Education and Lifelong Development Research

Vol. 2, No. 1, p. 39-51, 2025

Original article

Research on the technology transfer policy diffusion among "Double First-Class" universities in China

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Keywords:
Technology transfer
policy diffusion
higher education
S-Curve
neighborhood effect

Cited as:
Li, L., Song, J., & Zhang, Y. (2025). Research on the technology transfer policy diffusion among "Double First-Class" universities in China. Education and Lifelong Development Research, 2(1): 39-51.
https://doi.org/10.46690/elder.2025.01.05

Abstract:
Technology transfer serves as a critical link between scientific advancements and economic development, facilitating the transformation of research outcomes into societal benefits. In China, universities play a pivotal role in this process by bridging the gap between research innovation and its practical application. Drawing on the innovation diffusion theory, this study examines the diffusion dynamics of technology transfer policies among China's "Double First-Class" universities as an integral part of the national initiative aimed at fostering world-class institutions in terms of academic excellence as well as innovation capabilities. Systematic analysis of the temporal, spatial, and institutional factors influencing policy adoption reveals that the diffusion of these policies follows the typical S-curve innovation diffusion path. It also highlights significant regional disparities, with a marked "neighborhood effect", suggesting that universities in closer geographic and institutional proximity are more likely to share and adopt similar policies. Disciplinary and institutional factors also play a substantial role in shaping the diffusion process. Universities with varying subject strengths, administrative structures, and departmental responsibilities exhibit differing patterns of policy adoption and implementation. In conclusion, the diffusion of technology transfer policies among China's "Double First-Class" universities demonstrates a complex interplay of institutional, regional, and disciplinary factors. This study underscores the need for more targeted policy interventions that account for these variations while striving for a more coordinated and balanced approach to national innovation strategies. The findings further suggest that future policy efforts should focus on enhancing collaboration between universities of varying disciplines and resource levels, thereby fostering a more inclusive innovation ecosystem within China's higher education.

1. Introduction

The global political and economic landscape is currently undergoing profound and rapid transformations. A new wave of scientific and technological revolution is reshaping the global innovation ecosystem and is reconfiguring economic structures. This transformation presents both unprecedented challenges and new opportunities for China's scientific, technological, and socio-economic development. The Report of the 20th National Congress of the Communist Party of China (CPC) underscores the critical role of education, science and technology, and human resources as fundamental and strategic pillars for building a modern socialist nation. The report emphasizes the need to recognize science and technology as the primary productive forces, talent as the principal resource, and innovation as the primary driving force. It further advocates the implementation of strategies aimed at rejuvenating the country through education, strengthening national development through talent, and driving growth through innovation. These strategies are designed to foster the development of new fields and trajectories, while continually creating fresh momentum and competitive advantages.

Universities, as key sources of scientific and technological

Yandy Scientific Press

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Received January 12, 2025; revised February 26, 2025; accepted March 20, 2025; available online March 25, 2025.

innovation, bear the significant responsibility of providing intellectual and technological support for socio-economic advancement. The Ministry of Education in China prioritizes the enhancement of the technology transfer lifecycle as a critical reform initiative. This necessitates the creation of a strong educational framework for the country and investment in research and innovation at universities to accelerate the development of new industries and enhance the quality of existing industries, thus contributing to the attainment of high-quality productivity based on ingenuity and excellence (Ministry of Education, 2024). Furthermore, General Secretary Xi Jinping, in his address at the 2024 National Education Conference, stressed the importance of strengthening research collaborations between academic institutions and enterprises to facilitate the rapid transformation of scientific and technological achievements into productive forces (Xinhua News Agency, 2024).

As vital components of national strategic scientific and technological forces, high-level research universities bear the crucial responsibility of providing intellectual and technological support for national economic and social development. According to the Compilation of Statistics on Science and Technology of Higher Education Institutions in 2023, in 2022, ”211” universities and those under provincial and ministerial co-construction institutions received 401 science and technology progress awards, accounting for 75% of the national total; published 681,351 academic papers, constituting 52% of the national total; filed 139,563 patent applications, with 127,521 patents authorized and 5,511 patents sold. The actual income from technology transfer in that year reached 2.75 billion yuan. These figures reflect the significant contributions of these high-level research universities in promoting innovation and generating valuable research outputs. However, the efficiency and effectiveness of technology transfer can be enhanced further for even greater success.

To address the barriers hindering technology transfer, many universities have introduced relevant policies aimed at facilitating this valuable initiative. This trend has motivated the present study as a part of which the policy diffusion process related to technology transfer among “Double First-Class” universities in China is empirically analyzed. As leading research institutions in China, “Double First-Class” universities produce abundant scientific research and exhibit a strong commitment to technology transfer. They are often at the center of policy attention in the field of technology transfer and serve as key drivers of policy implementation. These universities are also highly responsive and can swiftly adapt to policy changes. Moreover, their wide distribution and diverse classifications provide a solid foundation for studying the diffusion of policies related to technology transfer. In this study, the policy diffusion theory framework is adopted to systematically analyze the relevant data on technology transfer policies spanning the 2001-2024 period. The diffusion characteristics and underlying patterns are examined from multiple perspectives, including temporal, spatial, disciplinary, hierarchical, and administrative dimensions.

2. Literature review

2.1 University technology transfer

Technology transfer is a critical mechanism for realizing the value of scientific and technological innovations, facilitating the translation of academic research into practical applications that drive economic and societal progress. A substantial body of literature has explored various aspects of university technology transfer, including different transfer modes and the factors that shape these processes.

The modes of university technology transfer are affected by both institutional and contextual factors. By mapping the technology transfer process at the University of Minnesota, Harmon et al. (1997) found that technology transfer to large companies or small firms, venture capital firms or intermediaries, and start-ups created by the university inventors predominated. More recently, cooperative research and development (R&D) between industry and universities has become a significant avenue for long-term university-industry partnerships (Pinto & Fernandes, 2021). In the Chinese context, Wu and Hou (2022) identified four primary modes of university technology transfer: project-based R&D models, which include commissioned research, cooperative research, and consulting services; platform-building models, such as joint R&D bases, co-developed derivative enterprises, and talent training platforms; intellectual property (IP) management models, including technology transfer, licensing, and valuation of technologies; and regional innovation models, which involve industry technology alliances, local research institutes, university-enterprise engineering centers, and regional technology transfer offices.

Technology transfer is influenced by factors operating at the micro, meso, and macro levels. At the micro level, the characteristics of technologies—such as their novelty, complexity, and maturity—are crucial determinants of the practicality and effectiveness of commercialization (D’Este & Patel, 2007). For example, more mature and commercially viable technologies are more likely to attract industry stakeholders and venture capitalists, while early-stage or highly experimental research may face greater barriers to commercialization.

