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A Comparative Study of the Correlation of Government-Industry-University-Research-Finance Based on NLP

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Abstract: This paper focuses on the collaborative innovation ecosystem of "Government - Industry - University - Research - Finance-Service-Application". It systematically analyzes the core positioning and correlation logic of the seven main subjects (government, industry, universities, research institutions, finance, services, and application), and explores practical paths such as the integration model centered on "industry-research", government-enterprise collaboration mechanisms, and two-way talent flow. Addressing prominent issues including insufficient efficiency of factor collaboration and imperfect interest distribution mechanisms, and combining regional practical cases, the paper proposes optimization strategies such as strengthening demand orientation, improving financial empowerment, and enhancing service support. It provides theoretical and practical references for promoting the in-depth integration of the innovation chain, industrial chain, capital chain, and talent chain, solving the disconnect between scientific research and industry, and fostering new quality productive forces.

Keywords: NLP; Cooperation Mechanism; Collaborative Innovation; Achievement Transformation; Innovation Ecosystem

1. Introduction

Against the backdrop of the deepening implementation of innovation-driven development strategies, "Government-Industry-University-Research-Finance" (GIURF) collaborative innovation has emerged as a pivotal institutional arrangement for integrating the innovation chain, industrial chain, capital chain, and talent chain. As such, it is widely regarded as a critical pathway for overcoming persistent bottlenecks in the commercialization of scientific and technological achievements and for cultivating new engines of industrial growth.

Over the past decade, a relatively comprehensive theoretical framework surrounding GIURF collaborative innovation has been established in the academic literature. Existing studies have extensively examined its structural configurations, governance mechanisms, and potential economic and technological impacts. However, a growing body of practical evidence suggests that the actual performance of GIURF collaboration remains far from satisfactory. In real-world settings, interactions among participating actors are often characterized by loose coordination, incomplete institutional mechanisms, suboptimal resource matching, and misaligned evaluation systems. These structural and operational deficiencies substantially constrain the effective release of collaborative synergies, thereby undermining the transformative potential that GIURF arrangements are expected to deliver.

Despite these widely acknowledged challenges, current research has largely fallen short in providing systematic, data-driven assessments of inter-actor relationships and heterogeneous development demands within GIURF systems. In particular, the dynamic linkages among different stakeholders and the specific mismatches that impede effective collaboration have not been sufficiently unpacked, limiting the practical relevance of existing theoretical insights.

To address these gaps, this study leverages natural language processing (NLP) techniques to extract and analyze large-scale textual data from the relevant literature, with the aim of identifying the core relational patterns and development priorities of key actors within

GIURF collaborative innovation. By integrating these findings with real-world multi-actor collaboration scenarios, the study conducts a systematic evaluation of the current state of collaboration, diagnoses salient weaknesses, and explores potential optimization pathways and innovative collaboration models. In doing so, this research seeks to provide robust empirical evidence and actionable policy implications for the construction of an efficient and sustainable collaborative innovation ecosystem.

2. Literature Review

Scholarly research on the "Government-Industry-University-Research-Finance" (GIURF) collaborative innovation model has gradually developed into a relatively comprehensive theoretical system. A systematic examination of the existing literature reveals a clear evolutionary trajectory in this field. At the level of theoretical development, prior studies have progressed from an emphasis on collaboration among core actors toward the integration of multi-actor innovation communities. Methodologically, research has advanced from descriptive analyses of collaboration mechanisms to more sophisticated system-level modeling approaches. In terms of practical application, the focus has expanded from conceptual exploration to empirical assessment of collaborative outcomes. Collectively, these studies provide a multi-dimensional foundation for understanding the underlying mechanisms of collaborative innovation.

