property abuse by anti-monopoly laws can improve the innovation environment of enterprises, accelerate the diffusion and interaction of new knowledge, and enhance enterprise knowledge accumulation. This is beneficial for strengthening the quality of enterprise human capital, thus providing positive feedback to technological innovation.

Based on this, we propose the following hypothesis.

H2b. The implementation of the Anti-Monopoly Law can promote enterprise innovation through human capital.

2.2.4. Antitrust, export and corporate innovation

The decision-making regarding export and international investment by businesses is the result of weighing the risks and rewards at the unit level. The legal systems and trade policy uncertainty caused by the competition culture in the destination country for exports create significant and long-lasting trade barriers [30]. This uncertainty will reduce the unit risk-reward that businesses can obtain from exports, leading them to postpone entry into new markets [31], reduce the scale of exports to the destination country, decrease investment, adjust the order of exports, or adopt a diversified export combination strategy in response to this risk. With the deepening of economic globalization, the international coordination of antitrust laws is becoming increasingly frequent, in line with the increasingly stringent international constraints that meet the compliance requirements of antitrust laws. The implementation of antitrust laws can enhance international cooperation among countries on competition policies, achieve alignment of competition rules, cultivate competition culture, strengthen identification with competition culture, and reduce the trade and investment uncertainty caused by differences in legal systems and competition culture. This is beneficial for enterprises to reasonably control the compliance risks of antitrust laws in exports and international investment, expand their export scale, and promote their international investment activities,

to harness the "learning-by-exporting effect" [32], the "export-induced innovation effect" and the optimization of innovative resources through international mergers and acquisitions, thereby strengthening their innovative capabilities.

Based on this, we propose the following hypothesis.

H2c. The impact of the Anti-Monopoly Law on enterprise innovation is stronger among exporting companies.

Fig. 1 presents the theoretical framework.

3. Data and methodology

3.1. Data

To evaluate the effect of antitrust on enterprise innovation in Science and Technology Park, we used the Beijing Zhongguancun micro-enterprise dataset and the Competition Law Index.

The Beijing Zhongguancun Micro-enterprise data. We used the Beijing Zhongguancun enterprise dataset from 2005 to 2015, which covers the manufacturing and service industries. The dataset is organized and collected by the Zhongguancun Management Committee, covering the basic information of enterprises, firm-year patent, financial information, firm characteristics, etc. The dataset has the advantages of high authority, a long period, and rich micro-information. These enterprises are mainly distributed in high-end fields such as new-generation information technology, integrated circuits, software and information services, aerospace, new materials, advanced manufacturing, energy conservation and environmental protection, and medicine and health. In the cleaned samples, the National Economic Industry Classification (GB/T4754-2002) two-digit code ranges from 19 to 87; has 134,123 samples with less than 200 employees, accounting for 92 %; and 2334 listed companies. That is, the sample is dominated by small- and medium-sized nonlisted companies.

The Competition Law Index. For the sake of robustness, we followed the ideas of Levine et al. [11]and adopted the Chinese data in the Competition Law Index compiled by Bradford and Chilton [33] and Bradford et al. [34] as antitrust data. The Competition Law Index is a comprehensive dataset covering 123 countries from 1888 to 2010. The indicators are coded based on statutory law rather than legal implementation; that is, they are coded according to the legal provisions issued by countries to regulate competition. In the specific application, the study extracts the data of the China Competition Law Index from 2005 to 2010.

The sample data was selected from the Zhongguancun area in Beijing, which does not guarantee that the study findings are universally applicable. However, for this study, these data have the following advantages: First, they are representative. Zhongguancun is one of the most influential high-tech industrial parks in China and is striving to become a world-leading Science and Technology Park. According to data released by the World Intellectual Property Organization, from 2021 to 2022, Beijing consistently ranked third globally in the ranking of science and technology clusters across various economies or cross-border regions. Although there was a decline in the ranking in 2023, it remained at the fourth position globally. By the end of 2022, Zhongguancun enterprises had a total of 9078 PCT (Patent Cooperation Treaty, PCT) patent applications, accounting for 79.2 % of Beijing. Using the data from Zhongguancun, we explored the impact of the Anti-Monopoly Law on the innovation behavior of typical innovative economies. Moreover, Zhongguancun enterprises also faced global competition challenges. Because the anti-monopoly law aims to maintain the macro competition order and has extraterritorial jurisdiction, this allows us to select local data without weakening the effect analysis of the anti-monopoly law, but to capture more detailed situational characteristics. The second advantage is to select samples from typical regions, which is conducive to eliminating the impact of differences in the quality of policy implementation. The third advantage is to expand the scope of the sample, focusing on the impact of the Anti-Monopoly Law on the innovative behavior of small- and medium-sized non-listed enterprises. By mainly using samples of small and medium-sized enterprises and non-listed enterprises, it can better reveal the effects

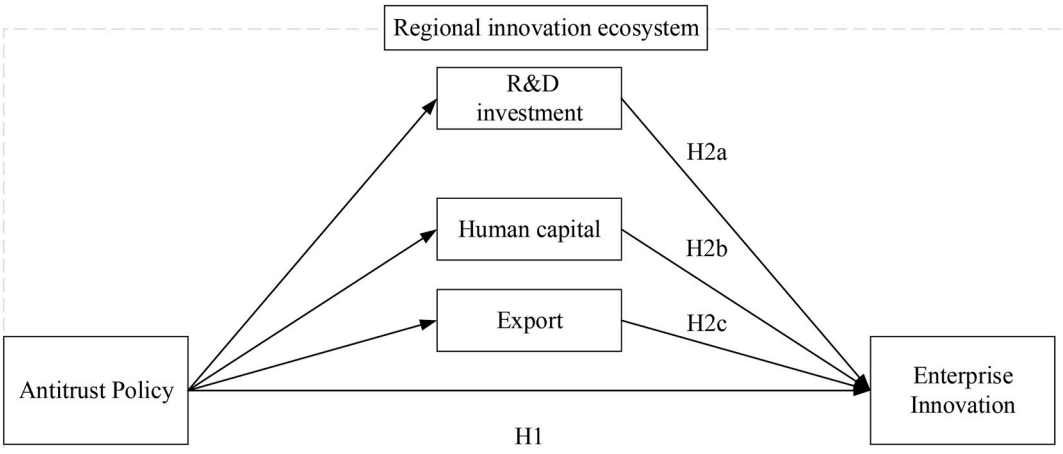

Fig. 1. Theoretical framework.

of the Anti-Monopoly Law on maintaining competition order and dynamic efficiency in enterprise innovation from a macro perspective. The fourth advantage is to exclude interference from other anti-monopoly regulatory policies and alleviate the problem of data truncation. Considering the "Opinions of the State Council on Establishing a Fair Competition Review System in the Construction of Market System" issued in 2016 as an important anti-monopoly regulatory policy, its implementation significantly affected the enforcement environment of the "Anti-Monopoly Law." Therefore, we selected data from 2005 to 2015. Moreover, the Zhongguancun database has been updated up to 2017. Selecting data from 2017 may introduce bias due to patent truncation. Setting 2015 as the end year addresses the patent truncation problem and improves the accuracy of experience identification.