At the meso level, the organizational factors within universities play a significant role in shaping the technology transfer efficiency. For instance, research teams’ productivity is directly linked to the commercialization potential of their technologies. Strong research teams are more likely to produce technologies that have substantial market value, which, in turn, enhances the university’s capacity for effective technology transfer (Powers & Campbell, 2011). As the central institutional mechanism in many universities in the U.S., the Technology Transfer Office (TTO) is integral to the technology transfer process (Chen et al., 2024). TTOs facilitate the identification, evaluation, protection, promotion, and commercialization of technologies, often through patenting, licensing, and start-up creation (Chen et al., 2024).

At the macro level, university technology transfer is affected by the broader regional and policy environment. Cooke et al. (1997) explored the role of regional innovation systems, emphasizing the importance of financial resources, institutionalized learning, and a production culture conducive to technology commercialization. According to these authors, strengthening regional capabilities and providing a supportive environment for technology transfer are essential for fostering innovation and increasing the effectiveness of university-industry collaborations. The policy and legal environment is another critical determinant of technology transfer. For example, the Bayh-Dole Act of 1980 in the United States, which granted universities the intellectual property rights for federally funded research, marked a pivotal development in enhancing university technology transfer. This landmark legislation is widely regarded as a catalyst for the growth of technology transfer in the U.S. universities and has served as a model for other countries seeking to promote the commercialization of public research.

In sum, extant body of literature on university technology transfer reveals a complex and multi-dimensional process that is shaped by various technological, organizational, and institutional factors. Its success is contingent upon the alignment of these factors, from the characteristics of technologies and the capacity of research teams to the institutional mechanisms and regional policies that support or hinder the transfer process. While Chinese universities have made significant strides in obtaining patents for proprietary innovations, the efficiency of technology transfer continues to present challenges and opportunities for further improvement.

2.2 Policy on university technology transfer

Technology transfer is an intricate, multi-faceted system involving numerous stakeholders and processes, with a long implementation cycle and inherent uncertainties (Sun, 2023). To mitigate these complexities and facilitate technology transfer, universities frequently issue policies to support the transfer process. The academic literature on university technology transfer policies primarily focuses on the historical evolution of such policies, their content, and the evaluation of their effectiveness.

The evolution of these policies has attracted considerable academic attention. Geuna and Rossi (2011) conducted a comprehensive review of the historical development of technology transfer policies in European universities, finding that, since the early 2000s, there has been a notable shift in patent ownership towards universities. Nonetheless, universities have maintained a high degree of collaboration with companies that retain substantial ownership of patents (Geuna and Rossi, 2011). In China, Wang and Zhang (2024) traced the evolution of technology transfer policies at local universities in China, categorizing the process into four stages: initial coverage, moderate adjustment, steady improvement, and dynamic development. They identified a pattern marked by both discontinuities and periods of balance, with a notable interaction between central and local policies that fostered a coordinated and adaptive policy environment (Wang & Zhang, 2024).

In terms of the policy content, significant research has been dedicated to understanding the specific policy tools employed to facilitate technology transfer. Zheng and Zhu (2022) subjected 103 policies related to technology transfer in Chinese universities to text analysis. They applied McDonnell and Elmore's classification to assess the tools used in these policies, and revealed a frequent reliance on command tools, such as regulatory mandates and requirements, while capacity-building and incentive tools were used with moderate frequency, and persuasion tools and system-change tools were underutilized (Zheng and Zhu, 2022). Similarly, focusing on the university technology transfer policies in Chongqing, Chen et al. (2023) developed a three-dimensional analytical framework that encompassed "basic policy tools", "technology transfer governance system", and "policy effectiveness". According to the obtained findings, the policy system in Chongqing was heavily reliant on "behavioral norms" policy tools, while the use of "guidance and incentive" policy tools was insufficient (Chen et al., 2023). This imbalance points to the need to optimize the structure of policy tools and place a greater emphasis on policies that guide and incentivize behavior, rather than solely regulate actions (Chen et al., 2023). Chen et al. (2023) thus concluded that the effectiveness of technology transfer could be enhanced by diversifying the policy toolset and fostering an environment that encourages innovation and collaboration.

As the discourse on technology transfer policies relies heavily on their impact and effectiveness, policy evaluation has been a prominent research area, with numerous studies focusing on the temporal dynamics and effectiveness of these policies. Zhong et al. (2021) observed that the impact of technology transfer policies was not immediate but typically manifested in the second or third year following implementation. This delayed effect underscores the complexity of technology transfer processes and the time required for policies to generate tangible outcomes. In a similar vein, Zhu and Chen (2023) employed indicators such as the economic impact of technology transfer and the conversion rate of scientific achievements to evaluate the success of university technology transfer policies. Their findings suggested that these policies had a significant positive impact on technology transfer (Zhu & Chen, 2023). Further analysis revealed that the policies exerted their influence by regulating key assets—financial, human, material, and network resources—and fostering a more conducive environment for the commercialization of university research (Zhu & Chen, 2023).

The literature on university technology transfer policies reveals a dynamic and evolving field, with a significant focus on the historical evolution of policies, the specific policy tools employed, and the evaluation of policy effectiveness. The presented findings highlight the critical role of policies in facilitating technology transfer. However, as the impact of individual policies tends to be examined in isolation, limited attention is paid to the broader interaction between policies across universities. Further research is thus needed to explore how these policies interact, evolve, and collectively shape the effectiveness of technology transfer processes, providing a more comprehensive understanding of the policy landscape that influences university-industry collaborations.

2.3 Policy diffusion theory

Policy diffusion refers to the process through which a policy innovation adopted by one entity or jurisdiction spreads to others over time (Walker, 1969). Walker (1969) posits that a policy or program constitutes an innovation for any state or organization that adopts it, regardless of how long it has existed or whether it has been previously adopted elsewhere. The adoption and spread of such policy innovations across various entities is what constitutes the process of policy diffusion (Walker, 1969). This conceptualization serves as the foundation for much of the contemporary research on policy diffusion aiming to elucidate the temporal and spatial dynamics of policies' spread.

The temporal patterns of policy diffusion have been widely studied, with scholars seeking to understand how innovations propagate over time. Rogers (1962) introduced the S-curve model of innovation diffusion, which has become a classic framework in the study of diffusion. The S-curve model delineates the process by which innovations initially diffuse among early adopters, followed by a broader adoption phase, and ultimately reaching laggards (Rogers, 1962). This model suggests that policy adoption follows a predictable pattern, starting slowly among early pioneers, accelerating as more entities adopt the policy, and then decelerating as fewer late adopters join the process (Rogers, 1962). However, Boushey (2010) argues that many policies do not adhere strictly to the classic S-curve, instead following alternative diffusion patterns such as steep S-curves, R-curves, and ladder curves, which better capture the variability and complexity of real-world policy diffusion.