2.1 Evolution of the Theoretical Framework: From Linear Collaboration to Multi-Actor Innovation Communities

The theoretical development of collaborative innovation research has undergone a gradual transition from simple, linear cooperation models to more complex, systemic frameworks. Early studies primarily focused on linear collaboration among the three core actors of industry, academia, and research institutions, emphasizing bilateral or trilateral interactions [1]. This perspective was subsequently enriched by the introduction of the Triple Helix model, which conceptualized innovation as the dynamic interaction among enterprises, universities, and government actors [2].

Building on this foundation, later research incorporated governmental and financial actors into the analytical framework, giving rise to the GIURF model and highlighting the formation of multilateral collaborative networks involving government, industry, academia, research institutions, and financial organizations [3]. More recently, scholars have further extended this framework by proposing a seven-actor innovation community, integrating elements of government, industry, academia, research, finance, service platforms, and users, thereby emphasizing the co-evolution and systemic integration of diverse innovation stakeholders [4-5]. Overall, this line of research reflects a clear trajectory of theoretical deepening, characterized by a shift from simplicity to complexity and from linear cooperation models to holistic, system-oriented perspectives.

2.2 Expansion of Research Perspectives: From Mechanism Analysis to System Modeling

Early studies in this field primarily concentrated on collaboration mechanisms such as knowledge transfer and organizational learning, seeking to explain how interactions among innovation actors facilitate collaborative outcomes [6]. Building on these mechanism-oriented analyses, subsequent research progressively incorporated more formal analytical frameworks, including the Triple Helix theory and evolutionary game models, to capture the strategic interactions and adaptive behaviors among multiple stakeholders [7–8].

Through the combined use of case-based inquiry and empirical modeling, these studies have examined the dynamic processes of strategic interaction and co-evolution among participating actors. As a result, research methods in this domain have exhibited a clear trend toward diversification, evolving from predominantly qualitative descriptions to integrated approaches that include quantitative validation and system-level modeling.

2.3 Deepening of Practical Applications: From Theoretical Exploration to Performance Evaluation

A growing number of studies have sought to empirically validate the practical effectiveness of the GIURF collaborative innovation model through case-based analyses. Research grounded in regional practices has demonstrated its role in alleviating constraints in innovation resources and in facilitating industrial upgrading [9–10].

Other studies, drawing on concrete implementation cases, have highlighted the critical enabling roles of financial support and intermediary services in enhancing collaborative innovation performance [11–12]. Correspondingly, evaluation approaches have evolved from reliance on single performance indicators to more multi-dimensional assessment frameworks, incorporating dimensions such as the depth, breadth, and sustainability of collaboration, thereby offering a more comprehensive perspective on collaborative outcomes.

Overall, the existing literature has generated substantial insights into GIURF collaborative innovation, establishing an integrated research framework that encompasses theoretical evolution, mechanism-oriented analysis, and empirical validation. Nevertheless, several critical issues remain insufficiently addressed. In particular, collaborative mechanisms under conditions of digital transformation, variations in effectiveness across heterogeneous industrial contexts, and the assessment of long-term collaborative outcomes warrant further systematic investigation. Addressing these unresolved issues is essential for advancing both theoretical understanding and practical guidance aimed at optimizing innovation ecosystems.

3. Association Analysis

Association analysis is a data mining technique designed to identify meaningful associations or correlation patterns among items within large-scale datasets [13]. In this study, a corpus of relevant literature was first systematically screened and compared by the research team to ensure thematic relevance and data quality. Subsequently, Python-based text processing scripts were employed to efficiently preprocess and analyze the selected documents. Texts exhibiting high semantic similarity were grouped into the same category, after which key terms were extracted from each cluster. Based on these results, the study examined and summarized the underlying associative relationships among the key actors involved in government–industry–university–research–finance (GIURF) collaborative innovation.