We screen our samples from the following aspects: (1) We eliminate agricultural samples. (2) We delete data that do not conform to accounting standards. Specifically, if (total liabilities + owner's equity)/total assets are more than 1.2 or less than 0.8. (3) We corrected samples with deviations in patent data. If the total number of patent applications of an enterprise in the current year ≠ (the number of invention patent applications + the number of non-invention patent applications), the company name and address were sequentially matched with the data of the State Intellectual Property and Patent Office and then corrected. For samples with missing numbers of patent applications, the same matching strategy was used. If the enterprise had no patent application information in the current year, the missing value was replaced with a value of 0. (4) We excluded the samples with missing or negative values of key indicators such as sales revenue, total assets, R&D investment, tax relief, subsidies, total number of employees, and total exports. (5) Based on the needs of panel estimation and difference-in-difference (DID) estimation, the observation samples with a 1-year data duration are excluded. (6) All nominal variables were deflated using the 2004 Beijing PPI data. Finally, we have obtained a sample comprising 103,353 firm-year observations spanning the period from 2005 to 2015.

3.2. Methodology

Our identification strategy mainly consists of two approaches: one is the Generalized Differences-in-Differences (DID) method, which is suitable for scenarios where the research subjects receive policy shocks to varying degrees; the other is the standard DID method. If the conclusions from the Generalized DID method support the research hypothesis, then when dividing the sample into treatment and control groups based on the intensity of the shock, the conclusions will still hold when applying the standard DID method. Therefore, the second approach can complement the first method.

To identify the causal relationship between antitrust and enterprise innovation, we regard the "Anti-Monopoly Law" implemented in China in 2008 as an exogenous policy impact. We exploit the industry variation in competition intensity before and after 2008 to construct the following DID empirical equation:

$$innovation_{fit+1} = \alpha_0 + \alpha_1 post_t \times hhi_i + \varphi X_{fit} + \lambda_f + \eta_t + \kappa_i + \varepsilon_{fit} \quad (1)$$

$$innovation_{fit+1} = \beta_0 + \beta_1 post_t \times treat_i + \varphi X_{fit} + \lambda_f + \eta_t + \kappa_i + \varepsilon_{fit} \quad (2)$$

where independent variable $innovation_{fit+1}$ refers to corporate innovation in industry i in enterprise f in year $t+1$. Considering that changes in industry competition intensity are related to the degree of monopoly of the industry before 2008. The higher the initial market concentration of the industry and the greater the degree of monopoly, the stronger the competition impact resulting from the implementation of the Anti-Monopoly Law. Therefore, we design treatment variables based on the initial market concentration of the industry to which the enterprise belongs. Specifically, we use two methods: one is to design a continuous treatment variable based on the initial market concentration of the industry to which the enterprise belongs (hhi_i), while the other is to design a binary treatment variable ($treat_i$). The value of treat is equal to 1 if the firm was in a high-market-concentration industry before 2008 and equal to 0 if the firm was in a low-market-concentration industry before 2008.

Based on data characteristics and existing literature, and following Balasubramanian and Sivadasan [35], we adopted the HHI (Herfindahl-Hirschman Index) of the two-digit code industry before 2008 (GB/T4754-2002 version) to measure different industry concentrations. Specifically, first, the company's sales volume was used to calculate the HHI of the two-digit code industry in each year before 2008. Second, the average value of the HHI from 2005 to 2007 was calculated according to the two-digit code industry. By using these methods, we can design continuous treatment variables (hhi_i). Moreover, considering that the geographical scope of the market affects the size of HHI and this study uses the Zhongguancun enterprise dataset, we define 0–1 dummy variables for industries with high market concentration to alleviate the measurement bias arising from the differences in geographical scope. Because binary dummy variables are set based on the degree of relative concentration rather than absolute concentration. If the average HHI of the two-digit code industry is greater than the overall average, it is defined as an industry with high market concentration, and the value is 1, otherwise zero. Compared with using the exact value of HHI to characterize market concentration, measurement problems can be overcome by handling dummy variables Valta [36]. In addition, to further mitigate potential selection bias, for binary treatment variables, we use Propensity Score Matching (PSM) with Difference-in-Differences (DID) regression analysis.

$post_t$ is a year dummy variable, that is, if t < 2008, the value is 0; otherwise, 1. We are interested in the coefficient of the interaction term *post*hhi* and *post*treat*, and the estimated coefficients α_1 and β_1 represent the average treatment effects. A positive and significant α_1 or β_1 indicates that the implementation of antitrust laws can promote enterprise innovation.

X_{fit} is the vector of control variables. We include firm-specific fixed effects λ_f and industry fixed effects κ_i[1] to, respectively, control for

[1] We control for industry-fixed effects at the 2-digit code.

characteristics that do not change over time at the firm and industry levels. We include year-fixed effects η_t to control for the impact at the national level and the trends that affect enterprise innovation over time, such as macroscopic policies, economic cycles, and legal and regulatory changes at the national level. The two-way fixed effects DID model has the advantage of eliminating interference from unobservable factors, thereby enhancing the confidence in estimation results. However, using the staggered DID model may lead to estimation biases. Since our study does not involve the staggered DID model, this concern is not relevant. ε_{fit} is a random error term. The regression standard errors are clustered at the firm level.

3.3. Variables and descriptive statistics

(1) **Dependent variable.** Following Fang et al. [37] and Aghion et al. [38], we utilized patents, a typical and widely used indicator, to measure enterprise innovation. This was achieved by measuring the natural logarithm of the number of patents filed (*lnpatent*) as well as its arcsinh transformation (*patent_n*). We chose the number of patent applications instead of patents granted because the former is closer to the time of knowledge innovation [39]. Moreover, there is a significant time lag from patent application to examination and then to public authorization, with the authorization time delay for invention patents differing from that of utility model and design patents. For robustness check, we also used the number of patent applications (*patent2_n*), invention patent filed *(lnpatent_inno*), and non-invention patent filed (*lnnoninno*) to measure enterprise innovation. Considering the influence of the zero value, we add the value 1 to the above variables and then take the natural logarithm value. Due to the lagged nature of patent applications, we use the number of patent applications in period t+1 as the dependent variable.

(2) **Control variables.** Drawing on existing literature, first, enterprise age affects the inclination towards risk investment and innovation performance, and this effect is non-linear [40]. We include both the linear (*lnage*) and quadratic terms (*lnage2*) of enterprise age to control for its impact. Second, to control for the influence of corporate profitability on innovation, we introduce a binary variable indicating whether the company is experiencing losses (*loss*). Third, considering the influence of company assets on innovation capability [41], we included this variable (*lnasset*). Fourth, to control for the effects of corporate capital structure or debt structure on innovation [42], we added the variable for asset-liability ratio (*wlev*). Fifth, as Garicano et al. [43] found that the distribution of firm sizes affects productivity distribution, we controlled for firm size (*lnemployee*). Sixth, given the widely supported effect of exporting on innovation [44], we included the variable for company exports (*lnexport*). Sevnenth, the innovation approach can significantly impact the innovation performance of enterprises. Therefore, we introduce a binary variable indicating whether the enterprise adopts an open innovation (*coinno*). Eighth, the attainment of high-tech certification not only signifies a company's higher innovation capability but also allows access to more innovation resources [45]. We measure high-tech certification based on whether the company has obtained high-tech certification (*hightech1*). Ninth, subsidies and tax relief are both important tools for governments to alter incentives for corporate innovation. Therefore, we controlled for government subsidies (*lnsubsidy*) and tax relief (*lntaxrelief*).