In addition to temporal patterns, the spatial dimensions of policy diffusion have also received significant attention. Brown and Cox (1971) assert that policies are more likely to diffuse between geographically proximate entities, leading to a hierarchical diffusion effect where "leaders"—typically more advanced or influential jurisdictions—are followed by "followers". This hierarchical pattern often manifests in policy adoption that moves from more developed regions or nations to less developed ones. Wang (2007) expanded on this concept by exploring diffusion in heterogeneous spatial contexts, noting that when institutional innovations occur in comprehensive national reform zones, diffusion tends to follow specific axial patterns, spreading initially along infrastructural or logistical axes (e.g., transportation corridors) before expanding to adjacent areas. This phenomenon—termed the "axial effect"—highlights the role of geographical and infrastructural factors in shaping the trajectory of policy diffusion. In the context of China, Wen (2020) studied crises policy diffusion and observed that spatial distribution follows central effect and involves four central diffusion modes.

Scholars have also examined the factors and mechanisms that drive policy diffusion. Meyer et al. (1997) argued that national policies and systems had become increasingly homogeneous, driven by external influences such as global culture, values, and social norms. These external drivers, along with the influence of international organizations and networks, facilitate convergence among different national and institutional policies. More recently, Yang and Liu (2024) examined the diffusion of vocational education and identified the socio-economic and political institutional context as the most significant factor. DiMaggio and Powell (1983) provided a theoretical framework that identifies the coercive, imitation, and normative mechanism as three primary mechanisms of policy diffusion. The coercive mechanism occurs when one entity adopts a policy due to external pressures, such as legal mandates or political force (DiMaggio & Powell, 1983). The imitation mechanism is characterized by the adoption of a policy as a result of the desire to emulate the actions of others, often more successful entities (DiMaggio & Powell, 1983). The normative mechanism involves the diffusion of policies through the influence of prevailing norms, values, and expectations within a given field (DiMaggio & Powell, 1983). Zhou and He (2019) applied these mechanisms to study the diffusion of the "application-assessment" system for doctoral admissions within China's "Double First-Class" universities, finding that all three mechanisms—coercive, imitation, and normative—played a role in the diffusion process. Additionally, they identified the competition mechanism as a critical driver of policy re-innovation during the diffusion process, suggesting that the competitive environment among universities fosters incremental policy changes and promotes innovation as institutions seek to improve their standing (Zhou & He, 2019).

In summary, the theory of policy diffusion provides valuable insights into the processes by which policy innovations spread across different entities and regions. As much of the existing research has focused on the temporal and spatial dynamics of policy diffusion in the public sector, there remains a significant gap in understanding how these principles apply to universities, particularly in the context of technology transfer. The diffusion of university policies related to technology transfer warrants further investigation, particularly in terms of how these policies evolve, how they spread across geographical spaces, and the mechanisms that drive their adoption. By exploring these dimensions, this study aims to contribute to a deeper understanding of the diffusion characteristics and processes of technology transfer policies in Chinese universities.

3. Research design

This study focuses on the technology transfer policies of "Double First-Class" universities in China for several reasons. First, these universities possess robust scientific research capabilities and serve as pivotal agents in the production of scientific and technological achievements. Given their central role in the generation of new knowledge and innovations, they are inherently involved in technology transfer. Consequently, these institutions have long recognized the importance of establishing frameworks for technology transfer and have therefore issued relevant policies earlier than other universities, thereby providing a rich data source for empirical analysis. Second, the heterogeneity in the types and levels of these universities, as well as their diversity in terms of disciplinary focus and institutional governance, ensures that they are representative of the broader landscape of higher education institutions in China. This diversity allows for a more comprehensive examination of the diffusion characteristics and underlying trends of technology transfer policies across different types of universities.

The technology transfer policies examined in this study belong to two main categories. The first category consists of implementation and management measures that govern the technology transfer process. These documents include formalized policy frameworks such as the "Implementation Measures for Promoting Technology Transfer at Beijing Institute of Technology" and the "Management Measures for Technology Transfer at Donghua University". The second category encompasses policy documents that provide more specific provisions for technology transfer. An example of this type of policy is the "Implementation Measures of Hunan Normal University on the Valuation of Technological Achievements into Shares for Enterprise Establishment", which stipulates that high-tech research can be converted into equity for start-ups. These policies detail specific operational procedures, equity distribution frameworks, and other related regulations, offering a more structured approach to university technology transfer. Both categories are considered critical components of the broader university technology transfer policy and are included in the analyses performed in this study.

The information utilized in these analyses were obtained through an extensive document search and supplementary interviews with university personnel. To ensure that all relevant policy documents issued by the universities were identified, the search strategy included using the name of the university as a prefix, followed by targeted keyword searches such as "management measures for technology transfer", "implementation rules for technology transfer", "technology transfer", "technical contract management", and so on. The search was subsequently expanded to include official university websites, academic repositories, and publicly available policy archives. In addition to these primary data sources, telephone interviews were conducted with relevant staff members at the university TTOs to obtain any further policy documents not accessible via the aforementioned means. As a result of this comprehensive strategy, a total of 685 potentially relevant policy documents were identified and compiled for further analysis.

The temporal scope of the study is determined by the year in which the universities first promulgated their technology transfer policies. This provides a clear starting point for examining the diffusion of these policies over time. Among the 147 "Double First-Class" universities, there are three military academies. Due to the unavailability of their policy documents, these institutions were excluded. Moreover, as 125 of the remaining 144 "Double First-Class" universities had issued relevant policies on technology transfer as of December 31st, 2024, this sample was subjected to detailed analyses aimed at elucidating the characteristics, patterns, and dynamics of policy diffusion across these leading institutions.

The analysis of policy diffusion characteristics presented in the next section will focus on several key dimensions, including the temporal and spatial patterns of diffusion, as well as the different types of universities that have adopted policies. By examining the policy issuance timelines, regional variations, and university types, the aim is to uncover the broader trends and diffusion patterns of technology transfer policies in Chinese universities.

4. Characteristics of technology transfer policy diffusion across "Double First-Class" universities

To clarify the evolution of policies at different stages and uncover the policy transmission paths among universities in various regions, the number and proportion of universities that issued technology transfer policies over time and across different locations is systematically studied. By examining the diffusion characteristics of technology transfer policies among "Double First-Class" universities from both temporal and spatial dimensions, this study uncovers the dynamic process of policy diffusion and highlights regional differences. To facilitate comprehensive analysis, "Double First-Class" universities were categorized based on discipline type, academic level, and competent authorities. The proportions of different types of universities that introduced technology transfer policies at each stage were then determined, providing deeper insights into the diffusion patterns across various institutions.