Table 1. Extracted Associations among Key Actors

Association	Government	Enterprises	Research Institutions	Universities	Finance
Government		Policy support, Financial subsidies, Market regulation, Platform development, Business environment optimization	Policy guidance, Financial support / Funding support, Collaborative mechanism development	Policy support, Research funding / Research grants, Industry–Education integration promotion	Policy incentives, Financial market regulation, Collaborative system development
Enterprises	Seeking policy support, Complying with regulation / Aligning with regulatory requirements, Participating in collaborative platforms		Short-term project collaboration, Jointly established laboratories / Co-established laboratories, Joint talent development / Collaborative talent training, R&D investment support / Support for R&D investment	Jointly established R&D platforms, Joint talent development / Collaborative talent training, Technology commercialization / Technology transfer, Project collaboration	Financing collaboration / Collaborative financing, Capital-enabled R&D / R&D supported by investment, Investment-driven technology commercialization projects
Research Institutions	Seeking policy and financial support, Responding to collaborative initiatives	R&D collaboration / Technological R&D collaboration, Technology transfer		Jointly established physical platforms / Jointly established R&D facilities, Collaborative R&D	Seeking R&D funding support, Financing collaboration for technology commercialization

		coordination / Technology commercialization alignment, Talent exchange / Personnel exchange		/ Joint R&D initiatives, Joint talent development / Collaborative talent training, Resource sharing	
Universities	Seeking policy and research funding support, Promoting industry–education integration	Collaborative R&D / Joint R&D, Joint talent development / Collaborative talent training, Technology commercialization / Technology transfer, Jointly established platforms / Co-established platforms	Collaborative R&D / Joint R&D, Jointly established platforms / Co-established platforms, Joint talent development / Collaborative talent training, Resource sharing		R&D financing / Financing for R&D, Technology–finance talent development, Capital collaboration for technology commercialization
Finance	Responding to policy guidance, Participating in collaborative financial systems	Providing credit / Credit provision, Equity investment, Financing services	Funding support for R&D and technology commercialization	Financial support for research, Collaborative talent development, Capital-enabled technology commercialization	

As shown in Table 1, the interactions among the five key actors—government, enterprises, research institutions, universities, and financial organizations—were systematically analyzed to elucidate their collaborative logic within the innovation ecosystem.

Government as the facilitator: The government provided policy, financial, and environmental support to enterprises, ensured resources and institutional mechanisms for research institutions and universities, and regulated the financial market while establishing collaborative frameworks. Other actors interacted with the government primarily to obtain support and respond to guidance.

Enterprises as the demand side: Enterprises sought governmental policies and funding, engaged in joint projects and talent cooperation with research institutions and universities, and connected with financial actors to secure capital support. Enterprises acted as the main conduit for technology commercialization and industrial application.

Research institutions and universities as the supply side: These actors relied on government resources and responded to enterprise demand by conducting R&D and talent collaboration. They also obtained financial support and jointly developed platforms and shared resources with other actors.

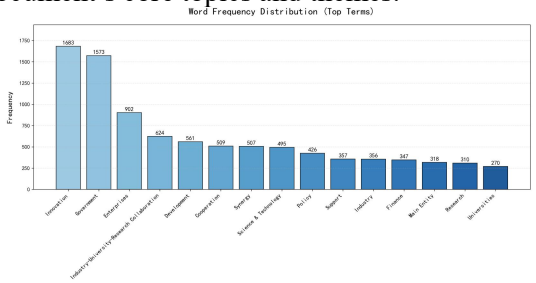
Financial institutions as the enabler: Financial actors responded to government guidance by providing financing and investment services to enterprises, research institutions, and universities. They also participated in talent development initiatives and capital-driven technology commercialization.

Overall, the five actors formed an interactive network characterized by a "government-led – enterprise-oriented – research/university-supplied – finance-enabled" structure. However, the current interactions are primarily unidirectional, focusing on resource provision rather than deep integration. Future efforts should strengthen cross-actor collaboration to transform from "fragmented support" to an "ecosystem-wide interactive model."