Table 1 reports the variable definition and descriptive statistics.

4. Results

4.1. Baseline estimates

Because our data is unbalanced panel data, we first test whether it is appropriate to apply a fixed effects model before conducting the regression. The p-value of the Hausman test is 0.0000, which significantly rejects the null hypothesis. Therefore, we adopt the fixed effects model.

Table 2 reports the impacts of antitrust on enterprise innovation. Columns (1) and (2) serve as the basis for comparison. After controlling for individual fixed, year fixed, and industry fixed effects and clustering them into individuals, only the core explanatory variable *post*hhi* is included. The results show that the estimated coefficient of *post*hhi* is positive at the statistical level of 1 %, implying that after implementing the Anti-Monopoly Law, innovation of enterprises in industries with high market concentration has achieved greater growth than those in industries with low market concentration. Compared to Columns (1) and (2), Columns (3) and (4) include control variables that affect the innovation of enterprises over time to weaken the interference of omitted variables on the estimated results. The estimated coefficient of *post*hhi* is still significantly positive. Once again, the implementation of the "Anti-Monopoly Law" has significantly enhanced enterprise innovation.

Selection bias can lead to estimation bias. To address concerns about potential bias resulting from differences in treatment assignment and the possibility of hidden selection bias in our data, we employ a Difference-in-Differences (DID) regression based on the propensity score matching (PSM) of variables. The results can be found in columns (5) to (8). The results confirm that antitrust has a significant promoting effect on enterprise innovation. H1 holds.

In terms of economic impact, holding other variables constant, according to the results in Column (3), the implementation of the Anti-Monopoly Law leads to an average increase of 2.56 % in enterprise innovation. This is calculated as the average value of HHI (0.1596) multiplied by 16.05%— an effect that is approximately 62.5 % of the findings in the study by Levine et al. [11]. Moreover, based on the results in Column (5), compared to enterprises in low-market concentration industries, enterprises in high-market-concentration industries experience a 1.93 % increase in innovation.

Table 1
Variable definition and descriptive statistics.

Variable	Definition	*N*	*Mean*	*SD*
lnpatent_ n	ln(firm *i*'s annual total number of patents filed in the next year + 1)	103,353	0.270	0.736
patent_n	arcsinh(firm *i*'s annual total number of patents filed in the next year)	103,353	0.338	0.901
patent2_n	firm *i*'s annual total number of patents filed in the next year	103,353	1.002	3.615
lnpatent1_inno	ln(firm *i*'s annual total number of invention patents filed in the next year + 1)	103,353	0.168	0.568
lnnoninno	ln(firm *i*'s annual total number of non-invention patents filed in the next year + 1)	103,353	0.146	0.520
lnage	ln(year of observation − year of business opening + 1)	103,353	1.889	0.689
lnage2	lnage squared	103,353	4.044	2.502
loss	Whether the corporate profit is negative in the current year, 1 yes, 0 no	103,353	0.348	0.476
lnasset	ln(firm *i*'s total annual actual assets in current year + 1)	103,353	9.343	2.137
wlev	Firm *i*'s total annual assets/firm *i*'s total annual liabilities	103,353	0.463	0.341
lnemployee	ln(firm *i*'s number of employees in the current year)	103,353	3.090	1.553
lnexport	ln (firm i's actual export amount in the current year)	103,353	0.571	2.020
coinno	Whether the R&D expenditure paid by firm *i* to research institutions in the current year is greater than 0 or whether the expenditure to universities is greater than 0, 1 yes, 0 no	103,353	0.282	0.450
hightech1	Whether the firm *i* has obtained the high-tech certification in the current year, 1 yes, 0 no	103,353	0.288	0.453
lnsubsidy	ln(firm *i*'s actual amount of subsidies received in the current year + 1)	103,353	1.024	2.395
lntaxrelief	ln(firm i's actual amount of tax relief received in the current year + 1)	103,353	1.767	2.956

Table 2
The impact of antitrust on enterprise innovation.

	Model 1			Model 2				
	GDID			PSM-DID				
					_support = = 1	_weight ! =	_support = = 1	_weight ! =
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	lnpatent_n	patent_n	lnpatent_n	patent_n	lnpatent_n	lnpatent_n	patent_n	patent_n
post*hhi	0.1433***	0.1776***	0.1605***	0.1841***				
	(0.0510)	(0.0629)	(0.0485)	(0.0572)				
post*treat					0.0193*	0.0198*	0.0256**	0.0288**
					(0.0103)	(0.0110)	(0.0128)	(0.0137)
lnage			−0.1004***	−0.1205***	−0.1077***	−0.1041***	−0.1310***	−0.1398***
			(0.0137)	(0.0164)	(0.0110)	(0.0129)	(0.0136)	(0.0157)
lnage2			0.0150***	0.0187***	0.0165***	0.0147***	0.0199***	0.0236***
			(0.0054)	(0.0064)	(0.0045)	(0.0056)	(0.0056)	(0.0065)
loss			−0.0088**	−0.0127**	−0.0092**	−0.0114**	−0.0117**	−0.0117**
			(0.0043)	(0.0053)	(0.0041)	(0.0047)	(0.0051)	(0.0057)
lnasset			0.0482***	0.0572***	0.0500***	0.0500***	0.0612***	0.0633***
			(0.0046)	(0.0054)	(0.0035)	(0.0040)	(0.0043)	(0.0049)
wlev			−0.0158	−0.0234*	−0.0164*	−0.0162*	−0.0213**	−0.0196
			(0.0104)	(0.0126)	(0.0086)	(0.0098)	(0.0107)	(0.0121)
lnemployee			0.0595***	0.0727***	0.0609***	0.0605***	0.0748***	0.0738***
			(0.0037)	(0.0045)	(0.0031)	(0.0035)	(0.0038)	(0.0042)
lnexport			0.0062*	0.0093**	0.0061**	0.0045	0.0075**	0.0063*
			(0.0033)	(0.0039)	(0.0027)	(0.0031)	(0.0033)	(0.0037)
coinno			0.0685***	0.0809***	0.0701***	0.0646***	0.0838***	0.0923***
			(0.0173)	(0.0205)	(0.0156)	(0.0179)	(0.0190)	(0.0220)
hightech1			0.0882***	0.1117***	0.0852***	0.0891***	0.1084***	0.1090***
			(0.0096)	(0.0116)	(0.0083)	(0.0094)	(0.0102)	(0.0113)
lnsubsidy			0.0035**	0.0037*	0.0035**	0.0051***	0.0041**	0.0042**
			(0.0017)	(0.0020)	(0.0015)	(0.0018)	(0.0018)	(0.0021)
lntaxrelief			0.0095***	0.0113***	0.0100***	0.0102***	0.0121***	0.0147***
			(0.0013)	(0.0015)	(0.0011)	(0.0013)	(0.0014)	(0.0016)
constant	0.2516***	0.3159***	−0.3126***	−0.3594***	−0.3115***	−0.3091***	−0.3731***	−0.3978***
	(0.0061)	(0.0075)	(0.0440)	(0.0520)	(0.0337)	(0.0397)	(0.0413)	(0.0476)
Firm FE	yes	yes	yes	yes	yes	yes	yes	yes
Industry FE	yes	yes	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes	yes	yes
N	103812	103812	103353	106982	104998	87031	105008	88371
Adj R^2	0.6006	0.5926	0.6112	0.6024	0.6120	0.6095	0.6044	0.6014

Note: The data in parentheses are cluster robust standard errors, *, **, *** indicate significance at the 10 %, 5 %, and 1 % statistical levels, respectively.