4.1 Temporal characteristics

To promote technology transfer, accelerate scientific and technological progress, and drive economic and social development, Chinese government enacted the Law of the People's Republic of China on Promoting Technology Transfer in 1996, marking the beginning of a new stage in technology transfer development. As key hubs of scientific and technological innovation, universities gradually began to formulate technology transfer policies.

To analyze the overall trend of policy diffusion, a line chart with the years on the horizontal axis and the (cumulative) number of universities that issued technology transfer policies on the vertical axis was generated. As shown in Fig. 1, the diffusion of technology transfer policies among "Double First-Class" universities follows an S-curve pattern with three distinct stages: the initial diffusion stage (2001-2014), the rapid growth stage (2015-2020), and the steady development stage (2021-2024).

The initial diffusion stage exhibits a sporadic and slow diffusion trend. In 2001, Sichuan University issued the Interim Provisions on the Valuation of Scientific and Technological Achievements as Capital Contribution. In the same year, China Agricultural University released the Interim Provisions on Promoting Technology Transfer. Subsequently, Beijing Institute of Technology (2002), Hunan Normal University (2005), Fuzhou University (2006), and Dalian University of Technology (2007) also successively issued relevant policies.

At the end of 2007, the Science and Technology Progress Law of the People's Republic of China was revised, emphasizing the role of science and technology as the primary productive force and advocating for technology transfer. This revision brought greater attention to technology transfer initiated by universities. In the following three years, ten "Double First-

Class" universities introduced technology transfer policies, marking a small peak in policy issuance and laying a crucial foundation for enhancing universities' scientific and technological innovation capabilities while supporting economic and social development.

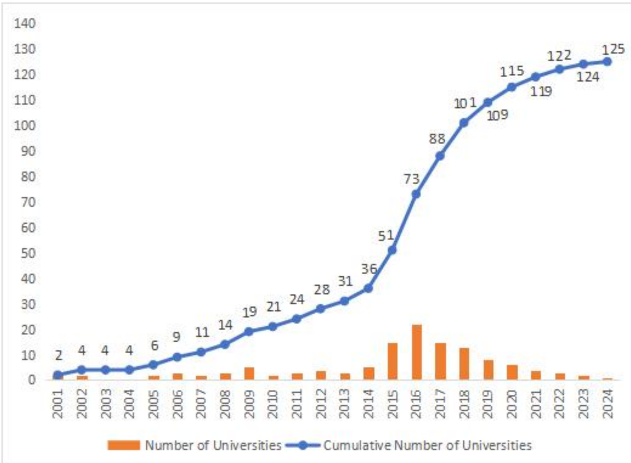

Fig. 1. The number and cumulative number of "Double First-Class" universities that issued technology transfer policies from 2001 to 2024.

Between 2011 and 2014, 3-5 universities issued technology transfer policies each year, leading to a steady cumulative increase. From 2001 to 2014, a total of 36 "Double First-Class" universities introduced such policies, fostering a policy environment that encouraged universities to actively engage in and promote technology transfer. This period provided a broad developmental space for the diffusion of technology transfer policies.

During the rapid growth stage (2015-2020), the number of universities issuing technology transfer policies increased sharply. This is not surprising given that the Law of the People's Republic of China on Promoting Technology Transfer underwent significant revisions in 2015. The new legislation delegated the rights to dispose of, use, and manage scientific and technological achievements and allowed universities to allocate no less than 50% of technology transfer income to inventors. These changes granted universities greater autonomy, enabling them to formulate technology transfer policies tailored to their specific needs.

In 2016, the General Office of the Ministry of Education issued the Notice on the Action Plan for Promoting Technology Transfer of Higher Education Institutions, requiring universities directly under the Ministry of Education to establish and enhance various systems and mechanisms related to technology transfer. In the following years, provincial governments introduced a series of relevant policies and regulations, including the Action Plan for Promoting Technology Transfer in Beijing (2016), the Regulations on Promoting Technology Transfer in Shanghai (2017), the Management Measures for the Hainan Province Technology Innovation and Transfer Platform (Trial) (2020), and so on. Over these six years, a total of 79 universities implemented technology transfer policies, reflecting a phase of rapid development. The annual number of newly introduced policies reached its peak during this period, providing strong institutional support for technology transfer.

During the steady development stage (2021-2024), the diffusion rate of technology transfer policies declined despite a highly favorable institutional and legislative environment. In 2021, Chinese government released the Outline of the 14th Five-Year Plan for National Economic and Social Development and the Long-Term Objectives for 2035, emphasizing the need to deepen reforms in the science and technology system, enhance national science and technology governance, and grant greater autonomy to research institutions and researchers. That same year, several authorities, including the Ministry of Industry and Information Technology, the Ministry of Transport, the Ministry of Water Resources, the Ministry of Agriculture and Rural Affairs, the Ministry of Commerce, the State Administration for Market Regulation, and the State Administration of Cultural Heritage, issued documents on scientific and technological innovation, many of which addressed technology transfer (Dong & Wu, 2022). The introduction of these policies further clarified the direction and priorities of technology transfer, playing a significant role in guiding universities in formulating their policies.

In 2022, the China Association for Science and Technology organized a summit forum on innovative methods and technology transfer, aiming to strengthen communication among universities. In 2023, the Forum on University Technology Transfer, Patent Operation, and Regional Innovation Development was held in Haikou, bringing together the representatives of nearly 30 renowned universities to share their practical experiences in technology transfer. In 2024, the Zhongguancun Forum Annual Meeting included, for the first time, a dedicated conference on promoting university technology transfer, focusing on fostering new momentum and enhancing the role of universities in advancing high-quality productivity. By providing platforms for universities to align with national strategic goals, exchange experiences in technology transfer, and connect with potential industry partners, these forums and conferences further incentivized the development of university technology transfer policies. However, as the majority of "Double First-Class" universities had already issued such policies, the number of new policies gradually declined, and the overall diffusion rate slowed significantly, marking the transition to a more mature and stable development phase.

In summary, the diffusion of technology transfer policies among "Double First-Class" universities follows an S-curve trend, progressing through three distinct stages—the initial diffusion, rapid growth, and steady development stage—exhibiting the classic phased pathway of policy diffusion.

