Pak. j. life soc. Sci. (2024), 22(2):13555-13576 E-ISSN: 2221-7630;P-ISSN: 1727-4915

Pakistan Journal of Life and Social Sciences
www.pjlss.edu.pk

https://doi.org/10.57239/PJLSS-2024-22.2.00971

RESEARCH ARTICLE

Determinants and Transformation Paths of Scientific Research Commercialization in Yangtze River Delta

Zhang Yuxin*

Department of Curriculum and Instructional Technology, Faculty of Education, University of Malaya, 50603 Kuala Lumpur, Malaysia

ARTICLE INFO

Received: Oct 5, 2024

Accepted: Nov 17, 2024

Keywords

Yangtze River Delta

Scientific Research

Commercialization

Dynamic QCA

Higher Education

***Corresponding Author:**

yuxin.922@outlook.com

ABSTRACT

The commercialization of scientific research refers to the process where university research is applied by companies, leading to marketable outcomes. In the Yangtze River Delta, this commercialization has encouraged regional innovation clusters. However, it has also created technological and economic disparities between areas closer to research hubs and those farther away. This study develops a framework using interface theory and dynamic Qualitative Comparative Analysis (QCA) based on panel data from 2013 to 2022. The purpose is to examine how economic development, policy support, and innovation resources interact in this process. The findings show that no single factor is sufficient for successful commercialization. Instead, factors like regional economic development, research incentives, innovation capacity, and talent reserves are all necessary. The study identifies three main pathways: (1) an economic integration and innovation resource-driven model, (2) a school-enterprise and research collaboration model, and (3) a government support-absent model. These pathways highlight different ways in which scientific research is commercialized in the Yangtze River Delta. Events like industrial restructuring and policy reforms in 2016, as well as the COVID-19 pandemic from 2020 to 2022, disrupted these pathways, impacting their consistency. This research provides policymakers with insights into the value of regional integration and the synergy of innovation resources to boost scientific research commercialization.

1. INTRODUCTION

In the context of a rapidly expanding global knowledge economy, the commercialization of scientific and technological achievements has become a key indicator of national and regional innovation capacity. The transformation process involves the application of basic research from universities, developed by companies, into real-world technologies and products with economic value (Song & Zhu, 2022). This transformation includes technology licensing, contract research, industrial clustering, open innovation, and academic entrepreneurship (M. Perkmann et al., 2021). In China, the "Law on Promoting the Transformation of Scientific and Technological Achievements" outlines multiple pathways for this process, including self-investment, technology transfer, licensing, and equity investment, which promote the commercialization and clustering of scientific and technology sectors. However, this approach has led to regional disparities in innovation capacity.

The commercialization process is complex and multi-stage, involving the progression from basic research to applied development and, finally, to market introduction. It relies on the coordinated efforts of universities, companies, and government agencies (J. Guo et al., 2023). Universities provide theoretical and technical foundations, companies develop these into marketable products, and government agencies facilitate the process through policies and financial incentives. These policies not only support industry-university cooperation, but also foster economic integration, thereby enhancing the utilization of research resources and driving commercialization efforts. Through increased patenting, technology transfer, and product commercialization, these collaborations help to expand the impact of scientific research.

Collaboration and clustering effects are crucial to this transformation. The triple helix model demonstrates the effective cooperation of government, academia, and industry in promoting technological innovation (Etzkowitz & Leydesdorff, 2000). Some examples include Silicon Valley, which benefits from close ties with Stanford University (R. Smilor et al., 2007), and Taiwan's Hsinchu Science Park, which collaborates with local universities to drive semiconductor innovation (Hu, 2011). In China, Shenzhen's open policies and investments in higher education have turned it into a technology hub (W.M. To et al., 2021). These cases highlight how collaborative efforts can create thriving innovation clusters that support economic growth.

The Yangtze River Delta, one of China's core innovation regions, demonstrates similar clustering effects. Cities like Shanghai, Hangzhou, and Suzhou, backed by universities such as Fudan University and Zhejiang University, are leaders in producing and commercializing scientific achievements. Under the Yangtze River Delta integration strategy, regional collaboration with businesses has accelerated the application of research outputs, driving economic development and high-quality growth (Z. Li, 2023a). This synergy is achieved through policy-driven investments and the stimulation of enterprise growth by university-driven innovations, forming a regional network for scientific and technological transformation.

Despite these successes, the concentration of technological resources in select cities has intensified the regional imbalance in technological and economic development. Southern cities, such as Shanghai, Hangzhou, and Suzhou, excel in research transformation and patent implementation, while northern areas face slower transformation rates. For example, university patents in the region have a commercialization rate of only 3.9% compared to 48.1% for enterprise patents (China National Intellectual Property Administration, 2023). This suggests that policy alone cannot bridge these regional disparities. Therefore, further research is needed to identify the factors and dynamics driving balanced development across provinces.

This disparity is not unique to the Yangtze River Delta but is a global phenomenon, prompting researchers to examine factors influencing the commercialization process and regional differences in innovation capacity. Scholars have proposed framework such as the "internal-external environment" to analyze obstacles to transformation, identifying key issues like uneven resource allocation, limited collaboration, and low transformation rates (J. Su et al., 2021; Y. Huang, 2022; J. Zhang, 2019; Z. Li, 2023b; Jinabhai, 2022). While evaluation methods such as Principal Component Analysis (PCA), Data Envelopment Analysis (DEA), and Structural Equation Modeling (SEM) are commonly used, these approaches have limitations in capturing the dynamic, multi-factor nature of the transformation process (J. Jiang et al., 2020; Wu, 2023; J. Guo et al., 2023; V. Mittal et al., 1998; Woodside & Zhang, 2013).

To address these limitations, this study applies a dynamic Qualitative Comparative Analysis (QCA) method. Using panel data, this study aims to explore causal pathways and temporal effects in the commercialization of scientific research. This study integrates interface theory with an analytical framework of economic development, policy support, and innovation resources. This study investigates how economic integration, policy support, and innovation resource coordination drive commercialization and answers the following research questions:

RQ1: What factors drive the commercialization of scientific research in the Yangtze River Delta over time?

RQ2: How do these factors exhibit temporal effects?

RQ3: Are there equivalent effects in factor combinations influencing research transformation?

RQ4: Does provincial consistency in factor configurations vary across regions?

2. LITERATURE REVIEW

Scientific and technological achievements, as products of knowledge creation, possess significant academic and economic value, serving as essential outputs of technological innovation (L. Zhang & H. Jiang, 2022). Over the years, the transformation of these achievements through academic publications, patents, and research projects has accelerated innovation and fostered economic growth (X. Hu et al., 2023; Mansfield, 1991). This transformation not only enhances the competitiveness of higher education, but also advances technological innovation, making it a critical component of regional development (Sterzi, 2013; Agrawal & Henderson, 2002).

The production and transformation of scientific achievements in universities are influenced by both internal and external factors. Previous studies indicate that school-enterprise collaboration positively affects universities' output of technological achievements (Lee, 2008; Ortega, 2011; Lee, 2009; Wang, 2007). However, different organizations' contributions to science and technology yield varied outcomes, influenced by policy and resource allocation (Y. Sun et al., 2020). Internally, factors such as research funding, researcher capabilities, and project scale are crucial determinants of the output of scientific achievements (R. P. O'Shea et al. 2007). Crucially, Y. -G. Lee et al., (2007) identified that research investment emerges as the most critical factor in fostering impactful technological outputs, especially when aligned with researcher efforts and institutional support (R. Griffith et al., 2004; Bush, 2021).

Thus, the transformation of scientific achievements in universities is a product of both internal capacities and external influences. Internally, university research strategies, talent integration, and resource management play key roles, while external policies and industry partnerships further enhance transformation outcomes. This study investigates these dimensions within the framework of regional integration, assessing the internal and external factors that drive effective scientific achievement transformation.

2.1. Interface theory

Interface theory, initially rooted in engineering, evolved to address business and economics by examining interactions within and across organizational boundaries (Vicente & Rasmussen, 1992). Applied to technology transfer, interface theory highlights the technology transfer interface as a convergence point where knowledge producers and users interact (Etzkowitz & Leydesdorff, 2000). In this context, the interface functions to buffer and selectively filter interactions between organizations, preserving the independence of each system while facilitating knowledge transfer. The transformation process in higher education, from research to commercialization, relies on this interface, which connects universities, industries, and governments to support innovation transfer (Aliyev & Shahverdiyeva, 2017). This interaction reflects both internal organizational functions and external market demands, impacting the goals and outcomes of scientific and technological transformation (Simon, 2019).

2.2. Internal dimension

Within the Yangtze River Delta, the internal dimension of scientific achievements transformation focuses on optimizing the resources within universities to enhance transformation rates. Based on interface theory, internal factors such as talent reserves, funding, and research networks play crucial roles. Studies show that the innovation levels of researchers and the quality of internal research cooperation significantly impact transformation outcomes (Y. Wu et al., 2015; X. Gao et al., 2014). For instance, adequate funding and collaborative networks support knowledge transfer from universities to enterprises, enhancing the practical application of research (R. Belderbos et al., 2004). However, some studies also suggest that increased R&D investment does not always lead to proportional improvements in transformation efficiency (W. Zhong et al., 2011; Liu & Jiang, 2001). Therefore, the internal dimension of higher education transformation includes balancing talent, financial resources, and collaborative efforts to maximize impact.

2.3. External dimension

The external dimension involves the environment in which universities interact with economic production entities, relying on policy and resource support from the government and industry.