4.2. Validity test of DID setting

4.2.1. Parallel trends assumption testing

Preliminary regression results show that the implementation of the Anti-Monopoly Law has a promoting effect on enterprise innovation. However, if before the implementation of the Anti-Monopoly Law, companies in other industries with varied market concentration levels showed significant differences in the development trend of innovation, this conclusion may capture this differential trend. To eliminate this reasonable doubt, following Jacobson et al. [46], we replace the variable *post* in models (1) and (2) with dummy variables of each year. This allows us to test whether the parallel trend assumption holds and to examine the dynamic impact of the Anti-Monopoly Law on corporate innovation. The regression equations are set as follows:

$$innovation_{fit} = \gamma_0 + \sum_{t \neq 2007} \gamma_t \eta_t \times hhi_i + \varphi X_{fit} + + \lambda_f + \eta_t + \kappa_i + \varepsilon_{fit} \tag{3}$$

$$innovation_{fit} = \rho_0 + \sum_{t \neq 2007} \rho_t \eta_t \times treat_i + \varphi X_{fit} + + \lambda_f + \eta_t + \kappa_i + \varepsilon_{fit} \tag{4}$$

We use 2007 as the base year for regression. Fig. 2 shows the estimates at the individual level with a 90 % confidence interval adjusted for the cluster standard error. Specifically, the first plot picture (Fig. 2a) uses *lnpatent_n* as a dependent variable, corresponding to Column (3) of Table 2. The second plot (Fig. 2b) replaces the dependent variable with *patent_n*, corresponding to Column (4) of Table 2. In the third plot (Fig. 2c), we use post*treat as an independent variable and *lnpatent_n* as the dependent variable, corresponding to Column (5) of Table 2. Finally, the fourth plot (Fig. 2d) utilizes post*treat as an independent variable and patent_n as the dependent variable, corresponding to Column (7) of Table 2.

The following four figures show two key points: (1) before the implementation of the Antitrust Law in 2008, no significant trend differences were found between enterprise innovation in high and low-market concentration industries (the estimated coefficients were not significant). (2) The significant effect of the Antitrust Law on enterprise technological innovation is evident in the year of implementation (the estimated coefficient is positive in 2008) and then peaks and decays slowly.

Although our research confirms that there are no pre-treatment trend differences, the validity of the parallel trends assumption cannot be solely dependent on pre-treatment trend tests. As Roth et al. [47] point out, that traditional pre-treatment trend tests are not only statistically inefficient but are also likely to introduce estimation biases. Consequently, following Rambachan and Roth [48], we further investigate the sensitivity of the parallel trends. The test is divided into two steps: first, we construct the maximum deviation of the parallel trends ($\overline{M}$); second, we plot the confidence intervals for the post-treatment point estimates according to the degree of deviation. If the confidence interval for the post-treatment point estimate does not include zero, this indicates that there is some robustness in the parallel trends assumption. Following Biasi and Sarsons [49], we set the maximum deviation degree $\overline{M} = 1$* standard error and then plot the 90 % confidence interval for the post-treatment point estimate. Because we believe that the magnitude of the various shocks contributing to the difference in parallel trends in the post-treatment period will not significantly differ from the pre-treatment period, and we have controlled for the effects of the post-treatment period in subsequent robustness checks, our analysis is based on bounds on relative magnitudes. Fig. 3 shows the results of the sensitivity test for parallel trends. Here, Fig. 3A uses *post*hhi* as the independent variable, and Fig. 3B uses *post*treat* as the independent variable, corresponding to Fig. 2A and C respectively. As shown in the figure, the innovation-promoting effect of antitrust law enforcement in the year of implementation is robust under the relative deviation constraint. In other words, even if there is some deviation in the parallel trends, the implementation of antitrust law can still significantly promote enterprise innovation.[2]

4.3. Robust test

4.3.1. Zero-inflated Poisson regressions

According to Chen & Roth [50], for outcome Y with a presence of zero values, Poisson regression is more appropriate. Given that our data contains a large number of zero values for patent applications, to retain as many samples as possible, we switch the dependent variable to the original value of patent application quantity and rerun the regression using Zero-Inflated Poisson Regression. We also tested the model's fit, and the results found that the Z value is 74.26, which significantly supports the use of Zero-Inflated Poisson Regression at the 1 % statistical level. The regression results are exhibited in Table 3, column (1). According to the results, the implementation of the anti-monopoly law has promoted corporate innovation at the 1 % statistical level. Hypothesis 1 has a certain robustness.

4.3.2. Same-year matched PSM-DID regressions

As we use panel data, treating the panel data as cross-sectional data for Propensity Score Matching (PSM) regression could lead to problems such as overmatching or matching across periods. To address this issue, we conducted PSM matching based on each year, followed by regression using the Difference-in-Differences (DID) method. The results of this approach are reported in columns (2) and

[2] According to Rambachan & Roth (2023), a sensitivity analysis for parallel trends is necessary during periods following policy implementation when the treatment effect is significantly different from zero. Based on our findings, the sensitivity tests for parallel trends are mostly passed. Although these results are not presented in the paper due to space constraints, they can be made available upon request from the authors.