4.2 Spatial characteristics

4.2.1 Regional distribution of university technology transfer policy diffusion

To analyze the spatial characteristics of the diffusion of technology transfer policies across universities, standard geographical divisions were adopted, categorizing China into seven major regions: East China, South China, Central China, North China, Northeast China, Northwest China, and Southwest China. By examining the cumulative number and proportion of universities that issued technology transfer policies in these regions at different stages of policy diffusion, this study provides a comprehensive overview of the spatial dynamics of technology transfer policies. The results are illustrated in Fig. 2 and 3.

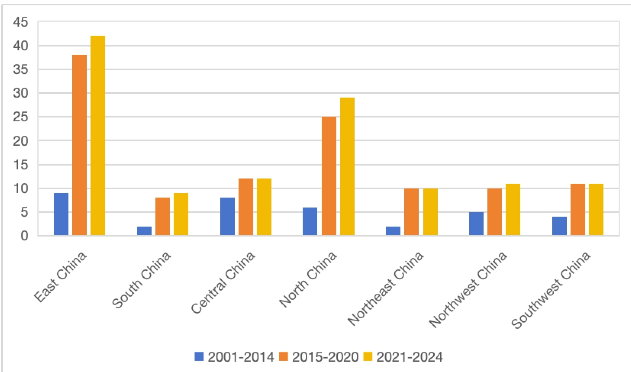

Fig. 2. Cumulative number of "Double First-Class" universities that issued technology transfer policy by region and period (2001-2024).

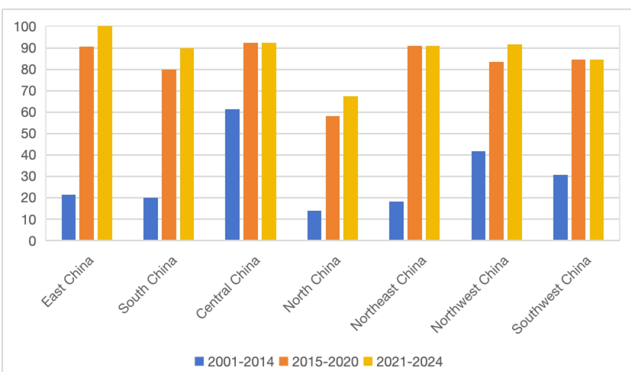

Fig. 3. Cumulative proportion of "Double First-Class" universities that issued technology transfer policy by region and period (2001-2024).

Several key observations emerge regarding the regional distribution of technology transfer policies of "Double First-Class" universities. In the initial diffusion stage, East China and Central China stood out in terms of the absolute number of universities adopting such policies. This pattern can be linked to stronger regional economic development, greater university scientific research capacity, and a higher demand for technology transfer in these areas, fostering an environment conducive to policy adoption. Moreover, universities in these regions, as early adopters, served as key examples and models that facilitated the diffusion of policies to other regions, thereby accelerating the nationwide adoption process. Central China and Northwest China exhibited a higher proportion of universities with technology transfer policies, which can likely be attributed to the relatively smaller number of universities in these regions.

During the rapid growth stage, there was a marked increase in the diffusion of technology transfer policies. Nonetheless, regional differences were evident, with "Double First-Class" universities in East China and North China issuing the highest number of policies, at 38 and 25 respectively. This is to be expected, given that, as hubs of research and education, these regions have established a strong foundation for policy development. Additionally, their well-developed industrial systems and high demand for technological innovation have incentivized universities to actively formulate and implement relevant policies, fostering a dynamic environment for technology transfer.

In terms of proportion, over 90% of "Double First-Class" universities in East China, Central China, and Northeast China had introduced such policies. South China, Northwest China, and Southwest China followed closely behind, with policy issuance exceeding 80%. This surge in adoption reflects the expansion of national scientific and technological innovation strategies and an accelerated effort to implement policies across a broader range of regions. The widespread adoption of policies during this phase highlights the growing institutionalization of technology transfer practices in China, reinforced by a national framework for innovation-driven development.

By the steady development stage, the diffusion of technology transfer policies had reached a high level of saturation across most regions. During this period, universities that had recently introduced technology transfer policies remained predominantly concentrated in East China and North China. Some "Double First-Class" universities in Central China and Northwest China had also started the policy implementation process. This pattern suggests that the adoption of these policies is closely tied to the research capabilities of universities within each region, the specific demands of local economic development, and the density of higher education institutions in the area. As regions with stronger research infrastructures and greater economic needs are more likely to prioritize and implement technology transfer policies, this trend underscores the importance of aligning policy initiatives with regional strengths and developmental goals to maximize their impact.

From the perspective of the final coverage ratio, with the exception of North China and Southwest China, the proportion of "Double First-Class" universities issuing technology transfer across the country had surpassed 90%, indicating significant progress in policy coverage and the maturation of the national policy framework. This phase marks a shift in focus from policy expansion to policy refinement and optimization. Unlike previous stages, the number of new policy issuances declined during this period, particularly in regions that had already achieved high levels of coverage. This decline suggests that most universities with the abundant resources and innovation capacity had already implemented policies in earlier stages, leaving limited room for further increases. Consequently, the emphasis on policy development transitioned from broad coverage to enhancing the depth and quality of policy implementation.

In conclusion, the spatial distribution of technology transfer policies in China's "Double First-Class" universities exhibits clear regional disparities, with a discernible policy diffusion gradient. This pattern reflects the spread of technology transfer policies from economically developed to less-developed regions, progressing from rapid expansion to steady consolidation. The phased nature of policy diffusion underscores the importance of regional coordination in developing technology transfer frameworks, highlighting the need to balance regional disparities to effectively implement national innovation strategies. These findings provide valuable insights into the dynamic nature of policy diffusion, offering strategic guidance for the future innovation and optimization of technology transfer policies across China's higher education institutions.

4.2.2 Provincial distribution of university technology transfer policy diffusion

Table 1 illustrates the cumulative number of universities that have issued technology transfer policies by province during the three stages of diffusion. The data highlights distinct provincial patterns in the adoption of policies, shedding light on the spatial dynamics of policy diffusion.

In the initial diffusion stage, universities primarily located in Jiangsu and Beijing were the first to implement technology transfer policies. These regions, which house a significant number of "Double First-Class" universities, are characterized by substantial scientific research resources and a pressing need to facilitate technology transfer. The relatively high level of economic development in these areas, combined with robust market demand for technological innovation, provided an ideal environment for the early introduction of such policies. Additionally, provinces like Hubei and Shaanxi, which benefit from unique geographic advantages and university clustering effects, also initiated policy adoption during this phase to stimulate local economic development. This distribution pattern indicates that, in the initial stages of policy diffusion, regions with a pronounced need for technology transfer tend to lead the way in policy issuance.