Interface theory posits that scientific achievements serve as connections between knowledge and economic systems, with policy and resource allocations shaping transformation potential (Ponomariov & Boardman, 2010; Dorf & Worthington, 1990; Corsten, 1987). External support, including government funding and corporate investment, plays a significant role in facilitating technology transfer and innovation. For instance, policy incentives and regional economic development levels have been shown to positively influence transformation rates (S. Liu, 2022; Grillo, 2011). While the comprehensive integration of these factors' direct impact on transformation efficiency is still under study, external resources are recognized as essential for technological achievements to reach commercialization stages, adapting as marketing and environmental conditions evolve (J. Han, 2012)

2.4. Functions and goals

Scientific and technological achievements within higher education serve dual functions, they act as public knowledge and technical knowledge with property rights (Aman, 2017). Patents and licensing revenue are direct indicators of successful transformation, reflecting universities' ability to turn knowledge into economically valuable outputs (Geuna & Rossi, 2011). However, the transformation process is often hindered by information asymmetry and market fluctuations, which can result in inefficiencies. By establishing clear roles and responsibilities within the interface, universities can mitigate these risks, ensuring smoother transfer and application of scientific achievements to industry (Y. Wu et al., 2015).

2.5. Regional integration perspective

Regional integration emphasizes the synergy among different stakeholders, balancing economic, social and technological needs within the region (Y. Liu et al., 2019). In the Yangtze River Delta, regional integration is achieved through dynamic cooperation between governments, universities, and enterprises, each contributing unique resources to the transformation process (A. L. Rossoni et al., 2023). Regional economic development and school-enterprise collaboration drive market demand and the dissemination of scientific achievements, creating favorable conditions for technology transfer (M. Perkmann et al., 2013). Government support, through policies and incentives, is a crucial factor in accelerating transformation, while research incentives at the university level further encourage knowledge transfer by motivating researchers (P. Azoulay et al., 2011).

In this study, regional integration is analyzed across three core perspectives, economic integration, policy integration, and innovation resource integration. Economic integration considers regional development levels and the impact of school-enterprise cooperation. Policy integration reflects government support and research incentives, while innovation resource integration includes research networks, talent reserves, and innovation levels. These dimensions form a comprehensive framework for analyzing the drivers of scientific achievement transformation and are used to build configuration pathways in this study (*Figure 1*).

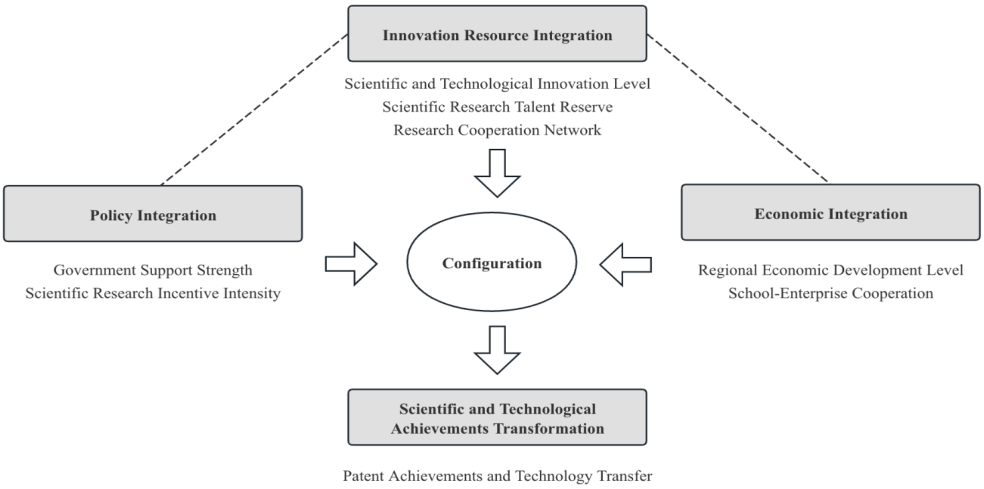

Figure 1: Influencing factor in analytical framework

3. DATA AND METHODOLOGY

3.1. Methodology

This study employs dynamic Qualitative Comparative Analysis (QCA) to evaluate the combined effects of various factors on the transformation of scientific and technological achievements in higher education within the Yangtze River Delta's regional integration framework. Dynamic QCA enables the analysis of changes over time by measuring inter-group, intra-group, and overall dimensions, capturing fluctuations in consistency across time and cases through consistency distance. To enhance the accuracy of this analysis, panel data is integrated with dynamic QCA using R software, which mitigates limitations related to the time dimension inherent in both panel data and QCA methodologies. Besides, Enhanced Standard Analysis (ESA) is applied within QCA to improve the precision of identified configurations.

Incorporating the time dimension reveals how factors such as policy, economic development, and innovation resource allocation interact over time, forming synergies that affect the transformation rate of scientific research achievements. This approach also allows the study to examine the multidimensional and interactive effects of these factors on regional innovation capacity, providing insights into the mechanisms behind technological innovation disparities across regions.

3.2. Sample and data

Given the data availability and completeness, this study uses panel data from the Yangtze River Delta region of China, spanning 2013 to 2022. Data on both outcome and conditional variables were sourced primarily from official statistical yearbooks. Specifically, regional economic development levels data were obtained from the China Statistical Yearbook, while indicators for school-enterprise cooperation, government support, research incentives, innovation levels, talent reserves, and cooperation networks were collected from the Compilation of Scientific and Technological Statistical Data of Higher Education Institutions. The outcome variables were represented by the income generated from patent sales and technology transfer by universities in each province and city, sourced from the same compilation. This study focuses on Shanghai, Anhui, Jiangsu, and Zhejiang, providing a comprehensive view of the Yangtze River Delta.

3.2.1. Measurement

For outcome variables, this study measures the transformation of scientific and technological achievements in universities using two financial indicators: annual income from patent sales (in thousand yuan) and technology transfer revenue (in thousand yuan). These metrics provide a direct reflection of the commercialization level of scientific achievements, illustrating the financial benefits derived from the transformation process. Previous research supports the use of patent licensing income and technology transfer revenue as effective indicators of technological transformation, as they encapsulate the economic value generated through university research outputs (D. S. Siegel et al., 2003).

In terms of condition variables, this study examines factors across three primary dimensions: economic integration, policy integration, and innovation resource integration. Each dimension includes specific indicators that reflect the conditions influencing scientific and technological transformation in the Yangtze River Delta regions.

Economic integration is represented by regional economic development levels and the strength of school-enterprise cooperation. To capture regional economic development, this study uses the GDP of each province and city within the Yangtze River Delta, which offers a measure of the broader economic environment impacting universities during the transformation process. School-enterprise cooperation is gauged by the ratio of enterprise-entrusted funds to total university funds. This ratio indicates the extent of collaboration between universities and industry, as such partnerships are known to facilitate the commercialization of innovative technologies and provide businesses with access to new technological solutions (Ankrah & AL-Tabbaa, 2015).

Policy integration is measured through indicators of government support strength and research incentive intensity. Government support is calculated as the ratio of government-allocated funds to total university research funding, reflecting the degree of public investment in higher education research activities. Such support is critical, as government funding often serves as a foundational source for university research and collaborative projects (J. A. Douglass et al., 2018). Research incentive intensity, on the other hand, is measured by the ratio of labor costs to total university expenditures, based on the premise that higher labor expenses contribute to motivating researchers, thereby enhancing engagement in research activities that support technological transformation (A. Suominen et al., 2021).

Innovation resource integration includes variables such as scientific and technological innovation levels, scientific research talent reserves, and research cooperation networks. The level of scientific and technological innovation is considered foundational to the transformation process and is measured through the number of scientific projects, academic publications, and patents produced by universities (D. Ren et al., 2017; Y. Han, 2016). Higher levels of innovation output are typically indicative of more advanced scientific activity within the institution. Talent reserves are measured by the number of full-time R&D personnel, acknowledging that human capital is a central driver of competitiveness and effective scientific transformation (Rahman, 2022). Finally, research cooperation networks are evaluated based on the number of participants involved in collaborative research projects within universities, indicating the extent of external engagement and partnership, which further supports the transformation of scientific achievements (L. Li et al., 2024). *Table 1* presents a detailed summary of these variables and their respective indicators.

Table 1: Definition of variables and calculation method

Variable type	**Variable name**		**Variable definition**	**Symbols**
Condition variables	Economic integration	Regional economic development level	Gross domestic product of each region (100 million yuan)	A
		School-enterprise cooperation	Ratio of entrusted funds of enterprises and institutions to total scientific and technological funds allocated	B
	Policy integration	Government support strength	The ratio of government funds allocated to the total science and technology funds allocated	C
		Research incentive intensity	The ratio of labor cost to total expenditure in colleges and universities	D
	Innovation resources integration	Scientific and technological innovation level	The sum of the total number of scientific and technological projects, academic papers and patent grants (item)	E
		Scientific research talent reserve	Research and development full-time personnel (person)	G
		Research cooperation network	Acceptance of cooperative research (person-times)	H
Outcome variable	Scientific and technological achievements transformation	Patent achievements and technology transfer	Average value of actual income in the year of patent output and technology transfer (thousand yuan)	Y

3.2.2 Data calibration

Data calibration is essential in the dynamic QCA method as it involves transforming variables into sets based on selected anchor points. This study employs direct calibration, referencing established theories and previous research to set calibration thresholds for consistency and coverage analysis within, between, and pooled groups. Three calibration thresholds were set at the 95% quantile (full membership point), 50% quantile (crossover point), and 5% quantile (not full-membership point) of the sample data. To avoid the fuzzy set membership score of 0.5, which could hinder case categorization, all scores below 1 were adjusted by adding 0.001, following the approach of Fiss (2011). This adjustment maintains relative consistency in membership scores between cases.

To enhance calibration accuracy and consistency, each variable underwent detailed descriptive statistical analysis, which informed the setting of calibration anchor points. This calibration approach standardizes variables within the economic integration (regional economic development levels, school-enterprise cooperation), policy integration (government support strength, research incentive intensity), and innovation resource integration (scientific and technological innovation levels, talent reserves, research cooperation networks) dimensions for the Yangtze River Delta. These calibrated data lay the foundation for the subsequent dynamic QCA analysis. Calibration results are shown in *Table 2*.