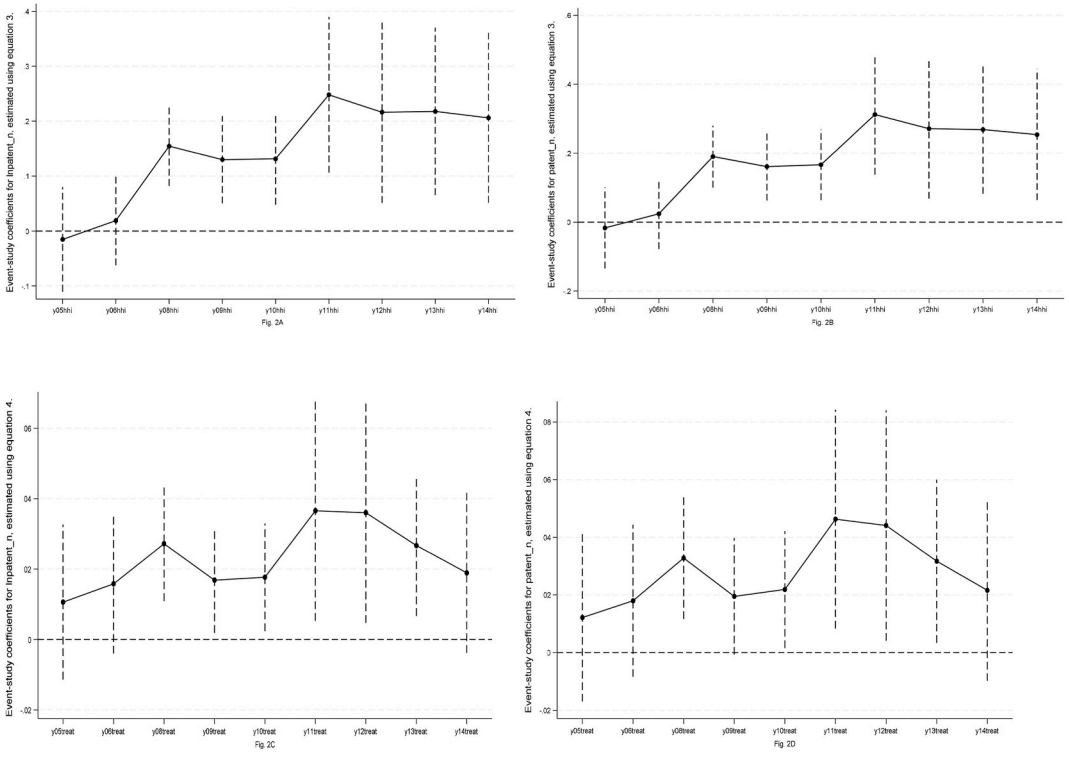

Fig. 2. The dynamic impact of antitrust on enterprise innovation.

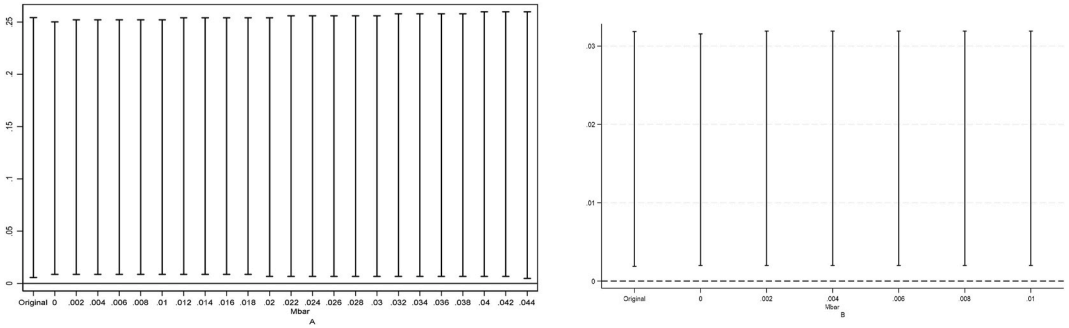

Fig. 3. Sensitivity analysis.

(3) of Table 3. The findings demonstrate that, even after resolving the issue of matching variables across time, the enforcement of antitrust laws continues to promote corporate innovation. Hypothesis 1 is thus corroborated once again.

4.3.3. Control industry market concentration time trend

Certain unobserved industry-specific factors may lead to a change in the industry market concentration over time. If the speculation is confirmed, then according to the SCP (Structure-Conduct-Performance) theory in industrial organization, such trend changes will affect the variation in enterprise innovation behavior. This implies that even if the Anti-Monopoly Law is not implemented, the innovation behavior of enterprises in industries with different market concentration levels will change along different paths, which introduces a bias in our estimates. Following Liu and Qiu [51], we included industry market concentration time trend (*trend*treat*). The regression results are shown in columns (1)–(2) of Table 4. From the results, after controlling the time trend of industry market concentration, the regression coefficient of *post*hhi* is still significantly positive.

4.3.4. Excluding the interference of the 2008 financial crisis

Data show that the total profit of the Zhongguancun Demonstration Zone was deeply affected by the 2008 financial crisis. Adhering to the principle of prudence, we must remove this distraction. Considering that the 2008 financial crisis had a greater impact on the

Table 3
Results from zero-inflated Poisson regressions and same-year matched PSM-DID regressions.

	Zero-inflated Poisson regressions	Same-year matched PSM-DID	
	(1)	(2)	(3)
	patent2_n	lnpatent_n	patent_new
post*hhi	0.0357*		
	(0.0210)		
post*treat		0.0520***	0.0730***
		(0.0111)	(0.0140)
constant	−0.0881***	−0.4160***	−0.6161***
	(0.0310)	(0.0429)	(0.0484)
inflate			
lnage	0.6598***		
	(0.0485)		
lnage2	−0.1498***		
	(0.0124)		
loss	0.0663***		
	(0.0233)		
lnasset	−0.1228***		
	(0.0072)		
wlev	−0.1873***		
	(0.0314)		
lnemployee	−0.2382***		
	(0.0100)		
lnexport	−0.0492***		
	(0.0038)		
coinno	−0.3901***		
	(0.0210)		
hightech1	−1.3267***		
	(0.0224)		
lnsubsidy	−0.0114***		
	(0.0035)		
lntaxrelief	−0.0296***		
	(0.0033)		
constant	3.9266***		
	(0.0669)		
Controls	yes	yes	yes
Firm FE	no	yes	yes
Industry FE	no	yes	yes
Year FE	yes	yes	yes
N	107925	105010	105010
Adj R^2		0.6110	0.5773

Note: The data in parentheses are cluster robust standard errors, *, **, *** indicate significance at the 10 %, 5 %, and 1 % statistical levels, respectively.

export-intensive industries, we added the interaction between the average export scale of the four-digit industry before 2008 $mean\_lnexport_i$ and $post_t$, that is, *post*mean_lnexport* to our regression equations (1) and (2). Columns (3) and (4) of Table 4 show that the estimated coefficient of *post*hhi* and *post*treat* are still positive and significant.

4.3.5. Eliminate the influence of the implementation of Labor Contract Law

The "Labor Contract Law" was implemented on January 1, 2008. Some studies have supported the idea that labor protection will change corporate innovation incentives, thereby affecting corporate innovation [52]. Therefore, we incorporate the term *post*labor* into our regression equations (1) and (2), which is the interaction between *post* and the labor intensity of the four-digit code industry before 2008 (equal to total employment/total sales income). Columns (5)–(6) of Table 4 report the results. There is no evidence that our preliminary results change after controlling for the effect of the Labor Contract Law. To ensure robustness, Columns (7) to (8) of Table 4 report the regression outcomes that account for both the influence of the 2008 financial crisis and the repercussions of the Labor Contract Law. Consistent with prior results, the effects of antitrust enforcement on enterprise innovation remain analogous.