During the rapid growth stage, a notable "neighborhood effect" became apparent, with policy diffusion spreading from core regions such as Beijing to Tianjin, and from Jiangsu to Shanghai, Zhejiang, Shandong, and Anhui. Similarly, the diffusion extended from Hubei and Shaanxi to neighboring regions such as Chongqing, Gansu, Henan, and Shanxi. This pattern suggests that regional collaboration and innovation linkages played a crucial role in accelerating policy adoption. Following the lead of core regions with strong radiative capabilities (e.g., Beijing and Jiangsu), universities in neighboring provinces swiftly implemented similar policies, resulting in a chain reaction of policy diffusion. Moreover, the regional economic transformation and the rising demand for technology transfer in adjacent provinces drove these regions to adopt policies more rapidly. This "neighborhood effect" underscores the spatial dimension of policy diffusion, illustrating a gradual, yet steady, expansion from more developed regions to less developed ones, and highlighting the deepening cooperative learning among universities.

In the steady development stage, the scope of policy adoption expanded further, with universities in regions such as Guangxi and Xinjiang introducing policies related to technology transfer. The broader geographical coverage during this stage reflects the comprehensive advancement of national science and technology innovation strategies and the increasing nationwide implementation of relevant policies. By this stage, universities in core regions, having implemented policies earlier, had provided successful models that institutions in other provinces could emulate, thus reducing uncertainty and fostering confidence in policy adoption. The realization that these policies were essential for standardizing the technology transfer process and stimulating the enthusiasm of researchers led to more widespread implementation. The primary characteristic of this stage is the deep penetration of policies from the central to peripheral regions, ensuring near-total coverage of policy implementation from core to less developed areas.

In summary, the diffusion of technology transfer policies across China's "Double First-Class" universities follows a gradient model characterized by a "neighborhood effect". Initially concentrated in core regions, the policy diffusion spread rapidly to surrounding provinces and later expanded to central, western, and border areas. This process reflects the gradual, spatially expansive nature of policy diffusion and highlights the importance of regional cooperation in strengthening innovation capacities. These findings provide valuable insights into the spatial dynamics of policy diffusion and underscore the significance of targeted policy interventions to optimize regional innovation ecosystems and further refine the national policy landscape.

4.3 Academic disciplines

The adoption of university technology transfer policies is closely linked to the characteristics of different academic disciplines. The nature of research, the types of achievements, and the potential applications of scientific findings within each discipline significantly affect when and how universities implement technology transfer policies. Using the classification method outlined in the China Education Yearbook, to facilitate further analyses, "Double First-Class" universities were categorized into twelve disciplines, allowing the cumulative proportion of universities in each discipline that have adopted such policies at various stages of diffusion to be determined (see Fig. 4).

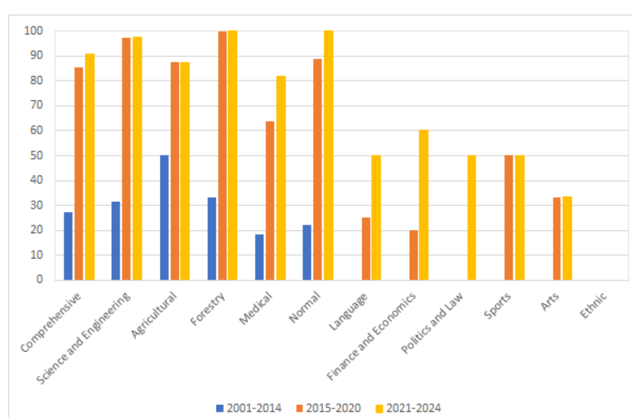

Fig. 4. Cumulative proportion of "Double First-Class" universities that issued technology transfer policies by academic discipline and period (2001-2024).

Table 1. Cumulative number of "Double First-Class" universities that issued technology transfer policies by province and period (2001-2024).

Period	Provinces (Number of Universities)
2001-2014	Jiangsu (7), Beijing (6), Hubei (5), Shaanxi (4), Guangdong (2), Hunan (2), Liaoning (2), Sichuan (2), Chongqing (2), Shanghai (1), Fujian (1), Henan (1), Gansu (1)
2015-2020	Beijing (20), Jiangsu (16), Shanghai (11), Guangdong (7), Shaanxi (7), Sichuan (7), Hubei (6), Heilongjiang (4), Hunan (4), Shandong (3), Zhejiang (3), Liaoning (3), Jilin (3), Fujian (2), Anhui (2), Tianjin (2), Shanxi (2), Henan (2), Chongqing (2), Jiangxi (1), Hainan (1), Neimenggu (1), Gansu (1), Ningxia (1), Xinjiang (1), Yunnan (1), Guizhou (1)
2021-2024	Beijing (23), Jiangsu (16), Shanghai (14), Guangdong (7), Shaanxi (7), Sichuan (7), Hubei (6), Heilongjiang (4), Hunan (4), Shandong (3), Zhejiang (3), Liaoning (3), Jilin (3), Tianjin (3), Fujian (2), Anhui (2), Henan (2), Shanxi (2), Xinjiang (2), Chongqing (2), Jiangxi (1), Hainan (1), Guangxi (1), Neimenggu (1), Gansu (1), Ningxia (1), Yunnan (1), Guizhou (1)

During the initial diffusion phase, although the proportion of comprehensive, or science and engineering universities that issued technology transfer policies, is lower than that of agricultural and forestry universities, they have an absolute numerical advantage, and are the most active in issuing technology transfer policies. This dominance likely reflects the broader range of disciplines and stronger research capabilities typically found in these types of universities. Their research outputs are often more closely aligned with market needs and possess greater potential for commercialization. The implementation of these policies provides institutional support and facilitates successful technology transfer.

In terms of proportion, at 50% and 33%, universities in agricultural and forestry disciplines exhibited the highest policy adoption rates, closely followed by science and engineering, comprehensive, normal, and medical universities. In contrast, institutions specializing in language, finance and economics, politics and law, sports, arts, and ethnic did not issue relevant policies during this stage. This discrepancy may be attributed to the inherently practical and applied nature of research in agricultural and forestry disciplines, where scientific advancements—such as improvements in breeding techniques, agricultural machinery, and ecological conservation—have immediate, direct applications in agriculture and rural economic development. Consequently, these universities recognized the pressing need to promote technology transfer, leading to the early introduction of related policies. Additionally, the smaller number of agricultural and forestry universities contributed to a higher concentration of policy adoption within a shorter timeframe. On the other hand, universities in other disciplines, influenced by factors such as the applicability of their research outputs and the maturity of their scientific findings, exhibited a slower rate of policy adoption.