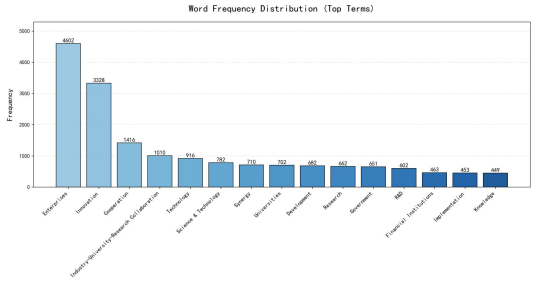
4. Term Frequency Analysis and Word Cloud Visualization

Term frequency (TF) refers to the number of times a specific term appears within a given document. It represents one of the most fundamental and intuitive features in natural language processing (NLP) and information

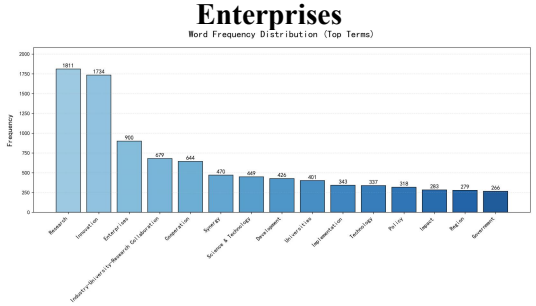
retrieval [14]. In a document, terms with higher frequencies are generally more indicative of the document's core topics and themes.



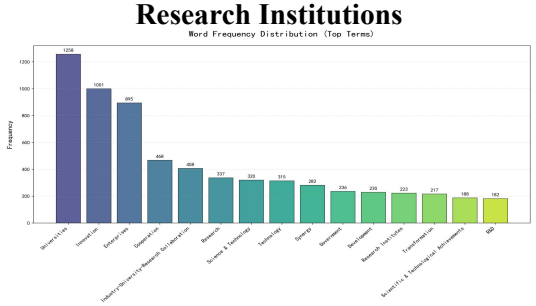
Government



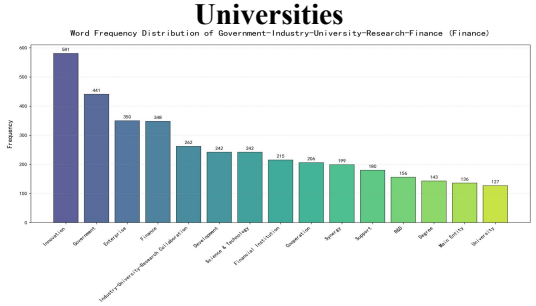
Enterprises



Research Institutions



Universities



Finance

Figure 1. Histogram of the Top 15 Keyword Term Frequencies for Government, Enterprises, Research Institutions, Universities, and Financial Organizations in the GIURF Collaborative Innovation System

Figure 1 illustrates the top ten keywords for each actor within the GIURF collaborative innovation system. The most frequent keywords for each actor were as follows:

Government: innovation, government, enterprise, industry–university–research collaboration, development, cooperation, coordination, science and technology, policy, support.

Enterprises: enterprise, innovation, cooperation, industry–university–research, technology, science and technology, coordination, universities, development, research.

Research institutions: innovation, enterprise, research, cooperation, government, industry–university–research, universities, science and technology, coordination, development.

Universities: university, innovation, enterprise, cooperation, industry–university–research, research, science and technology, technology, coordination, government.

Financial institutions: innovation, government, enterprise, finance, industry–university–research, development, science and technology, financial institutions, cooperation, coordination.

These patterns indicate differentiated functional emphases among the actors. The government primarily provides guidance and support, promoting industry–university–research collaboration. Enterprises focus on seeking partnerships to drive technological innovation and industrial upgrading. Research institutions adopt a demand-oriented approach, facilitating applied research and technology commercialization. Universities leverage scientific and educational strengths to support industrial development and talent cultivation. Financial institutions provide capital enablement, catalyzing value creation throughout the innovation chain.

Word clouds are graphical representations that visually display the frequency of keywords in textual data. Terms that occur more frequently in the source documents are depicted larger, bolder, and more prominently in the word cloud. By presenting the high-frequency keywords from the literature, word clouds facilitate readers' understanding of the core relationships among government, enterprises, research institutions, universities, and financial organizations within the GIURF collaborative innovation system.