4.3.6. Change the identification strategy

If increased competitive intensity from the implementation of the Anti-Monopoly Law can spur corporate innovation, similar results are expected even when the identification strategy is changed. Hence, taking inspiration from Levine et al. [11], this paper employs the competition law index for China compiled by Bradford and Chilton [32] and Bradford et al. [33] from 2005 to 2010 as a proxy measure for the effects of anti-monopoly regulation. The sample is categorized based on whether firms initially belonged to industries with high market concentration, resulting in two sub-samples: one for high-market concentration industries and another for low-market concentration industries. Regressions are then carried out for each sub-sample separately. The estimated coefficient value

Table 4
Results of controlling for the impact of the financial crisis and the Labor Contract Law.

	Market Concentration Time Trend		Financial Crisis		Labor Contract Law		Financial Crisis + Labor Contract Law	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	lnpatent_n	*patent_n*	*lnpatent_n*	*lnpatent_n*	*lnpatent_n*	*lnpatent_n*	*lnpatent_n*	*lnpatent_n*
*post*hhi*	0.1219**	0.1511**	0.1442***		0.1608***		0.1442***	
	(0.0508)	(0.0627)	(0.0490)		(0.0486)		(0.0491)	
*post*treat*				0.0255**		0.0217*		0.0252**
				(0.0122)		(0.0123)		(0.0122)
*trend*hhi*	0.0108	0.0134						
	(0.0125)	(0.0153)						
*post*mean_lnexport*			0.0823***	0.0920***			0.0833***	0.0935***
			(0.0234)	(0.0232)			(0.0238)	(0.0235)
*post*labor*					−2.1659	−2.3392	0.1060	0.1782
					(1.4191)	(1.4840)	(0.7807)	(0.7741)
constant	−0.3179***	−0.3765***	−0.3301***	−0.3186***	−0.3075***	−0.2903***	−0.3317***	−0.3205***
	(0.0447)	(0.0539)	(0.0440)	(0.0437)	(0.0445)	(0.0441)	(0.0444)	(0.0441)
Controls	yes	yes	yes	yes	yes	yes	yes	yes
Firm FE	yes	yes	yes	yes	yes	yes	yes	yes
Industry FE	yes	yes	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes	yes	yes
N	103353	103341	103353	103341	103296	103284	103296	103284
Adj R^2	0.6112	0.6032	0.6113	0.6111	0.6113	0.6111	0.6114	0.6112

Note: The data in parentheses are cluster robust standard errors, *, **, *** indicate significance at the 10 %, 5 %, and 1 % statistical levels, respectively.

for the Competition Law Index (*cli_overrall*) is expected to be larger in industries with high market concentration. As shown in columns (1)–(2) of Table 5, as expected, the coefficient of *cli_overrall* is greater in industries with high market concentration.

4.3.7. Influence of the National Innovation Demonstration Zone

Zhongguancun became the first National Innovation Demonstration Zone in China in 2009. The policy is an important confounding event because it aims to foster innovation and its implementation time overlaps with the Anti-Monopoly Law. If the National Innovation Demonstration Zone promotes enterprise innovation effectively, there should be a considerable increase in innovation in industries with high initial innovation intensity before 2008. To control for the interference of this confounding factor, we generate one dummy variable $post09_t$, coded as 1, if the year is greater than or equal to 2009, otherwise it is assigned a value of 0. And we generate a new treatment *isodensity*, which is equal to the ratio of the total number of invention patent applications in the two-digit code industry *i* from 2005 to 2007 to the total number of employees during the same period. We generate the interaction $post09_t$*$innodensity_i$ and add it

Table 5
Replacing identification strategies and controlling the impact of Zhongguancun National Independent Innovation Demonstration Zone.

	Industry with low market concentration	Industry with high market concentration	Controlling the influence of National Independent Innovation Demonstration Zones	
	(1)	(2)	(3)	(4)
	lnpatent_n	lnpatent_n	lnpatent_n	lnpatent_n
cli_overall	0.0632***	0.1038***		
	(0.0122)	(0.0254)		
post*hhi			0.1663***	
			(0.0490)	
post*treat				0.0202*
				(0.0123)
post09*innodensity			−0.8459	−0.6787
			(0.5784)	(0.5714)
constant	−0.1624***	−0.0734	−0.3084***	−0.2916***
	(0.0392)	(0.0593)	(0.0440)	(0.0437)
Controls	yes	yes	yes	yes
Firm FE	yes	yes	yes	yes
Industry FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
N	50162	19823	103353	103341
Adj R^2	0.6001	0.5958	0.6112	0.6110

Note: The data in parentheses are cluster robust standard errors, *, **, *** indicate significance at the 10 %, 5 %, and 1 % statistical levels, respectively.

to our regression equations (1) and (2). Columns (3)–(4) of Table 5 display the results. The results show that H1 still holds after controlling for this confounding factor.

4.3.8. Change the sample range and dependent variable

To significantly overcome the estimation bias resulting from differences in sample selection, we adjusted the sample range as follows: (1) adding the agricultural samples with frequency greater than or equal to 2; (2) excluding the data of 2008. As listed in (1)–(5) in Table 6, our result is supported.

We replaced the dependent variables with the number of invention and non-invention patents filed. This allows us to test the robustness of the results as well as the quality differences in the impact of the Antitrust Law on enterprise innovation. Following earlier studies, high-quality innovation can be measured by the number of invention patent applications, whereas low-quality innovation is measured by the number of non-invention patent applications. The regression results are shown in columns (6)–(7) of Table 6. The results suggest that altering the dependent variable will not alter the finding that the Anti-Monopoly Law can more effectively promote enterprise innovation. Moreover, the marginal impact of antitrust enforcement on firms' high-quality innovation is greater.

4.3.9. Placebo test with random assignment of treatment and implementation year

To exclude the interference of other unobserved missing features on the benchmark regression results, we first randomly generate average HHI for the two-digit code industry between 2005 and 2007, ranging from 0 to 1, and then create a continuous treatment variable, $hhi_i^{\ pseudo}$. Second, we randomly selected a year between 2005 and 2015 as the implementation year of the Anti-Monopoly Law to generate the variable $post_t^{\ pseudo}$. Finally, we generated variable $post_t^{\ pseudo} * hhi_i^{\ pseudo}$ to replace variable $post_t{*}hhi_i$ in the regression equation (1) for the placebo test. Fig. 4 shows the cumulative probability distribution and density function of the estimated coefficients with the number of patent applications as the dependent variable, repeating the above process 500 times. The dashed line in the figure is at 0.1605, which corresponds to the value in column (3) of Table 2.

4.4. Heterogeneity

4.4.1. Industry heterogeneity

Considering the important position of the electronic information industry in the industrial structure of Zhongguancun,[3] we followed the technical fields of enterprises stipulated in the "Statistical Statement System of Enterprises in National High-tech Zones and High-tech Enterprises," referred to the National Economic Industry Classification (GB/T4754-2002) and "Electronic Information Industry Classification Catalog," and classified the samples into electronic and nonelectronic information industry by matching the industry four-digit code. Columns (1)–(4) of panel A in Table 7 suggest that the regression coefficient of *post*hhi* is significantly positive in the electronic information industry but not in the non-electronic information industry sample. Perhaps because compared with advanced manufacturing, new energy and energy saving, environmental protection, new materials, biomedicine, and other industries, the electronic information industry has a relatively short innovation cycle and a faster iteration speed of new products. Therefore, the improvement in innovation results measured annually would be larger.