Table 2: Calibrations statistics

Variables			**Calibration**		
			Fully in	**Crossover**	**Fully out**
Condition variables	Economic integration	Regional economic development level	103401.24	43087.01	21769.68
		School-enterprise cooperation	0.41	0.24	0.11
	Policy integration	Government support strength	0.78	0.65	0.52
		Research incentive intensity	0.79	0.71	0.60
	Innovation resources integration	Scientific and technological innovation level	223783.5	98683	47137.35
		Scientific research talent reserve	501	270	134.8
		Research cooperation network	32830.55	19873	10705.35
Outcome variable	Scientific and technological achievements transformation	Patent achievements and technology transfer	351441.55	123288.5	33059.93

4. DATA ANALYSIS AND EMPIRICAL RESULTS

4.1. Necessary conditions analysis

In dynamic QCA analysis, the first step is often to identify which antecedent variables serve as necessary conditions for successful commercialization outcomes. Necessary conditions are critical factors that must be present for high commercialization outcomes to occur, though their presence alone does not guarantee the result (X. Xie et al., 2024). If a necessary condition is absent, the outcome will consistently fail to occur (Rihoux, B., & Ragin, C, 2009). When a necessary condition is identified, it implies that the antecedent variable is indispensable in the model for understanding successful transformation paths.

Dynamic QCA uses consistency and coverage to evaluate the strength of the causal relationship between antecedent variables and the outcome (P. Carmona et al., 2023). Consistency reflects the theoretical relevance of the relationship, while coverage indicates the proportion of cases where this relationship holds. A variable is deemed a necessary condition if its consistency level exceeds 0.9, which is the threshold for considering a condition as necessary for the outcome (Zhao & Li, 2023). In panel data analysis within QCA, if the adjusted distance between groups is less than 0.2, the pooled consistency can be considered reliable for judgment (X. Fan et al., 2023). Conversely, when the adjusted distance exceeds 0.2, further investigation is required to determine the condition's stability as a necessary factor.

This study aims to explore the key conditions promoting high levels of scientific research commercialization within the Yangtze River Delta, focusing on the 'high conditions-high results' model. As indicated in *Table 3*, most antecedent variables in this analysis have adjusted distances exceeding 0.2, and none exhibit pooled consistency values above 0.9. The only condition with an adjusted distance below 0.2 is condition B (school-enterprise cooperation), but its pooled consistency still falls below the 0.9 threshold, suggesting it does not qualify as a necessary condition for commercialization.

Table 3: Results of univariate analysis of necessary conditions

Condition variables	**High-scientific and technological achievements transformation in higher education**				**Low-scientific and technological achievements transformation in higher education**			
	Pooled Consistency	**Pooled Coverage**	**Between consistency**	**Within consistency**	**Pooled Consistency**	**Pooled Coverage**	**Between consistency**	**Within consistency**
A	0.771	0.733	0.258	0.652	0.455	0.509	0.349	0.775
~A	0.483	0.43	0.371	0.707	0.761	0.796	0.160	0.299
B	0.782	0.725	0.156	0.482	0.528	0.575	0.265	0.698
~B	0.542	0.494	0.185	0.652	0.748	0.801	0.287	0.400
C	0.509	0.456	0.207	0.800	0.72	0.758	0.211	0.575
~C	0.731	0.69	0.214	0.652	0.484	0.536	0.302	0.865
D	0.611	0.597	0.356	0.698	0.59	0.678	0.124	0.572
~D	0.671	0.582	0.338	0.509	0.649	0.662	0.185	0.592
E	0.844	0.836	0.214	0.523	0.425	0.495	0.222	0.781
~E	0.49	0.421	0.432	0.630	0.859	0.866	0.087	0.156
G	0.763	0.791	0.265	0.542	0.427	0.52	0.342	0.841

~G	0.537	0.444	0.516	0.602	0.828	0.804	0.182	0.320
H	0.757	0.684	0.262	0.545	0.511	0.542	0.385	0.833
~H	0.492	0.462	0.316	0.739	0.702	0.773	0.240	0.622

When the adjusted distance exceeds 0.2, additional checks are needed, including yearly consistency exceeding 0.9, coverage above 0.5, and whether the data points concentrate on the right side of the y-axis (Schneider & Wagemann, 2012). As seen in *Table 4*, conditions such as High C (Government support strength) and High D (Research incentive intensity) do not achieve yearly consistency levels above 0.9, indicating they are not necessary for commercialization outcomes. *Figure 2* shows that conditions High A (Regional economic development level), High E (Scientific and technological innovation level), High G (Scientific research talent reserve), and High H (Research cooperation network) are concentrated on the right side of the y-axis (between 0.7 and 1) but do not meet the 0.9 consistency threshold, further confirming their lack of necessity.

Table 4: ***Changes in between group consistency***

Cause and effect combination		**Year**									
		2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
High A	Between consistency adjusted distance	0.432	0.557	0.64	0.962	0.99	0.85	0.724	0.879	0.879	0.849
High C		0.692	0.59	0.507	0.49	0.561	0.544	0.602	0.397	0.446	0.369
High D		0.504	0.258	0.297	0.547	0.526	0.653	0.685	0.676	0.798	0.799
High E		0.582	0.625	0.616	0.961	0.99	0.92	0.868	0.99	0.939	0.903
High G		0.539	0.493	0.554	0.981	0.896	0.693	0.792	0.99	0.837	0.856
High H		0.937	0.887	0.951	0.99	0.896	0.762	0.888	0.82	0.479	0.44

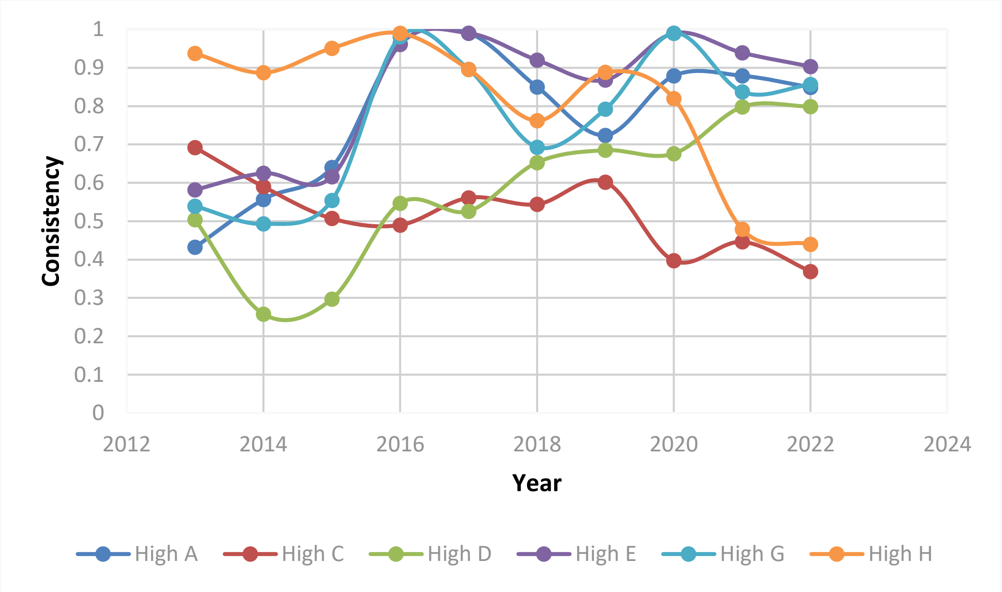

Figure 2: Changes in between consistency

4.2. Sufficient condition analysis and conformational results

Configuration analysis, the core of QCA, aims to examine how combinations of different antecedent conditions influence outcomes. The standard for sufficiency is the consistency level, which Schneider, C & Wagemann, C. (2012) suggest should not be lower than 0.75. Prior to sufficiency analysis, it is necessary to determine the consistency threshold and frequency threshold (T. Greckhamer et al., 2018). For small to medium-sized samples, the frequency threshold could be set to 1, while for large samples, it should be greater than 1. Based on previous studies and the specific context of this study, this study set the consistency threshold at 0.9, the frequency threshold at 2, and the PRI threshold at 0.75 (S. Zhang et al., 2023). After constructing the truth table, enhanced standard analysis (ESA) is used to exclude contradictory simplification assumptions from counterfactual analysis. Considering China's vast territory and significant provincial resource differences, it is difficult to uniformly judge the impact of antecedent conditions on outcomes. Thus, this study does not presuppose the direction and instead considers both the presence or absence of conditions. Finally, the enhanced simple solution, intermediate solution, and complex solution are obtained. This strategy helps precisely analyze the synergistic effects of various factors in enhancing scientific and technological achievements transformation within the Yangtze River Delta integration. The study primarily focuses on the enhanced intermediate solution, supplemented by the enhanced simple solution, to identify core and edge conditions.

4.2.1. Pooled results

Table 5 presents the pooled configuration analysis results. Three configurations (Pathway 1, Pathway 2, and Pathway 3) emerge as sufficient for achieving high levels of scientific research commercialization in the Yangtze River Delta. The overall consistency is 0.912 (greater than 0.75), and the overall coverage is 0.621, indicating that these configurations provide a reliable and comprehensive explanation of the transformation process. The consistency of individual configurations and overall consistency are both greater than 0.8. The within-group consistency distance and between-group consistency distance for individual configurations are all below 0.2, indicating that the overall consistency has strong explanatory power. Based on this, the configurations are less affected by time and spatial factors, and all configurations can sufficiently explain the outcomes.