Figure 2 presents the word clouds of government, enterprises, research institutions, universities, and financial organizations, with

keywords arranged according to font size. The relative prominence of terms visually reflects their importance and interconnections, forming coherent and logically structured thematic expressions without additional interpretation. Specifically:

The government word cloud emphasizes guiding innovation policies to coordinate technology enterprises and promote development.

Enterprises are depicted as actively linking industry–university–research actors to advance technological innovation and applied research.

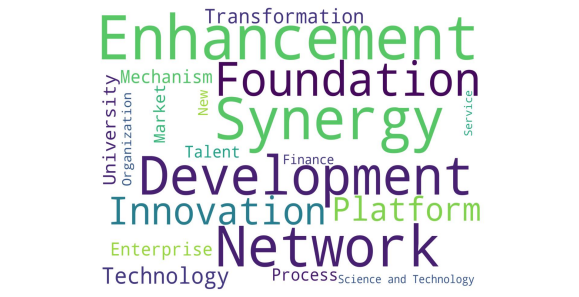
The research institutions word cloud highlights collaborative innovation among government, enterprises, and universities, jointly promoting technological research and cooperation.

Universities are shown coordinating with enterprises to support and enable technological innovation.

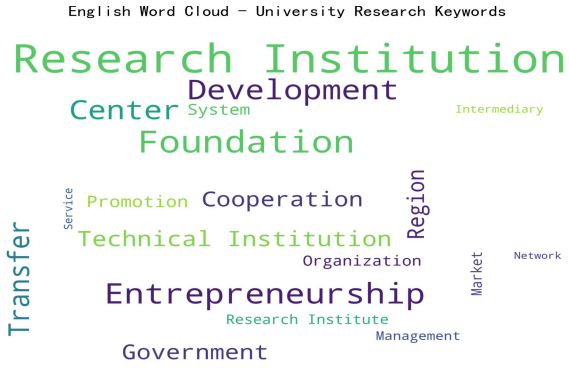
Financial institutions provide capital enablement for industry–university–research collaboration, facilitating government–enterprise cooperation and driving innovation-driven development.

Government

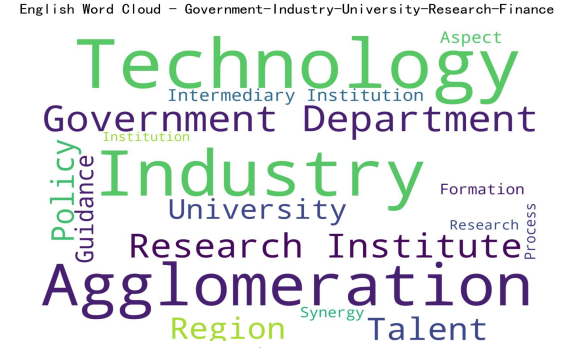
Enterprises



Research Institutions



Universities



Finance

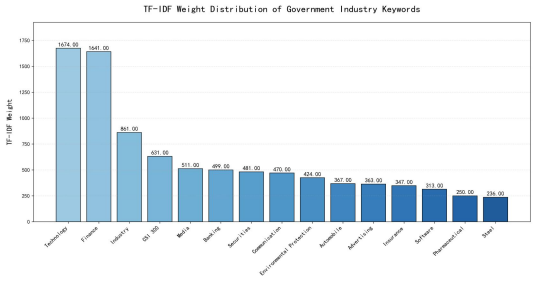
Figure 2. Word Cloud of Keywords for Government, Enterprises, Research Institutions, Universities, and Financial Organizations in the GIURF Collaborative Innovation System

5. Keyword Inverse Document Frequency (IDF) Analysis

Term frequency (TF) quantifies the number of occurrences of a word within a single document to assess its relative importance, based on the fundamental assumption that higher-frequency terms generally convey more key information [15]. However, this approach has notable limitations: some frequently occurring common words (e.g., function words) carry little substantive information, whereas certain low-frequency terms or emerging domain-specific words may possess greater semantic distinctiveness and analytical value.