4.4.2. Financial constraint heterogeneity

Financial constraints are an important factor affecting enterprise innovation [53] and lead to two diametrically opposite conclusions: promotion [53] and inhibition [54]. We explore the financial constraint heterogeneity by constructing the interaction term *post*hhi*asa* for financing constraints *asa* and *post*treat,* and by adding *asa* and *post*treat*asa* to our regression equation (1). Following Hadlock and Pierce [55], the financial constraint is measured by the SA index, which has the advantages of strong exogenousness, easy measurement, and high robustness. The SA index was tailed at the 1 % level to reduce the influence of outliers. Since the SA index is negative, the absolute value *asa* is taken for convenience. The larger the value of the financing constraint *asa*, the more serious the financing constraint. As shown in columns (1)–(2) of panel B in Table 7, the estimated coefficient of *post*hhi* is significantly positive. The coefficient of *post*hhi*asa* is significantly negative, indicating that the boosting effect of antitrust on enterprise innovation mainly occurs in samples with small financing constraints.

4.4.3. Innovation model heterogeneity

Closed and open innovation are two different modes for enterprises to conduct innovation. Thus, under different innovation models, is there a difference in the impact of the Anti-Monopoly Law on enterprise innovation? To test this heterogeneity, we divided the sample into two groups, open innovation and closed innovation, and then conducted group regression. Results in columns (3)–(4) of panel B in Table 7 show that the promotional effects of antitrust on firm innovation are greater in the sample of firms that engage in open innovation.

[3] There are six key technical fields in Zhongguancun, namely, electronic information, advanced manufacturing, new energy and energy saving, environmental protection, new materials, and biomedicine. According to the "Zhongguancun Index" from 2005 to 2012, the proportion of the electronic information industry's total income in Zhongguancun was 57.4 %, 59 %, 62.7 %, 56.5 %, 47.9 %, 47.4 %, 40.5 %, and 35.7 %, respectively.

Table 6
Change the sample range and dependent variable.

	Increasing sample size				Excluding data from 2008	Changing independent variable	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	lnpatent_n	patent_n	lnpatent_n	patent_n	lnpatent_n	lnpatent1_inno	lnnoninno
post*hhi	0.1484***	0.1841***			0.1749***	0.1382***	0.0978***
	(0.0463)	(0.0572)			(0.0561)	(0.0393)	(0.0366)
post*treat			0.0193*	0.0254**			
			(0.0102)	(0.0127)			
constant	−0.3020***	−0.3594***	−0.3071***	−0.3637***	−0.3176***	−0.2813***	−0.1526***
	(0.0430)	(0.0520)	(0.0330)	(0.0404)	(0.0470)	(0.0371)	(0.0326)
Controls	yes	yes	yes	yes	yes	yes	yes
Firm FE	yes	yes	yes	yes	yes	yes	yes
Industry FE	yes	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes	yes
N	106982	106982	108675	108675	89485	103353	103353
Adj R^2	0.6107	0.6024	0.6106	0.6027	0.6164	0.5954	0.5251

Note: The data in parentheses are cluster robust standard errors, *, **, *** indicate significance at the 10 %, 5 %, and 1 % statistical levels, respectively.

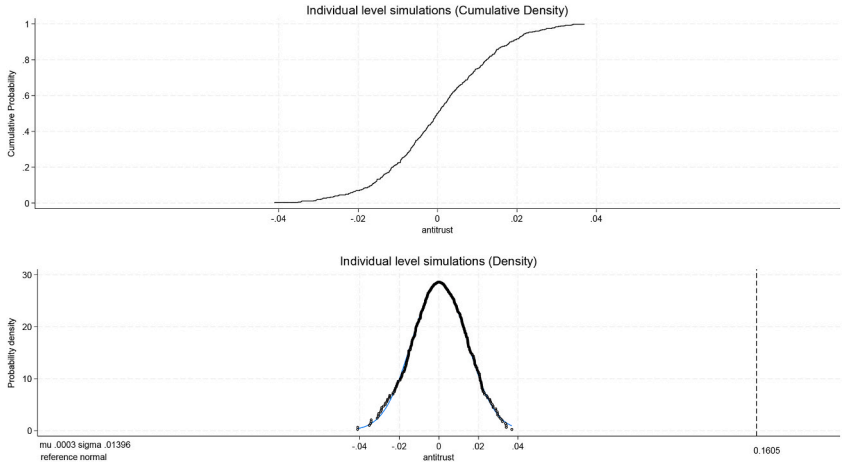

Fig. 4. Placebo test.

5. Channel test

We probe the mechanisms through which antitrust policy fosters enterprise innovation. Specifically, how did the implementation of the Antitrust Law increase enterprise innovation? We argue that the enforcement of the Antitrust Law has led to increased R&D investment and the enhancement of human capital. Furthermore, the innovation-stimulating effects of the Antitrust law are amplified as export intensity grows.

To formally test hypotheses H2 and H2b, drawing on Chen et al. [56], we establish the following econometric equation.

$$mechanism_{fit} = c_0 + c_1 post_t \times hhi_i + \varphi X_{fit} + \lambda_f + \eta_t + \kappa_i + \varepsilon_{fit} \quad (5)$$

where $mechanism_{fit}$ represents R&D investment and human capital, respectively. R&D investment is measured by the natural logarithm of company *i*'s R&D investment *lnrdexpend* and the proportion of R&D investment to sales revenue *rd_density*. Human capital is measured by the human capital scale *human* (the natural logarithm of the total number of Ph.D. and master's degree employees plus 1) and the proportion of R&D personnel *rd_staff_per* (the number of R&D personnel/total number of employees).

To test H2c, we introduced an interaction term between export1 and *post*hhi* to equation (1). If the coefficient of the interaction term is significantly positive, it implies that the pro-innovation effect of antitrust policy is greater among exporting firms. Export is measured by the natural logarithm of company i's actual export value (*lnexport)* and the dummy variable *export1* for whether a firm exports. If the export amount is greater than 1, *export1* is assigned a value of 1; otherwise, *export1* is 0.

Table 8 presents the channel test results. The results indicate that the implementation of the Anti-Monopoly Law significantly increased enterprise R&D investment (columns (1)–(2)) and human capital (columns (3)–(4)). Specifically, R&D investment and human capital can account for the impact of the implementation of the Anti-Monopoly Law on enterprise innovation, suggesting that

Table 7
Heterogeneity analysis results.