Table 5: Antecedent condition configurations for scientific and technological achievements transformation in higher education

Condition variable		**Configuration /Pathway 1**	**Configuration /Pathway 2**	**Configuration /Pathway 3**
Economic integration	Regional economic development level （A）	●	●	●
	School-enterprise cooperation（B）	ⓧ	●	
Policy integration	Government support strength（C）		ⓧ	ⓧ
	Scientific research incentive intensity （D）		ⓧ	
Innovation resources integration	Scientific and technological innovation level （E）	●		●
	Scientific research talent reserve（G）	●		●
	Research cooperation network （H）		●	ⓧ
Consistency		0.892	0.946	0.964
PRI		0.683	0.904	0.891
Original coverage		0.310	0.441	0.297
Unique coverage		0.086	0.217	0.030
Consistency distance between groups		0.024	0.029	0.01
Consistency distance within groups		0.13	0.017	0.063
Overall PRI		0.845		
Overall consistency		0.912		
Overall coverage		0.621		
Note：●ⓧ indicates that the core condition appears and does not appear; ⓧ indicates that the marginal condition does not occur; A space indicates that the condition is irrelevant (i.e., it may or may not occur)				

Configuration 1 (Pathway 1) combines regional economic development (A), scientific and technological innovation level (E), and scientific research talent reserve (G). This pathway has a consistency score of 0.892 and an original coverage of 0.310. The high consistency suggests that this combination reliably supports commercialization outcomes, while the coverage indicates that it applies to a substantial proportion of cases. The absence of school-enterprise cooperation (B) in this configuration implies that, in economically robust regions with high innovation and talent reserves, formal partnerships with enterprises may be less critical. For example, Shanghai, as a financial and technological hub, relies more on market-driven innovation rather than highly structured academic partnerships (Zhang & Wu, 2012). This pathway reflects a model where a strong economic base, innovation capabilities, and a rich talent pool create a self-sustaining environment for commercialization, allowing these regions to be less dependent on structured collaborations.

Configuration 2 (Pathway 1) includes regional economic development level (A), school-enterprise cooperation (B), and research cooperation network (H) as core conditions, while government support (C) is a core missing condition and scientific research incentive intensity (D) is a marginal missing condition. This configuration has a high consistency of 0.946 and original coverage of 0.441, indicating both strong reliability and broad applicability in explaining successful commercialization. The results show that when regional economic strength, school-enterprise cooperation, and research networks are in place, the absence of government support does not hinder the commercialization process. In other words, a combination of economic resources and collaborative networks can compensate for the lack of government support, allowing for effective commercialization. This pathway is notably evident in regions like Jiangsu and Zhejiang. For instance, Jiangsu promotes school-enterprise cooperation through initiatives like the Suzhou Industrial Park, where universities and private enterprises collaborate on research projects (Yang, 2023). Similarly, Zhejiang's digital innovation ecosystem benefits from close cooperation between academic institutions and the private sector, particularly in e-commerce and smart manufacturing (L. Ma et al., 2019). This pathway reflects a market-driven model where close cooperation between enterprises and research institutions facilitates research application and commercialization without the need for direct government intervention.

Configuration 3 (Pathway 3) involves regional economic development level (A), scientific and technological innovation level (E), and scientific research talent reserve (G) as core conditions, with government support (C) as a core missing condition and research cooperation network (H) as a peripheral missing condition. This pathway achieves the highest consistency at 0.964, with an original coverage of 0.297, making it the most reliable predictor of successful commercialization outcomes, albeit with narrower applicability. This pathway highlights a model where strong economic development, innovation, and talent reserves are sufficient for commercialization, even without government support or extensive research networks. The peripheral absence of research cooperation network (H) suggests that collaboration among research institutions may be less necessary when regional resources are substantial, indicating that local talent and innovation capabilities can independently drive successful commercialization outcomes. Zhejiang and Shanghai stand out in this configuration. For instance, Shanghai boasts a strong innovation infrastructure and talent resources in fields such as biotechnology, artificial intelligence, and advanced manufacturing, creating a self-sustaining innovation ecosystem (S. L. Sun et al., 2019). Similarly, Zhejiang excels in the digital economy and innovative tech startups, driven by a highly skilled workforce and a conducive innovation environment.

In summary, the pooled results reveal multiple viable pathways to commercialization, highlighting the importance of regional economic development level (A) across all configurations. This emphasizes the foundational role of a strong economic base in supporting research commercialization. Furthermore, government support (C) appears as a core missing condition in two pathways, demonstrating that successful commercialization can be achieved in a market-driven environment without direct government involvement when other conditions, such as partnerships or local resources, are sufficiently robust.

4.2.2. Between results

In the between-group analysis, each configuration is assessed across different regions within the Yangtze River Delta to determine the stability and applicability of these pathways across varied contexts. As shown in *Table 5*, the between-group consistency distances of the three configurations are all below 0.2, indicating no significant time effects. The consistency across clusters is visually represented in *Figures 3, 4, and 5* for Configurations 1, 2, and 3, respectively.

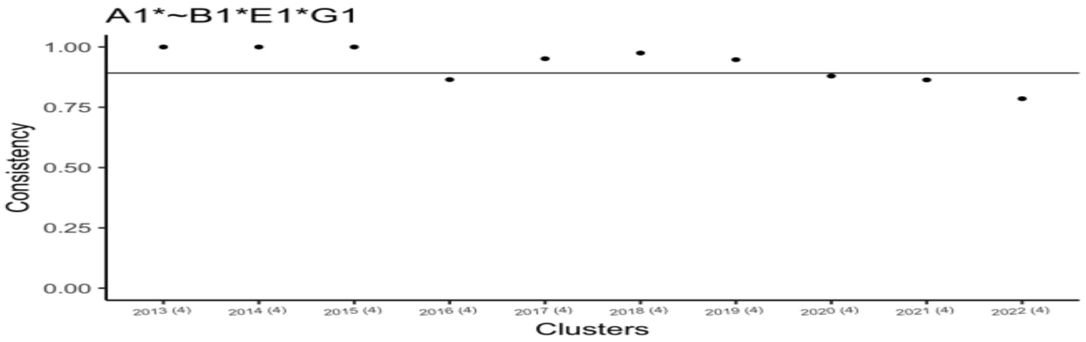

Figure 3: Configuration 1

Configuration 1 (*Figure 3*), which includes regional economic development (A), scientific and technological innovation (E), and scientific research talent reserve (G) as core conditions (with the absence of school-enterprise cooperation (B)), generally maintains high consistency across clusters, remaining above the 0.75 threshold throughout most of the period.

However, there is a slight dip in consistency around 2016 and 2022, with values closer to the 0.75 threshold. The decline in 2016 can be attributed to the restructuring of the regional economic industrial base. The Yangtze River Delta had traditionally relied on manufacturing as an economic pillar (Y. Yang, et al., 2022). Besides, in 2016, the Chinese government prioritized and promoted a shift toward innovation-driven and high-tech industries. This transition temporarily disrupted the established industrial structure and regional economy. The mismatch between traditional and emerging industries during this period contributed to the decline in consistency, slowing the momentum that had previously driven regional innovation.

Similarly, the dip around 2022 reflects the economic effects of the post-COVID-19 period, affecting talent mobility and regional innovation output. Pandemic-related control measures restricted international talent mobility (L. Piccoli et al., 2021). Yangtze River Delta relies on international high-end talent as an innovation hub, it was unable to fully utilize global research resources during this period. This led to delays or cancellations of innovation collaboration projects, affecting progress in high-tech sectors.

Despite these minor fluctuations, the pathway remains robust, indicating that economically advanced areas with strong innovation capacity and talent resources can achieve commercialization outcomes without relying heavily on structured school-enterprise collaborations.

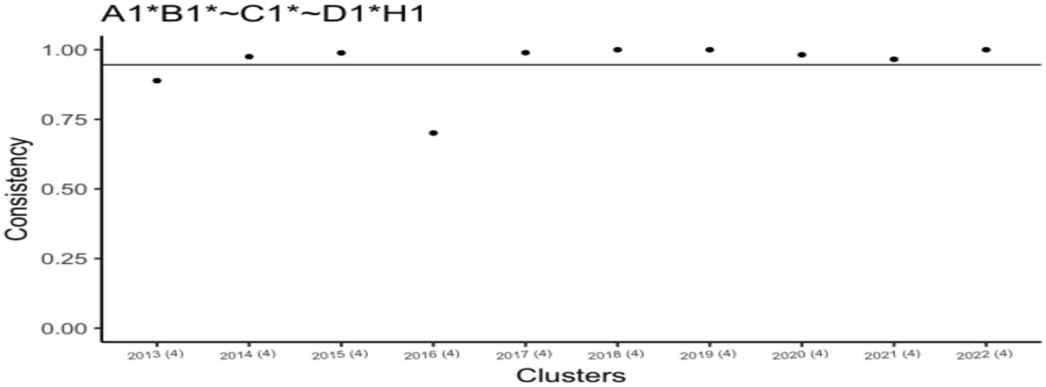

Figure 4: Configuration 2

Configuration 2 (*Figure 4*) comprises regional economic development (A), school-enterprise cooperation (B), and research cooperation network (H) as core conditions, with government support (C) as a core missing condition and scientific research incentive intensity (D) as a peripheral missing condition. While this configuration displays stable consistency, there is a notable dip around 2016 where the value briefly drops below 0.75.

The "Mass Entrepreneurship and Innovation" strategy introduced in 2015 and 2016 encouraged universities and enterprises to pursue independent innovation activities (Z. Li et al., 2018). During this period, these regions have experienced shifts in school-enterprise partnerships and collaboration structures, which have influenced the effectiveness of this pathway. Additionally, the revised "Law on Promoting the Transformation of Scientific and Technological Achievements," implemented in 2016, aimed to strengthen legal support for research transformation. After 2016, the consistency stabilizes, suggesting that reestablished or strengthened partnerships helped maintain the pathway's effectiveness in commercialization without government intervention. This configuration appears particularly relevant in regions where industry-academic partnerships and collaborative networks play a significant role in facilitating research-to-market transformation, compensating for limited direct government funding.