To address this limitation, the inverse document frequency (IDF) metric is introduced. IDF adjusts the weight of a term by considering its distribution across the entire corpus: a term appearing in many documents is assigned a lower IDF value, whereas a term concentrated in only a few documents is assigned a higher weight [16]. The calculation of IDF is formally expressed as:

$$\mathrm{IDF}=\log\left(\frac{N}{n_t+1}\right)$$



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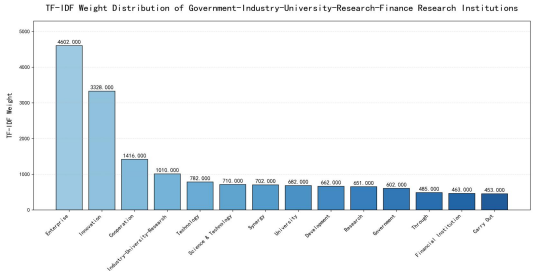
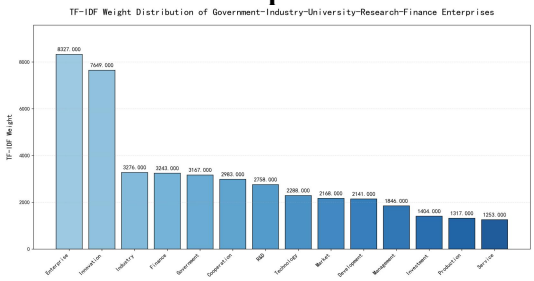
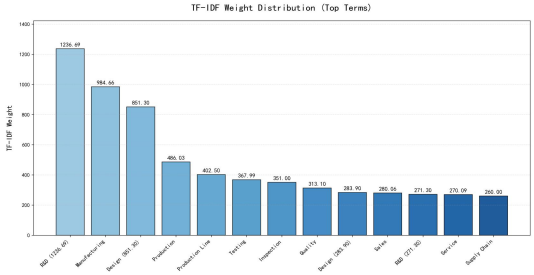


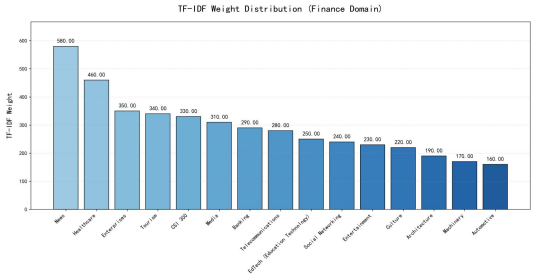
Enterprises



Research Institutions



Universities



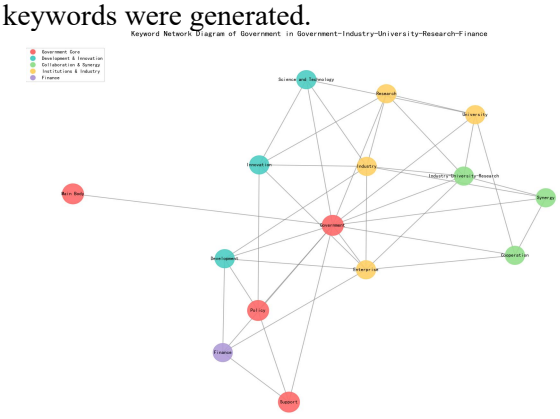
Finance

Figure 3. Top 15 Keywords by Inverse Document Frequency (IDF) for Government, Enterprises, Research Institutions, Universities, and Financial Organizations in the GIURF Collaborative Innovation System