The rapid growth stage saw the continued dominance of comprehensive and science and engineering universities in technology transfer policy issuance. However, this stage also witnessed significant policy adoption by medical, normal, and agricultural universities. This expansion likely reflects a diversification of demand for technology transfer and a substantial increase in the reliance of various industries and fields on scientific and technological innovation. Consequently, the introduction of these policies became crucial to meeting the growing need for technological advancements across diverse sectors.

In terms of the proportion of adopting institutions within each discipline, universities in forestry and science and engineering disciplines led the way, with 100% and 97% of institutions, respectively, adopting technology transfer policies. Other notable disciplines included normal universities (89%), agricultural universities (88%), and comprehensive universities (85%). Medical universities, however, had a lower adoption rate of 64%. This trend indicates that universities in disciplines characterized by a high demand for technology transfer have not only been quick to adopt policies but have also exerted a strong demonstration effect, thereby accelerating policy diffusion in their respective fields. In parallel, universities in other disciplines began to recognize the importance of technology transfer, resulting in a broader, albeit slower, diffusion of policies.

During the steady development stage, comprehensive and science and engineering universities maintained their leading role, with a cumulative total of 87 institutions implementing technology transfer policies. Medical, normal, and agricultural universities also saw growth, reaching a combined 25 institutions with such policies. Notably, six universities specializing in language, finance and economics, and politics and law introduced these policies, marking an increase from the previous stage. This expansion could be attributed to two factors. First, these specialized universities may have begun exploring the intersection of their disciplinary strengths and societal needs, prompting them to promote technology transfer and, consequently, implement supporting policies. Second, with more established best practices available, these institutions may have adopted such policies through imitation, leveraging the experience of other universities.

In this period, the proportion of universities in disciplines such as forestry, normal education, science and engineering, and comprehensive fields that had adopted technology transfer policies surpassed 90%, with agricultural (88%) and medical (82%) institutions following closely behind. In contrast, universities specializing in language, politics and law, and sports had a policy adoption rate of only 50%. The high adoption rates observed in forestry, science and engineering, and comprehensive universities reflect the substantial market demand and practical applicability of their research outputs. While agricultural and medical universities had a somewhat lower, yet still significant, policy adoption rate, this lag may be attributed to the unique nature of their research outputs and the more complex market pathways for technology transfer. Conversely, universities focused on language, politics and law, and sports, which are less involved in technology transfer, exhibited slower policy adoption.

In summary, the technology transfer policy diffusion processes across China's "Double First-Class" universities reveal clear disciplinary disparities. Science and engineering and comprehensive universities, as key contributors to technological innovation, led significant policy adoption during all stages. Agricultural and forestry universities, driven by the practical applications of their research and the national emphasis on their contributions to rural and ecological development, consistently demonstrated higher rates of policy adoption. Meanwhile, liberal arts disciplines, such as language, politics and law, and sports, lagged due to the relatively lower applicability of their research and the challenges associated with technology transfer in these domains. The gradual narrowing of policy adoption gaps between disciplines reflects an increasing recognition of the importance of technology transfer across all academic fields. These trends underscore the need for additional policy efforts to account for the distinct characteristics and market demands of different disciplines, providing a foundation for more targeted policy guidance in the future.

4.4 University tiers

Categorizing universities by tier offers valuable insights into the factors influencing the adoption of technology transfer policies. Analyzing the relationship between university tier and the timing of policy issuance allows for a more nuanced understanding of the diffusion process. For this study, "Double First-Class" universities are classified into three tiers: "985 Project", "211 Project", and "Non-985/211" universities. Fig. 5 illustrates the policy adoption rates for each tier at different stages of diffusion.

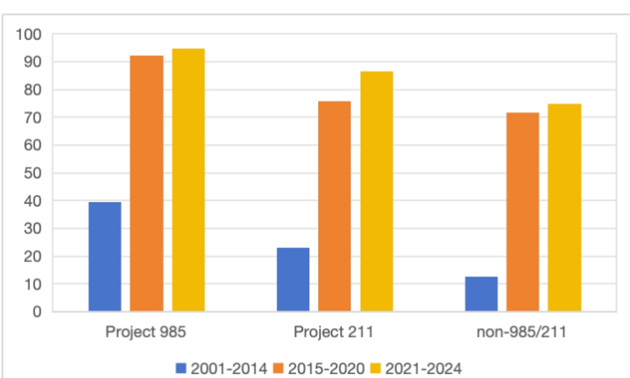

Fig. 5. Cumulative proportion of "Double First-Class" universities that issued technology transfer policies by tier and period (2001-2024).

The initial diffusion stage reveals a clear hierarchical pattern in technology transfer policy adoption. "985 Project" universities led with a 39% adoption rate, followed by "211 Project" universities at 23%, and "Non-985/211" universities with a significantly lower rate of 13%. The higher adoption rate among "985 Project" universities likely reflects their position as leading national research institutions. These universities boast a significant portion of national research resources, attract top talent, and possess substantial original innovation capabilities, creating a pressing need for formalized policies to facilitate technology transfer. "211 Project" universities are less well-resourced and thus tend to adopt policies at a more moderate pace, often following the example set by the "985" institutions. The slower adoption among "Non-985/211" universities likely stems from their more limited research capacity and weaker institutional support for technology transfer.

During the rapid growth stage, technology transfer policy adoption accelerated across all tiers. At 92%, "985 Project" universities achieved near-total coverage. "211 Project" universities saw an increase to 76%, while "Non-985/211" universities reached 72%. This significant expansion narrowed the gap between "211 Project" and "Non-985/211" universities, suggesting a substantial increase in demand for technology transfer across all institutions. "211 Project" universities, benefiting from regional resource integration, and "Non-985/211" universities, recognizing the growing importance of applied research, made significant strides in policy adoption, reducing the lag behind "985 Project" universities.

In the steady development stage, policy adoption reached 95% in "985 Project" universities, 86% in "211 Project" universities, and 75% in "Non-985/211" universities. The rate of increase in policy adoption among "211 Project" universities was notably higher than that of the other two groups, indicating a shift in focus from "elite-driven breakthroughs" to "comprehensive policy coverage". The growing convergence in policy adoption rates suggests an emerging trend toward the coordinated development of universities at different levels.

In summary, the technology transfer policy adoption by "Double First-Class" universities exhibits a clear hierarchical pattern. "985 Project" universities consistently served as pioneers and role models, leading the way in policy implementation. The diffusion process followed a hierarchical structure, with higher-tier universities demonstrating greater demand for, and earlier adoption of, technology transfer policies. Over time, the gap in adoption rates narrowed, reflecting a dynamic progression from "elite leadership" to "inclusive coverage" and indicating a trend toward greater parity in the technology transfer landscape. The evolving roles of universities at different tiers in this process demonstrate a clear trajectory of policy diffusion from top-tier institutions to broader inclusion.