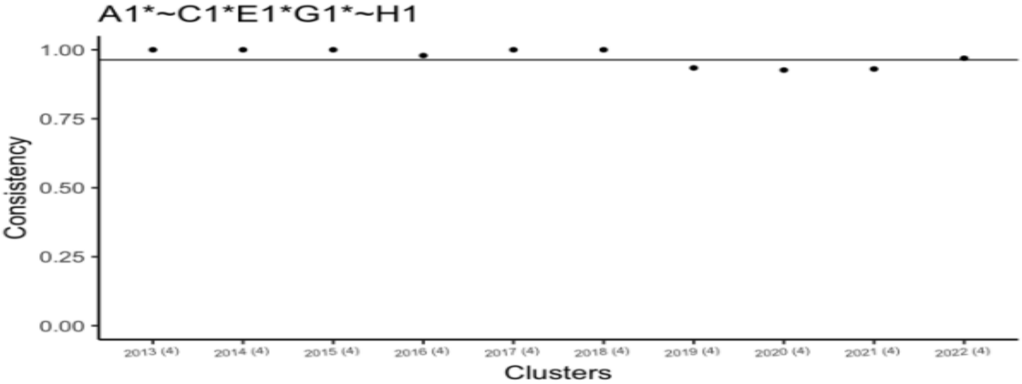

Figure 5: Configuration 3

Configuration 3 (*Figure 5*) features regional economic development (A), scientific and technological innovation (E), and scientific research talent reserve (G) as core conditions, with government support (C) as a core missing condition and research cooperation network (H) as a peripheral missing condition. This configuration maintains relatively high consistency across clusters, staying mostly above 0.75, with slight dips observed from 2019 to 2021.

The decline in consistency in 2019 can be attributed to economic fluctuations. China's economy slowed in 2019 due to internal and external pressures, such as the U.S.-China trade war (Pencea, 2019). The slowdown, along with supply chain disruptions, affected manufacturing output, investment, and exports, weakening the economic foundation needed for research transformation. The drop in consistency from 2020 to 2021 was directly caused by the COVID-19 pandemic. The pandemic limited the movement of researchers both domestically and internationally, while the temporary shift in funding priorities (toward pandemic-related research) reduced the ability to conduct scientific research in non-pandemic-related areas.

Nevertheless, the generally high consistency values suggest that regions with substantial economic, innovation, and talent resources can drive commercialization without heavy reliance on government support or extensive research cooperation networks. The resilience of this pathway across clusters indicates that strong local resources can sustain commercialization efforts independently, even amidst broader economic shifts.

4.2.3. Within results

The within-group analysis examines the consistency and explanatory power of each configuration across the regions within the Yangtze River Delta: Shanghai, Anhui, Jiangsu, and Zhejiang. Similar to the between-group analysis, the within-group consistency distances for Configurations 2 and 3 are below 0.2, indicating no significant differences in explanatory power across provinces. As shown in *Table 5*, Shanghai, Jiangsu, and Zhejiang exhibit high consistency in all configurations, while Anhui shows a lower consistency, particularly in Configurations 1 and 3, where values fall below 0.9. This discrepancy highlights regional variation, with Anhui demonstrating a weaker alignment with these configurations, possibly due to differences in economic development, innovation infrastructure, or collaborative networks compared to the more developed provinces.

Configuration 2 passed both normality and homogeneity tests, making it suitable for one-way ANOVA analysis. As shown in *Table 6*, the ANOVA results indicate a mean consistency of 0.954 with a standard deviation of 0.036, and the Shapiro-Wilk (S-W) value of 0.968 confirms normality. This high consistency across regions suggests that Configuration 2's reliance on regional economic development (A), school-enterprise cooperation (B), and research cooperation network (H) as core conditions is well-suited for each province, especially in Jiangsu and Zhejiang, where collaborative networks and enterprise partnerships are strong. *Figure 6* shows high consistency for Configuration 2 across regions, with values ranging from 0.91 in Anhui to 0.99 in Shanghai. This result illustrates that this configuration can effectively support commercialization in various regional contexts, where established school-enterprise networks offset the need for direct government support.

Table 6: Results of the ANOVA

	Mean	SD	S-W
Configuration / Pathway 2 Consistency	0.954	0.036	0.968

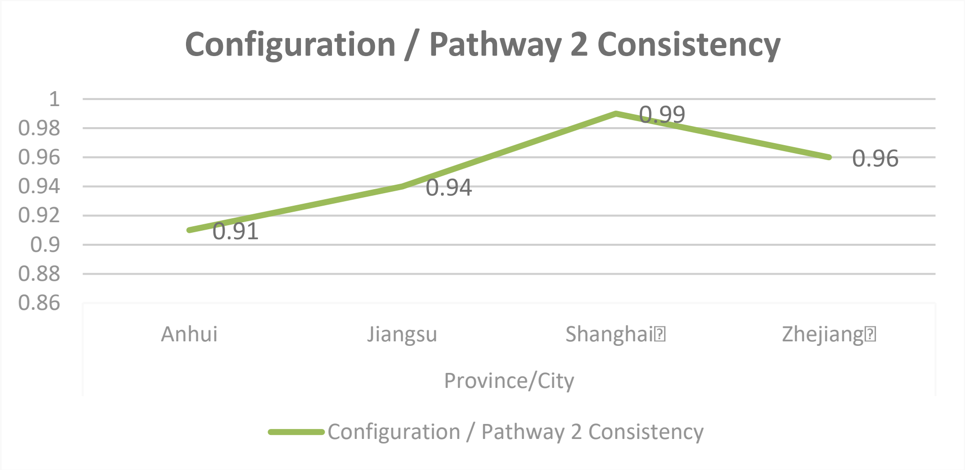

Figure 6: Consistency of configuration 2

Configuration 2 demonstrates high coverage in Jiangsu (0.765) and Zhejiang (0.699) (*Table 7*), indicating that this configuration is particularly well-suited to these regions. In Jiangsu, the high-tech manufacturing sector relies heavily on school-enterprise collaboration. Industrial parks and research institutions work closely with local businesses to meet industry needs, aligning well with Configuration 2's focus on school-enterprise networks. Zhejiang, known for its entrepreneurial culture and strong private sector, also benefits from Configuration 2. Firms in Zhejiang actively engage with academic institutions to drive technological advancement, which supports commercialization efforts.

The lower coverage in Anhui (0.201) and Shanghai (0.146) may reflect the different commercialization dynamics in these regions. In Anhui, a less developed industrial ecosystem may hinder effective school-enterprise collaboration, reducing the applicability of Configuration 2. In Shanghai, where government-backed initiatives often play a significant role, the city may rely more on formalized, top-down commercialization approaches rather than purely market-driven partnerships, which could explain the lower fit for this configuration.

Table 7: Within-groups coverage results for scientific and technological achievements transformation in higher education

	Shanghai	**Anhui**	**Jiangsu**	**Zhejiang**
Configuration / Pathway 1	0.467	0.251	0.141	0.519
Configuration / Pathway 2	0.146	0.201	0.765	0.699
Configuration / Pathway 3	0.137	0.201	0.297	0.851

Configurations 1 and 3 demonstrate the highest coverage in Zhejiang, highlighting that Zhejiang's local economic and innovation resources are well-suited to these internal-resource-driven models. Both configurations focus on regional economic development (A), scientific and technological innovation level (E), and scientific research talent reserve (G), while minimizing reliance on school-enterprise cooperation (B) and government support (C).

As shown in *Table 7*, Zhejiang has the highest coverage for both configurations, with 0.519 for Configuration 1 and 0.851 for Configuration 3. Zhejiang's vibrant private sector, marked by numerous high-tech firms and an entrepreneurial culture, allows the region to leverage internal resources for commercialization without significant external support. This aligns well with Configurations 1 and 3, which prioritize independent commercialization based on local resources. *Figure 7* further supports this alignment, showing high consistency values of 0.979 for Configuration 1 and 0.976 for Configuration 3 in Zhejiang, confirming that Zhejiang's commercialization efforts are well-supported by its local innovation infrastructure.

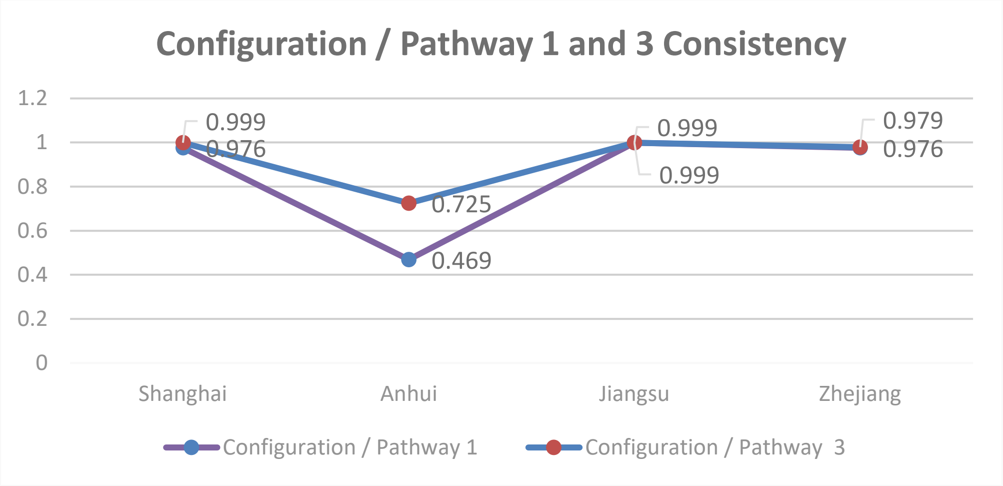

Figure 7: Consistency of Configuration 1 and 3

Shanghai shows moderate coverage for Configuration 1 (0.467) but lower coverage for Configuration 3 (0.137). This suggests that Shanghai's commercialization model can partially align with an internal-resource-driven approach but generally relies on more structured networks or government-backed initiatives, which Configuration 3 lacks. Although Shanghai's economic and technological sectors provide robust support for commercialization under Configuration 1 (as indicated by its high consistency of 0.999 in *Figure 7*), the city's preference for formalized partnerships likely explains the reduced fit for Configuration 3.

Anhui and Jiangsu show significantly lower coverage for both Configurations 1 and 3. Anhui's coverage is 0.251 for Configuration 1 and 0.201 for Configuration 3, reflecting the region's limitations in economic and innovation infrastructure that make independent commercialization challenging. Anhui may require more structured partnerships or government support to effectively commercialize research. Similarly, Jiangsu shows a lower coverage of 0.141 for Configuration 1 and 0.297 for Configuration 3, suggesting that while it has substantial resources, the region's commercialization strategy favors collaborative networks rather than purely internal resources. The consistency values in *Figure 7* (0.725 for Configuration 1 and 0.469 for Configuration 3 in Anhui) further indicate that Anhui and Jiangsu may struggle to apply these configurations effectively.