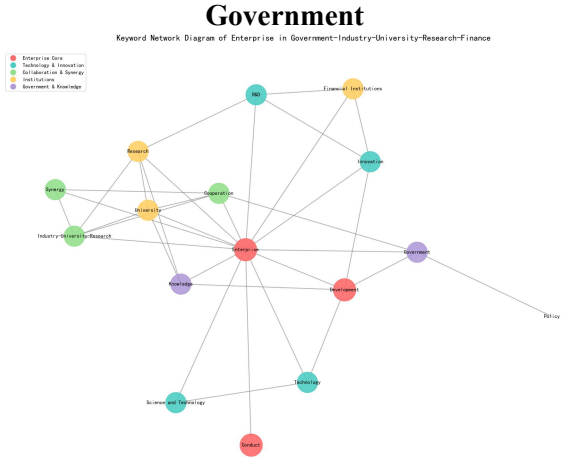
In Figure 3, the top 15 keywords by inverse document frequency (IDF) for each actor in the GIURF collaborative innovation system differ markedly. The vertical axis for financial institutions is capped at 1,000, whereas the axes for government and universities do not exceed 2,000. For enterprises and research institutions, the vertical axes reach 5,000 and 9,000, respectively. These patterns indicate that the thematic focus of enterprises and research institutions is more concentrated compared with the other actors.

6. Thematic Network Relationships

In this study, the text associated with government, enterprises, research institutions, universities, and financial organizations was first tokenized, and theme identifiers were extracted from each paragraph. Subsequently, the co-occurrence frequency of any two actors within the same paragraph was calculated, and the results were stored in a two-dimensional matrix [17]. This matrix served as the foundation for constructing the thematic network, with each element representing the co-occurrence frequency between a specific pair of actors, corresponding to the edge weight in the network. Finally, using the NetworkX library in Python, five visualizations of the co-occurrence networks for each actor's keywords were generated.



Government



Enterprises

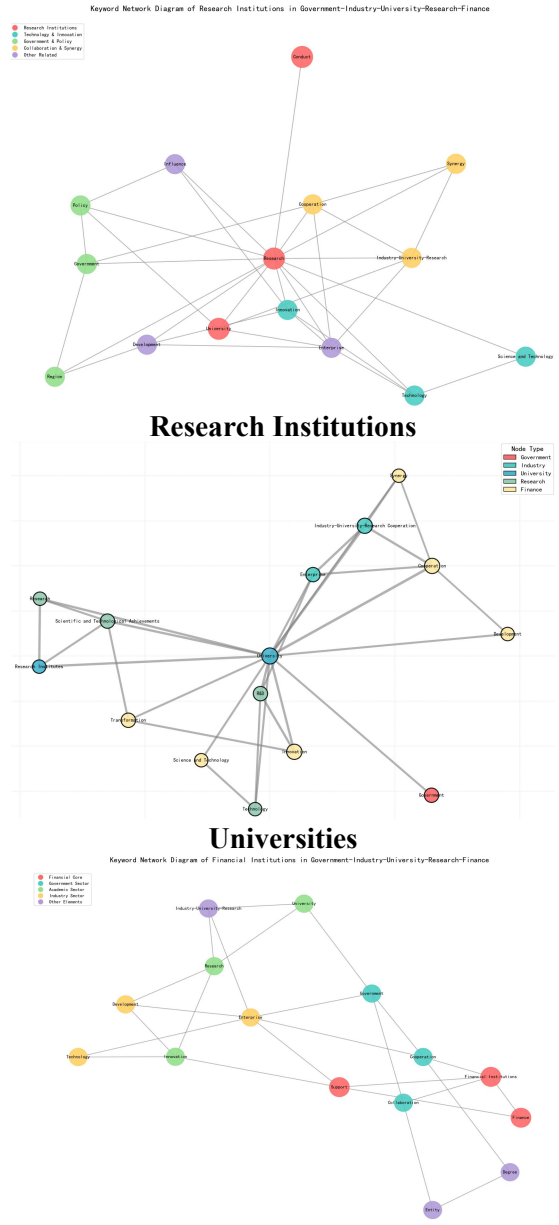


Figure 4. Network of Keyword Co-occurrences among Government, Enterprises, Research Institutions, Universities, and Financial Organizations in the GIURF Collaborative Innovation System