4.5 Competent authorities

The role of competent authorities significantly influences both the direction and resource allocation for university technology transfer policies. To examine this phenomenon further, "Double First-Class" universities were categorized into "Ministry of Education", "Other Ministry", and "Local" universities based on their affiliation. Fig. 6 presents the proportion of

"Double First-Class" universities that issued technology transfer policies for each category at different stages of diffusion.

The distribution of policy adoption across different categories of competent authorities reveals notable trends in the pace and extent of policy adoption. In the initial diffusion stage, universities under the Ministry of Education exhibited the highest proportion of policy adoption, reflecting their central role in national educational and scientific strategies. Universities affiliated with other ministries and local institutions followed with comparatively lower proportions, indicative of their relatively delayed engagement with technology transfer efforts, often due to more sector-specific research needs or resource limitations.

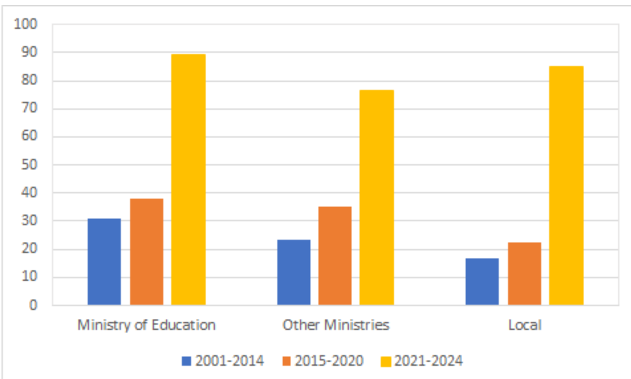

Fig. 6. Cumulative proportion of "Double First-Class" universities that issued technology transfer policies by competent authority and period (2001-2024).

During the rapid growth stage, a narrowing gap between the proportion of policy issuances by universities under the Ministry of Education and those under other ministries was observed. This convergence reflects the increasing scientific and technological achievements in ministries such as Industry and Information Technology, Transport, and others, where universities' research agendas are tightly aligned with specific industrial and technological priorities. In contrast, local universities continued to exhibit a relatively slower adoption rate, likely due to their focus on regional development and the challenges encountered in technology transfer.

By the steady development stage, the policy adoption rates across the three categories of universities began to converge more significantly. While universities under the Ministry of Education maintained a higher adoption rate, local universities surpassed those under other ministries in policy issuance. This shift indicates the broader diffusion of technology transfer policies, driven by national strategies aimed at fostering innovation across all regions and university types. Local universities increasingly embraced these policies, further emphasizing the policy's reach and the broader institutional commitment to technology transfer.

These findings suggest that the diffusion of technology transfer policies in China has progressively expanded from a central focus on leading national universities to a more balanced representation of universities from various sectors and regions. This trend reflects a gradual shift from a centralized policy model toward a more inclusive and regionally coordinated framework, underscoring the evolving role of different competent authorities in shaping the trajectory of technology transfer across higher education institutions.

5. Conclusion and discussion

This study investigated the diffusion of technology transfer policies across "Double First-Class" universities by analyzing its temporal and spatial dynamics. Temporally, the diffusion follows an S-shaped curve, progressing through three distinct stages: the initial diffusion stage (2001-2014), the rapid growth stage (2015-2020), and the steady development stage (2021-2024), reflecting a classic evolutionary trajectory. Spatially, policy adoption reveals significant regional disparities, exhibiting a "neighborhood effect" that starts from core regions and spreads outward to surrounding provinces, ultimately reaching more distant areas, forming a "gradient" diffusion pattern that results in broad coverage.

To gain a more comprehensive insight into these processes, variations in policy adoption across universities—categorized by discipline, tier, and competent authority—were explored. Universities with highly applicable research and strong demand for technology transfer were found to adopt policies at higher rates. A hierarchical pattern emerged across university tiers, with higher-level institutions leading the way and policy adoption cascading down to lower-tier institutions. Universities under the Ministry of Education played a key demonstrative role, with policy diffusion moving toward more balanced and comprehensive coverage across all university categories.

Based on these findings, several recommendations can be made to further promote the diffusion of technology transfer policies in China. Firstly, during the initial diffusion and rapid growth stages, emphasis should be placed on demonstrating successful models and providing guidance to facilitate broader policy adoption. Replicable and scalable models should be developed based on the experiences of pilot universities. In the steady development stage, a long-term mechanism should be established to integrate these policies into routine university management, including regular revaluation of policy, shifting from short-term incentives to sustainable practices.

Secondly, policy support and resource sharing should be strategically employed to foster regional collaboration. Universities in developed regions are encouraged to share best practices and resources with those in less-developed regions to promote cross-regional diffusion and ensure more equitable development across the national higher education system.

Thirdly, recognizing the diverse characteristics and needs of different university types, policies should be tailored to specific institutional contexts. A stratified approach to policy implementation, considering the unique circumstances of each institution, is thus essential. Collaborative initiatives among universities in different disciplines should be strengthened. Interdisciplinary platforms for technology transfer should be encouraged, particularly among agricultural, forestry, and science and engineering universities. Greater attention may be given to disciplines like language and sports, where commercialization potential remains largely untapped, but can be considerably enhanced through targeted funding, market development initiatives, and specialized training.

Given the inherent disparities in resources and achievements among "Double First-Class" universities, differentiated policy support is needed. Performance evaluation criteria should be adapted to the specific context of each university, avoiding a one-size-fits-all approach to ensure fairness and effectiveness, especially in resource-constrained environments. Pilot programs should be conducted across diverse university types, including representatives from universities under the Ministry of Education, universities under other ministries, and local universities. These programs can explore innovative policy models that, if successful, can be scaled up. Local universities, in particular, should receive increased support and policy focus to better serve regional economic development and contribute to local innovation ecosystems.

In conclusion, the diffusion of technology transfer policies across "Double First-Class" universities is a dynamic, stage-driven process influenced by temporal, spatial, and institutional factors. A more regionally coordinated, discipline-focused, and context-specific approach to policy dissemination can enhance its effectiveness, promoting the broader goal of technology transfer and contributing to national economic and technological advancement.

Acknowledgments

This work was financially supported by Beijing Social Science Fund Decision-making Consulting Project "Research on the Collaborative Development Model and Promotion Mechanism of 'Government-University-Industry-Firm-Society' for University Technology Transfer in Beijing" (No. 22JCC078)

Conflict of interest

The author declares no conflict of interest.

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