The Kruskal-Wallis H Test results in *Table 8* indicate no statistically significant differences across regions for Configurations 1 and 3 ($p = 0.392$), despite the variability in coverage. This suggests that while Configurations 1 and 3 can apply to different regions, their effectiveness depends heavily on the strength of each region's economic and innovation resources.

Table 8: Results of the Kruskal-Wallis H Test

	Mean	**SD**	**P**
Configuration / Pathway 1 Consistency	0.855	0.258	0.392
Configuration / Pathway 3 Consistency	0.925	0.134	0.392

5. CONCLUSION

5.1. Discussion

This study highlights distinct regional dynamics within the Yangtze River Delta that influence the effectiveness of various commercialization models for scientific and technological achievements in higher education. The results underscore the necessity of tailoring commercialization strategies to each region's unique economic structure, innovation capacity, and collaboration landscape.

Zhejiang demonstrates a strong alignment with configurations reliant on internal resources, reflecting the region's robust private sector, innovation infrastructure, and high levels of economic autonomy in commercialization. The results suggest that Zhejiang's commercialization strategy can effectively focus on reinforcing private-sector-led innovation with selective partnerships that complement its established capabilities. Policies that incentivize private-sector investment in commercialization projects, alongside targeted support for industry-academic collaborations, could enhance Zhejiang's flexibility, enabling it to maximize outcomes under both independent and partnership-driven models. Maintaining this adaptability will allow Zhejiang to continue leveraging its entrepreneurial culture and technological assets to support sustainable commercialization.

Shanghai, with its preference for structured, government-supported commercialization, reveals the benefits of integrating market-driven initiatives within a structured model. Shanghai's approach, while effective within its established framework, may benefit from policies that encourage increased private-sector participation in the commercialization process. A balanced model that retains core government support while incentivizing private-sector involvement could offer Shanghai greater agility in adapting to shifting market demands and emerging innovation trends. Policymakers could consider mechanisms such as public-private partnerships, innovation grants, and tax incentives for private investment in commercialization projects, thereby broadening Shanghai's strategic scope while retaining the stability of its government-backed framework.

Jiangsu shows a high alignment with collaborative models, particularly those that emphasize school-enterprise cooperation and research networks, underscoring the role of industry-academic partnerships in the region's commercialization success. Jiangsu's industrial base, particularly within the high-tech manufacturing sector, relies heavily on these collaborations to adapt research outputs for practical applications. To maintain and expand this momentum, Jiangsu could prioritize policy measures that support infrastructure development for collaborative projects, increase funding for joint industry-academia initiatives, and facilitate access to cross-regional research networks. This partnership-focused strategy aligns well with Jiangsu's current industrial structure and will ensure that commercialization efforts remain closely tied to market needs, fostering a more resilient and responsive commercialization ecosystem.

Anhui exhibits the greatest need for foundational investment in both internal resources and external networks, as current limitations in economic and innovation infrastructure hinder the region's ability to support either independent or collaboration-based commercialization models effectively. The results suggest that Anhui requires a dual strategy focused on building internal economic and innovation capacity while establishing new collaborative partnerships. Government-led initiatives to attract investment in research facilities, foster talent development, and support school-enterprise partnerships could provide the structural foundation Anhui needs to engage more actively in commercialization. Furthermore, targeted incentives to facilitate knowledge transfer, such as grants for collaborative projects and subsidies for industry-academia partnerships, would help bridge existing gaps, positioning Anhui to adopt a more balanced and sustainable commercialization approach over time.

5.2. Theoretical implications

This study enriches the theoretical understanding of determinants and transformation paths in the commercialization of scientific research within the context of the Yangtze River Delta. Unlike previous studies that focus on isolated variables, this research adopts a dynamic QCA approach to integrate economic development, policy support, and innovation resource factors within a unified framework grounded in interface theory. By analyzing the interactions among seven secondary conditions across these dimensions, this study reveals the intricate causal mechanisms that drive effective commercialization pathways in higher education.

Additionally, this study is the first to apply the dynamic QCA to examine the commercialization of scientific research in the Yangtze River Delta over time, utilizing provincial panel data from 2013 to 2022. This longitudinal approach advances beyond traditional regression and cross-sectional analyses by capturing both temporal dynamics and configuration effects. This methodology enables a more nuanced understanding of how provincial differences in consistency and coverage influence commercialization outcomes, thereby enhancing the analytical scope and contributing to a multi-dimensional framework for studying regional integration's impact on the transformation of scientific research achievements.

5.3. Practical implications

From a policy perspective, this study provides actionable insights for designing targeted commercialization strategies that align with each region's strengths and developmental needs. Policymakers in regions like Zhejiang, which exhibit strong internal resources, can focus on policies that further incentivize private-sector investment and selective partnerships to enhance independent commercialization. For Shanghai, where structured, government-backed models prevail, there is a clear opportunity to introduce policies that encourage more market-driven collaborations, potentially through public-private partnerships or incentives for private investment in innovation. Jiangsu's reliance on collaborative networks suggests that enhancing funding and support for industry-academia partnerships would sustain its commercialization momentum. In contrast, Anhui's need for foundational investments indicates a priority for policies that build internal capacity and foster new collaborative networks. These policy recommendations support regional economic growth by aligning commercialization efforts with local capabilities and challenges, thereby maximizing the impact of scientific and technological achievements.

Practically, the findings provide valuable insights for university administrators, industry leaders, and regional development agencies seeking to optimize the commercialization of research. Universities in regions with strong private sectors, such as Zhejiang, may focus on fostering relationships with local industries, while universities in areas like Jiangsu could prioritize establishing and expanding research networks with high-tech firms. For regions with emerging innovation ecosystems, like Anhui, universities and industry stakeholders might concentrate on building foundational collaborations, securing funding, and developing research capabilities to support effective commercialization pathways. Development agencies can use these insights to craft programs that facilitate knowledge exchange and technology transfer, ensuring that research outputs are translated into economic benefits across diverse regional contexts.

5.4. Limitations and suggestions for future research

While this study offers valuable insights into the commercialization of scientific research in the Yangtze River Delta, several limitations warrant consideration. First, the study is region-specific, focusing exclusively on the Yangtze River Delta, which may limit the generalizability of findings to other regions with differing economic, policy, and innovation landscapes. Future research could expand this framework to other regions within China or internationally to assess the adaptability and relevance of the identified commercialization pathways in varying contexts.

Second, while the dynamic QCA method allows for a nuanced analysis of causal configurations over time, it remains dependent on the availability and quality of panel data. In this study, data from 2013 to 2022 was utilized, but the scope of analysis could be enriched by including more recent data as it becomes available, especially considering rapid technological and policy changes.

Lastly, this study focuses on seven secondary conditions based on economic, policy, and innovation resource integration. While these factors are crucial, future research could explore additional variables, such as institutional support structures, specific industry characteristics, or international collaborations, to deepen the understanding of commercialization drivers. Extending the framework to include these variables could uncover new configurations and pathways that further enhance the theoretical understanding of scientific research commercialization.

Credit authorship contribution statement

Zhang Yuxin: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Writing–original draft, Writing–review & editing.

REFERENCES

Aliyev, A. G., & Shahverdiyeva, R. O. (2017). Structural analysis of the transformation processes of scientific and technical ideas and knowledge into innovations in technoparks. International Journal of Engineering and Manufacturing, 7(2), 1.

Aman, G. (2017). Intellectual Property, Traditional Knowledge, and Bioprospecting: Searching for Efficient Balance of Rights. University of Toronto (Doctoral dissertation).

Amaral, M., Ferreira, A., & Teodoro, P. (2011). Building an entrepreneurial university in Brazil: the role and potential of university–industry linkages in promoting regional economic development. Industry and Higher Education, 25(5), 383-395.

Ankrah, S., & AL-Tabbaa, O. (2015). Universities–industry collaboration: A systematic review. Scandinavian Journal of Management, 31(3), 387–408. https://doi.org/10.1016/j.scaman.2015.02.003

Arora, A., Belenzon, S., Patacconi, A., & Suh, J. (2020). The changing structure of American innovation: Some cautionary remarks for economic growth. Innovation Policy and the Economy, 20(1), 39-93.

Azoulay, P., Graff Zivin, J. S., & Manso, G. (2011). Incentives and creativity: evidence from the academic life sciences. The RAND Journal of Economics, 42(3), 527-554.

Belderbos, R., Carree, M., & Lokshin, B. (2004). Cooperative R&D and firm performance. Research policy, 33(10), 1477-1492.

Bodas Freitas, I. M., Geuna, A., & Rossi, F. (2013). Finding the right partners: Institutional and personal modes of governance of university–industry interactions. Research Policy, 42(1), 50–62. https://doi.org/10.1016/j.respol.2012.06.007

Bozeman, B. (2000). Technology transfer and public policy: a review of research and theory. Research policy, 29(4-5), 627-655.

Bruneel, J., D'Este, P., & Salter, A. (2010). Investigating the factors that diminish the barriers to university–industry collaboration. Research Policy.

Bush, V. (2021). Science, the endless frontier.

Carmona, P., Momparler, A., & Climent, F. (2023). A Fuzzy-Set Qualitative Comparative Analysis of Causal Configurations Influencing Mutual Fund Performance: The Role of Fund Manager Skill. Mathematics, 11(21), 4500.

Chakrabarti, A. K. (1991). Competition in high technology: Analysis of patents of US, Japan, UK, France, West Germany, and Canada. IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT, 38(1).

Chen, F., Liu, H., & Ge, Y. (2021). How does integration affect industrial innovation through networks in technology-sourcing overseas M&A? A comparison between China and the US. Journal of Business Research, 122, 281-292.