Panel A	The electronic and information industry		Nonelectronic and information industry	
	(1)	(2)	(3)	(4)
	lnpatent_n	patent_n	lnpatent_n	patent_n
post*hhi	0.3587***	0.4422***	0.0759	0.0902
	(0.0934)	(0.1150)	(0.0722)	(0.0889)
constant	−0.3721***	−0.4437***	−0.2800***	−0.3398***
	(0.0637)	(0.0759)	(0.0673)	(0.0824)
Controls	yes	yes	yes	yes
Firm FE	yes	yes	yes	yes
Industry FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
N	46269	46269	55386	55386
Adj R^2	0.5829	0.5733	0.6317	0.6230

Panel B	***Financial constraint***		***Closed innovation***	***Open innovation***
	(1)	(2)	(3)	(4)
	lnpatent_n	patent_n	lnpatent_n	lnpatent_n
post*hhi	1.2993***	1.5088***	0.1387*	0.1497***
	(0.2377)	(0.2835)	(0.0743)	(0.0528)
post*hhi*asa	−0.3585***	−0.4126***		
	(0.0695)	(0.0828)		
asa	−0.3560***	−0.4284***		
	(0.0341)	(0.0404)		
constant	0.8920***	1.0740***	−0.3295***	−0.2938**
	(0.0943)	(0.1126)	(0.0834)	(0.1391)
Controls	yes	yes	yes	yes
Firm FE	yes	yes	yes	yes
Industry FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
N	103353	103353	77926	29999
Adj R^2	0.6156	0.6075	0.5952	0.6835

Note: The data in parentheses are cluster robust standard errors, *, **, *** indicate significance at the 10 %, 5 %, and 1 % statistical levels, respectively.

Table 8
Channel test results.

	R&D channel		Human capital channel		Export channel	
	(1)	(2)	(3)	(4)	(5)	(6)
	wlnrdexpend	rd_density	rd_staff_*per*	human	lnpatent_n	lnpatent_n
post*hhi	1.5523***	0.8148***	0.2279***	0.1644***	0.1462***	0.1422***
	(0.2262)	(0.1865)	(0.0204)	(0.0500)	(0.0483)	(0.0483)
export1					−0.0086	
					(0.0208)	
post*hhi*export1					0.2203***	
					(0.0758)	
post*hhi*lnexport						0.0384***
						(0.0111)
lnexport						0.0006
						(0.0037)
constant	−0.7196***	0.6933***	0.1460***	−0.2522***	−0.3137***	−0.3133***
	(0.1305)	(0.1652)	(0.0129)	(0.0332)	(0.0440)	(0.0440)
Controls	yes	yes	yes	yes	yes	yes
Firm FE	yes	yes	yes	yes	yes	yes
Industry FE	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes
N	141561	67923	141531	141505	103353	103353
Adj R^2	0.5206	0.3394	0.4044	0.8543	0.6113	0.6114

Note: The data in parentheses are cluster robust standard errors, *, **, *** indicate significance at the 10 %, 5 %, and 1 % statistical levels, respectively.

antitrust increased enterprise innovation of Zhongguancun Science and Technology Park by boosting firms' R&D investment and human capital. Columns (5)–(6) indicate that the positive impact of antitrust policy on firm innovation increases with the growth of exports. H2a,H2b and H2c hold.

6. Conclusions

6.1. Research conclusions

Innovation is fundamental to long-term economic growth. Whether competition can promote innovation has always been the focus of academic research. The competition shock resulting from the implementation of the Anti-Monopoly Law of China in 2008 provided a unique opportunity to study the impact of the introduction of antitrust policy in emerging countries on corporate innovation. Promotion of enterprise innovation in Science and Technology parks to drive national enterprise innovation is an important path for China. This study explores whether the implementation of the Anti-Monopoly Law in China, the world's largest developing country, has an impact on enterprise innovation in Science and Technology parks. For the analysis, we used the Zhongguancun dataset, which is a unique sample with small- and medium-sized nonlisted enterprises as the main body and the electronic information industry as its important pillar industry.

Using a cross-industry DID design, we found that the implementation of the Anti-Monopoly Law in China increased enterprise innovation in Zhongguancun Science and Technology Park. Our results showed that after the implementation of the Anti-Monopoly Law, firms in industries with high market concentration experienced faster increases in patent applications. Nevertheless, the impact of antitrust policy on enterprise innovation is heterogeneous. Our analysis indicates that the promotion effect of the implementation of the Anti-Monopoly Law on enterprise innovation is greater in the electronic information industry, among firms with low financing constraints, and among firms that conduct open innovation. We also provide evidence that R&D investment, export, and human capital are the possible channels through which antitrust policy affects enterprise innovation. This empirical evidence, based on China's market reform practices, identifies the causal relationship between the antitrust policy and enterprise innovation. This not only enriches the relevant research on competition and innovation but also deepens our understanding of how the antitrust policy affects the development of Zhongguancun Science and Technology Park. Furthermore, it provides insight into the potential economic consequences of digital antitrust policies.

6.2. Policy implications

Our study has important policy implications. First, China and other emerging countries should realize the economic constitutional status of the Anti-Monopoly Law and establish a competition policy system with the Anti-Monopoly Law as the core to continually incentivize innovation through anti-monopoly measures. Strengthening antitrust enforcement and enhancing the accountability of antitrust agencies for anticompetitive behavior is crucial. Intensifying regulation of monopolies in key sectors, establishing an antitrust enforcement database, conducting retrospective analyses of antitrust cases, and dynamically adjusting antitrust guidelines and regulations are also necessary measures. Increase investment in antitrust resources, establish a pool of competition law enforcement experts and consultants, strengthen the construction of antitrust enforcement teams, and enhance the sophistication and professionalism of antitrust enforcemen. Second, the government should adhere to the concept of "promoting innovation through fair competition," incorporate the fair competition system into the national innovation system, promote the construction of an innovation environment indicator system covering the effect of anti-monopoly enforcement, and explore the introduction of supporting assessment rules. Reasonably utilize antitrust exemption clauses to guide and encourage healthy and fair competition among internet platforms, promoting data interoperability among platforms. Third, emerging countries should establish an institutional system to promote competition while developing Science and Technology Parks.

6.3. Limitations and future research

This study has some limitations that require further investigation in the future. First, this paper focuses on the Zhongguancun Science Park to explore the impact of antitrust policies on corporate innovation. Further investigation is needed to determine whether antitrust policies can uniformly promote the development of all enterprises within regional innovation ecosystems. Additionally, considering that the uniqueness of different regional innovation ecosystems may affect the relationship between antitrust policies and enterprise innovation, it is essential to expand the research sample to include more Science and Technology parks in the future. This will enhance the generalizability of the research findings and deepen the analysis of their specificity within different regional innovation ecosystems. Second, policies such as high-tech recognition and tax incentives are important policy tools used by the Chinese government to promote innovation and development in science park enterprises. The synergy between these policy tools and antitrust policy in promoting corporate innovation has not been examined in this paper. Future research could explore whether innovation policies and antitrust policies can synergistically promote corporate innovation and investigate the underlying channels of impact. Third, there may be discrepancies between the enactment of antitrust laws and their actual enforcement effectiveness, especially across different regions. This study employs the DID method to construct antitrust variables, which naturally eliminates the interference of regional factors on research conclusions. However, it fails to specifically reflect the differences in enforcement strictness across different regions and the resulting differences in outcomes. In the future, leveraging antitrust enforcement data could further enrich the existing analysis.

Data availability statement

The data that has been used is confidential.

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CRediT authorship contribution statement

Wenna Wang: Writing – review & editing, Writing – original draft, Data curation, Conceptualization. **Beibei Hu:** Writing – review & editing, Formal analysis. **Jiejiao Liu:** Writing – review & editing, Resources. **Zhen Yang:** Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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