China National Intellectual Property Administration (2023). Patent Investigation Report of China. [In Chinese].

Corsten, H. (1987). Technology transfer from universities to small and medium-sized enterprises—an empirical survey from the standpoint of such enterprises. Technovation, 6(1), 57-68.

Dorf, R. C., & Worthington, K. K. (1990). Technology transfer from universities and research laboratories. Technological forecasting and social change, 37(3), 251-266.

Douglass, J. A., King, C. J., & SL, N. I. (2018). The role of universities in economic competitiveness in California. 2018-02-13). https://cshe. berkeley. edu/sites/default/files/publications/roleuniversitieseconcompetitivenesscalifornia. report_informe_california. january_2018. pdf.

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: From National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. Research Policy, 29(2), 109–123. https://doi.org/10.1016/S0048-7333(99)00055-4

Fan, X., Ren, S., & Liu, Y. (2023). The Driving Factors of Green Technology Innovation Efficiency—A Study Based on the Dynamic QCA Method. Sustainability, 15(12), 9845.

Fang, J., Jiang, Z., & Xie, Z. (2021). Research on Computer Assisted Performance Intelligent Evaluation Model of Achievements Transformation through Principal Component Analysis. Journal of Physics.

Feller, I., Ailes, C. P., & Roessner, J. D. (2002). Impacts of research universities on technological innovation in industry: evidence from engineering research centers. Research policy, 31(3), 457-474.

Figueiredo, N. L., & Ferreira, J. J. M. (2022). More than meets the partner: A systematic review and agenda for University–Industry cooperation. Management Review Quarterly, 72(1), 231–273. https://doi.org/10.1007/s11301-020-00209-2

Fiss, P. C. (2011). Building better causal theories: A fuzzy set approach to typologies in organization research. Academy of management journal, 54(2), 393-420.

Gao, X., Guo, X., & Guan, J. (2014). An analysis of the patenting activities and collaboration among industry-university-research institutes in the Chinese ICT sector. Scientometrics, 98, 247-263.

Gao, Y., & Gu, H. (2023). Research on the influence path of the unit environment of medical and health institutions on achievement transformation output. PLOS ONE, 18(12), e0295446. https://doi.org/10.1371/journal.pone.0295446

Gersbach, H., Sorger, G., & Amon, C. (2018). Hierarchical growth: Basic and applied research. Journal of Economic Dynamics and Control, 90, 434-459.

Geuna, A., & Muscio, A. (2009). The Governance of University Knowledge Transfer: A Critical Review of the Literature. Minerva, 47(1), 93–114. https://doi.org/10.1007/s11024-009-9118-2

Geuna, A., & Rossi, F. (2011). Changes to university IPR regulations in Europe and the impact on academic patenting. Research Policy, 40(8), 1068–1076. https://doi.org/10.1016/j.respol.2011.05.008

Greckhamer, T., Furnari, S., Fiss, P. C., & Aguilera, R. V. (2018). Studying configurations with qualitative comparative analysis: Best practices in strategy and organization research. Strategic Organization, 16(4), 482–495. https://doi.org/10.1177/1476127018786487

Griffith, R., Redding, S., & Reenen, J. V. (2004). Mapping the two faces of R&D: Productivity growth in a panel of OECD industries. Review of economics and statistics, 86(4), 883-895.

Grillo, F. (2011). Public investments in R&D as a tool for regional economic development. European Institute of the London School of Economics (Doctoral dissertation).

Guo, J., Liu, J., Liao, X., & Liu, X. (2023). What Affects the Efficiency of Science and Technology Output and Transformation in Universities?–Evidence From Chinese Universities. IEEE Access, 11, 114201–114219. https://doi.org/10.1109/ACCESS.2023.3322431

Han, J. (2012). A Study of Financial Distress and R&D in Chinese Enterprises. University of St. Andrews (Doctoral dissertation).

Han, Y. (2016). Research on Scientific and Technical Achievements Transformation of Colleges Based on the Perspective of Interest. Proceedings of the 2016 International Conference on Contemporary Education, Social Sciences and Humanities. 2016 International Conference on Contemporary Education, Social Sciences and Humanities, St. Petersburg, Russia. https://doi.org/10.2991/iccessh-16.2016.51

Heitor, M., Horta, H., & Mendonça, J. (2014). Developing human capital and research capacity: Science policies promoting brain gain. Technological Forecasting and Social Change, 82, 6–22. https://doi.org/10.1016/j.techfore.2013.07.008

Hu, X., Zhang, Z., & Lv, C. (2023). The impact of technological transformation on basic research results: The moderating effect of intellectual property protection. Journal of Innovation & Knowledge, 8(4), 100443.

Hu, M. C. (2011). Evolution of knowledge creation and diffusion: the revisit of Taiwan's Hsinchu Science Park. Scientometrics, 88(3), 949-977.

Huang, C. (2007). China's innovation system and industrial competitiveness in the global context. Universidade de Aveiro. (Doctoral dissertation).

Huang, Y. (2022). How can the combination of entrepreneurship policies activate regional innovation capability? A comparative study of Chinese provinces based on fsQCA.

Huang, Y., & Kang, Y. (2023). Report on Innovation and Development of China's Special Economic Zones. In Annual Report on the Development of China's Special Economic Zones (2020) (pp. 73-92). Singapore: Springer Nature Singapore.

Jiang, J., Lee, S. K., & Rah, M.-J. (2020). Assessing the research efficiency of Chinese higher education institutions by data envelopment analysis. Asia Pacific Education Review, 21(3), 423–440. https://doi.org/10.1007/s12564-020-09634-0

Jici, W., & Tong, X. (2005). Sustaining urban growth through innovative capacity: Beijing and Shanghai in comparison. Available at SSRN 695486.

Jinabhai, C. D. (2022). Investigating the imperatives of research transformation at a University of Technology in South Africa (Doctoral dissertation).

Katz, J. S., & Martin, B. R. (1997). What is research collaboration?. Research policy, 26(1), 1-18.

Kostka, G. (2024). China–A Rising Tech Power?: National Ambitions and Local Realities.

Lai, W. H. (2011). Willingness-to-engage in technology transfer in industry–university collaborations. Journal of Business Research, 64(11), 1218-1223.

Lee, S., & Bozeman, B. (2005). The impact of research collaboration on scientific productivity. Social studies of science, 35(5), 673-702.

Lee, Y.-G., Lee, J.-D., Song, Y.-I., & Lee, S.-J. (2007). An in-depth empirical analysis of patent citation counts using zero-inflated count data model: The case of KIST. Scientometrics, 70(1), 27–39. https://doi.org/10.1007/s11192-007-0102-z

Lee, Y. G. (2008). Patent licensability and life: A study of US patents registered by South Korean public research institutes. Scientometrics, 75, 463-471.

Lee, Y. G. (2009). What affects a patent's value? An analysis of variables that affect technological, direct economic, and indirect economic value: An exploratory conceptual approach. Scientometrics, 79(3), 623-633.

Lei, X. P., Zhao, Z. Y., Zhang, X., Chen, D. Z., Huang, M. H., & Zhao, Y. H. (2012). The inventive activities and collaboration pattern of university–industry–government in China based on patent analysis. Scientometrics, 90(1), 231-251.

Li, L., Chen, W., Song, B., & Cui, C. (2024). How to effectively promote the transformation of ecological and environmental scientific and technological achievements? A case study from China. Clean Technologies and Environmental Policy, 1-23.

Li, W., & Zhang, P. (2021). Developing the transformation of scientific and technological achievements in colleges and universities to boost the development of low-carbon economy. International Journal of Low-Carbon Technologies, 16(2), 305–316. https://doi.org/10.1093/ijlct/ctaa066

Li, Z. (2023a). Impact of Technological Innovation on the Yangtze River Delta Region's Economy Based on a Quantile Regression. In Y. Jiang, G. Li, & W. X. Li (Eds.), Proceedings of the 8th International Conference on Financial Innovation and Economic Development (ICFIED 2023) (Vol. 237, pp. 507–525). Atlantis Press International BV. https://doi.org/10.2991/978-94-6463-142-5_58

Li, Z. (2023b). Research on school enterprise cooperation mode under the mechanism of "craftsman leading and collaborative education". SHS Web of Conferences.

Li, Z., Yu, Z., & Daya, Z. (2018). Strategic Foresight and Policy Interpretation of Mass Entrepreneurship and Innovation (MEI) in China. In 2018 Portland International Conference on Management of Engineering and Technology (PICMET) (pp. 1-9). IEEE.

Liang, L., Chen, L., Wu, Y., & Yuan, J. (2012). The role of Chinese universities in enterprise–university research collaboration. Scientometrics, 90(1), 253-269.

Liu, S. (2022). Entrepreneurship, innovation and regional economic development: Spatial variations and empirical analyses of firm formation, small business innovation and income inequality. Northeastern University. (Doctoral dissertation)

Liu, H., & Jiang, Y. (2001). Technology transfer from higher education institutions to industry in China: nature and implications. Technovation, 21(3), 175-188.

Liu, X., Zhou, L., & Chen, G. (2019). Research on the Construction Path of High-Level Universities Under the Background of'Double World-Class' in China: Taking Jiangsu Province as an Example.

Liu, Y., Li, L., & Zheng, F. T. (2019). Regional synergy and economic growth: evidence from total effect and regional effect in China. International Regional Science Review, 42(5-6), 431-458.

Lv, C., Bian, B., Lee, C. C., & He, Z. (2021). Regional gap and the trend of green finance development in China. Energy Economics, 102, 105476.

Ma, L., Liu, Z., Huang, X., & Li, T. (2019). The impact of local government policy on innovation ecosystem in knowledge resource scarce region: Case study of Changzhou, China. Science, Technology and Society, 24(1), 29-52.

Mansfield, E. (1991). Academic research and industrial innovation. Research Policy, 20(1), 1–12. https://doi.org/10.1016/0048-7333(91)90080-A

Mittal, V., Ross, W. T., & Baldasare, P. M. (1998). The Asymmetric Impact of Negative and Positive Attribute-Level Performance on Overall Satisfaction and Repurchase Intentions. Journal of Marketing, 62(1), 33–47.

Mowery, D. C., & Sampat, B. N. (1980). The Bayh-Dole Act of 1980 and University–Industry Technology Transfer: A Model for Other OECD Governments?

Ortega, J. L. (2011). Collaboration patterns in patent networks and their relationship with the transfer of technology: the case study of the CSIC patents. Scientometrics, 87(3), 657-666.

O'Shea, R. P., Allen, T. J., Morse, K. P., O'Gorman, C., & Roche, F. (2007). Delineating the anatomy of an entrepreneurial university: The Massachusetts Institute of Technology experience. R&D Management,37(1), 1–16.

Pencea, S. (2019). The looming USA-china trade war and its consequences 1. Global Economic Observer, 7(1), 283-298.

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., Fini, R., Geuna, A., Grimaldi, R., Hughes, A., Krabel, S., Kitson, M., Llerena, P., Lissoni, F., Salter, A., & Sobrero, M. (2013). Academic engagement and commercialisation: A review of the literature on university–industry relations. Research Policy, 42(2), 423–442. https://doi.org/10.1016/j.respol.2012.09.007.

Perkmann, M., Salandra, R., Tartari, V., McKelvey, M., & Hughes, A. (2021). Academic engagement: A review of the literature 2011-2019. Research policy, 50(1), 104114.

Piccoli, L., Dzankic, J., & Ruedin, D. (2021). Citizenship, Migration and Mobility in a Pandemic (CMMP): A global dataset of COVID-19 restrictions on human movement. PloS one, 16(3), e0248066.

Ponomariov, B. L., & Boardman, P. C. (2010). Influencing scientists' collaboration and productivity patterns through new institutions: University research centers and scientific and technical human capital. Research Policy, 39(5), 613-624.

Rahman, A. A. (2022). Core Technological Competence and Competitive Advantage: A Study on Chinese High-Tech SMEs. Frontiers in Psychology, 13.

Ren, D., Song, W., & Ni, Y. (2017). Study on the Scientific and Technological Transformation Mechanism in Universities. Open Journal of Social Sciences, 05(06), 271–285. https://doi.org/10.4236/jss.2017.56023

Rihoux, B., & Ragin, C. C. (Eds.). (2009). Configurational comparative methods: Qualitative comparative analysis (QCA) and related techniques (Vol. 51). Sage.

Rossoni, A. L., De Vasconcellos, E. P. G., & De Castilho Rossoni, R. L. (2023). Barriers and facilitators of university-industry collaboration for research, development and innovation: A systematic review. Management Review Quarterly. https://doi.org/10.1007/s11301-023-00349-1

Schneider, C. Q., & Wagemann, C. (2012). Set-theoretic methods for the social sciences: A guide to qualitative comparative analysis. Cambridge University Press.

Shen, W., & Vanhullebusch, M. (2015). Where is the Alchemy? The experiment of the Shanghai Free trade zone in freeing the foreign investment regime in China. European Business Organization Law Review, 16, 321-352.

Siegel, D. S., Waldman, D., & Link, A. (2003). Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: an exploratory study. Research policy, 32(1), 27-48.

Simon, H. A. (2019). The Sciences of the Artificial, reissue of the third edition with a new introduction by John Laird. MIT press.

Smilor, R., O'donnell, N., Stein, G., & Welborn III, R. S. (2007). The research university and the development of high-technology centers in the United States. Economic Development Quarterly, 21(3), 203-222.

Song, D., & Zhu, M. (2022). Policy Research on the transformation of scientific and technological achievements in Colleges and Universities—Based on International Comparison and Chinese practice. Advances in Education, Humanities and Social Science Research, 1(1), 427-427.

Sterzi, V. (2013). Patent quality and ownership: An analysis of UK faculty patenting. Research Policy, 42(2), 564-576.

Su, J., Su, K., & Wang, S. (2021). Does the Digital Economy Promote Industrial Structural Upgrading?—A Test of Mediating Effects Based on Heterogeneous Technological Innovation.

Sun, S. L., Zhang, Y., Cao, Y., Dong, J., & Cantwell, J. (2019). Enriching innovation ecosystems: The role of government in a university science park. Global Transitions, 1, 104-119.

Sun, Y., Zhang, C., & Kok, R. A. W. (2020). The role of research outcome quality in the relationship between university research collaboration and technology transfer: Empirical results from China. Scientometrics, 122(2), 1003–1026. https://doi.org/10.1007/s11192-019-03330-6

Suominen, A., Kauppinen, H., & Hyytinen, K. (2021). 'Gold','Ribbon'or 'Puzzle': What motivates researchers to work in Research and Technology Organizations. Technological Forecasting and Social Change, 170, 120882.

To, W. M., Lee, P. K., & Lau, A. K. (2021). Economic and environmental changes in Shenzhen—A technology hub in southern China. Sustainability, 13(10), 5545.

Vicente, K. J., & Rasmussen, J. (1992). Ecological interface design: Theoretical foundations. IEEE Transactions on systems, man, and cybernetics, 22(4), 589-606.

Wang, J., Ma, X., Zhao, Y., Zhao, J., & Heydari, M. (2022). Impact of scientific and technological innovation policies on innovation efficiency of high-technology industrial parks – A dual analysis with linear regression and QCA. International Journal of Innovation Studies, 6(3), 169–182. https://doi.org/10.1016/j.ijis.2022.06.001

Wang, W., & Wang, S. (2024). Analysis of factors affecting the transformation of scientific and technological achievements in universities based on structural equation modeling.

Wang, S. J. (2007). Factors to evaluate a patent in addition to citations. Scientometrics, 71(3), 509-522.

Woodside, A. G., & Zhang, M. (2013). Cultural Diversity and Marketing Transactions: Are Market Integration, Large Community Size, and World Religions Necessary for Fairness in Ephemeral Exchanges? Psychology & Marketing, 30(3), 263–276. https://doi.org/10.1002/mar.20603

Wu, L. (2023). Technological achievements in regional economic development: An econometrics analysis based on DEA.

Wu, W. (2007). Cultivating research universities and industrial linkages in China: The case of Shanghai. World Development, 35(6), 1075-1093.

Wu, Y., Welch, E. W., & Huang, W.-L. (2015). Commercialization of university inventions: Individual and institutional factors affecting licensing of university patents. Technovation, 36–37, 12–25. https://doi.org/10.1016/j.technovation.2014.09.004

Xie, X., Han, Y., & Tan, H. (2024). Greening China's digital economy: exploring the contribution of the East–West Computing Resources Transmission Project to CO2 reduction. Humanities and Social Sciences Communications, 11(1), 1-15.

Xie, Wang. (2023). How does the innovation ecosystem promote the transformation efficiency of university scientific and technological achievements at the regional level: FsQCA analysis from a configuration perspective. Journal of Higher Education Management. [In Chinese].

Yang, Y. (2022). Research on the Impact of Incentive Measures on the Performance of Efficient Technology Transfer. Economics and Management, 1.

Yang, H. (2023). Construction of Modern Vocational Education System in Anhui Province: A Reflective Study in the Context of Yangtze River Delta Integration. Advances in Vocational and Technical Education, 5(6), 32-41.

Yang, Y., Lu, H., Liang, D., Chen, Y., Tian, P., Xia, J., ... & Lei, X. (2022). Ecological sustainability and its driving factor of urban agglomerations in the Yangtze River Economic Belt based on three-dimensional ecological footprint analysis. Journal of Cleaner Production, 330, 129802.

Yang, Z., Shen, C., & Lam, F. I. (2024). Scientific and Technological Innovation and Cooperation in the Greater Bay Area of China: A Case Study of University Patent Applications and Transformation.

You, L., Gao, Z. (2023). The Internal Logic and Driving Mode of Scientific and Technological Achievements Transformation in Universities Under TOE Framework. China Higher Education Research. [In Chinese].

Zhang, J. (2019). Exploration and Reflection on School-Enterprise Cooperation in Higher Vocational Colleges under the Background of Industry-Education Integration. Open Journal of Social Sciences.

Zhang, L., & Kinser, K. (2019). Independent Chinese-foreign collaborative universities and their quest for legitimacy. In Chinese-Foreign Cooperation in Running Schools (pp. 96-114). Routledge.

Zhang, L., Jiang, H. (2022). Multiple Concurrent Causality and Multiple Paths of University's Science and Technology Achievement Award Policy —— Based on QCA Analysis of "Double First-class" Universities. Society of China University Journals. [In Chinese].

Zhang, S., Wang, X., & Wang, H. (2023). Exploring configurations of social determinants for enhancing older adult health in China: an fuzzy-set qualitative comparative analysis based on 31 provinces in China. Frontiers in Public Health, 11, 1255877.

Zhang, F., & Wu, F. (2012). "Fostering Indigenous Innovation Capacities": The Development of Biotechnology in Shanghai's Zhangjiang High-Tech Park. Urban Geography, 33(5), 728-755.

Zhang, Yang, & Li. (2022). Research on the Path of Improving the Transformation Performance of Scientific and Technological Achievements in Colleges and Universities in China —— Based on the Fuzzy Set Qualitative Comparative Analysis of 38 Colleges and Universities. Society of China University Journals. [In Chinese].

Zhao, R., & Li, L. (2023). Pressure, state and response: Configurational analysis of organizational resilience in tourism businesses following the COVID-19 pandemic crisis. Humanities and Social Sciences Communications, 10(1), 370. https://doi.org/10.1057/s41599-023-01788-7

Zhong, W., Yuan, W., Li, S. X., & Huang, Z. (2011). The performance evaluation of regional R&D investments in China: An application of DEA based on the first official China economic census data. Omega, 39(4), 447-455.

Zucker, L. G., & Darby, M. R. (1996). Star scientists and institutional transformation: Patterns of invention and innovation in the formation of the biotechnology industry. Proceedings of the National Academy of Sciences, 93(23), 12709-12716.