A careful examination of Figure 4 reveals distinct patterns in the keyword co-occurrence networks of the five actors. In the government network, policy instruments support industrial development, forming a policy–industry linkage system. Research and development generate innovation, which in turn promotes industrial growth, while industry feedback fuels further R&D, establishing a virtuous cycle for industrial upgrading. Research institutions and universities engage in academic exchanges and collaborate with enterprises in applied research, using coordination as a bridge to jointly drive innovation, thus forming a triadic industry–university–research collaborative innovation ecosystem. Universities, by establishing extensive collaborative networks with enterprises and other institutions, translate knowledge into practical technologies that jointly contribute to economic and social development, enabling the spillover of knowledge value. Financial institutions are embedded within the industry–university–research collaboration network, linking universities, research institutes, and enterprises through capital, thereby facilitating the synergistic integration of knowledge, technology, capital, and market, and accelerating the commercialization of innovative outcomes.

7. Current Status Assessment and Optimization Pathways

Based on the aforementioned analysis, one specific inter-actor relationship within the GIURF collaborative innovation system was selected for detailed examination, focusing on the current status and potential optimization pathways [18].

7.1 Government–Enterprise Relationship

Table 2. Current Status and Recommendations for the Government–Enterprise Relationship

Category	Mainstream Practices	Existing Limitations	Recommendations for Improvement	Proposed Innovative Practices
Policy and Financial Support	Policy Support and Financial Subsidies	Fragmented policies and poor alignment; complex application procedures and slow fund disbursement; enterprises tend to be dependent on policy support; some enterprises lack awareness of available policies.	Integrate policies and establish differentiated programs; streamline procedures and expedite fund disbursement; develop platforms to facilitate policy implementation.	Promote a “policy + finance” integrated approach; establish intelligent matching platforms; implement feedback mechanisms to adjust policies.
Market Regulation and Services	Market Regulation and	Cumbersome inspections disrupting business operations; lack of corrective guidance;	Standardize inspections and reduce their frequency; provide corrective guidance;	Promote a “regulation + service” approach; establish credit-file-based

	Administrative Inspection	inconsistent standards; weak intellectual property protection.	unify standards; strengthen intellectual property protection.	tiered supervision; set up intellectual property protection centers.
Industry–University–Research Collaboration	Industry–University–Research Collaboration and Platform Development	Platform operations are overly formalized; lack of full-chain services; small- and medium-sized enterprises face difficulties in participation.	Clarify rights and responsibilities; establish shared mechanisms; expand platform services; provide targeted funding support for small- and medium-sized enterprises.	Establish digital collaborative platforms; implement a "challenge-driven leadership" approach; set up demonstration bases to disseminate best practices.
Business Environment Assurance	Business Environment Optimization and Rights Protection	High entry barriers; low government administrative efficiency; difficulties in enterprise financing; poor communication between government and enterprises.	Remove entry barriers and ensure fairness; deepen the "delegation, regulation, and service" reform; expand financing channels; establish communication mechanisms.	Promote "seamless approval" processes; develop supply chain finance platforms; establish closed-loop mechanisms to address enterprise demands.

The patterns distilled from Table 2 reveal that,from the perspective of "government–enterprise collaborative empowerment for development", interactions between government and enterprises were analyzed across four primary domains: policy and funding support, regulatory services, industry–university–research (IUR) collaboration, and business environment optimization. Existing practices established a foundational support framework centered on policy subsidies, market regulation, platform construction, and environmental improvements. However, notable shortcomings were identified, including fragmented policies, regulatory practices that disrupt business operations, overly formalized platforms, and structural barriers within the business environment, collectively leading to insufficient resource alignment and service efficiency.

Proposed improvements focused on policy integration, standardized regulation, strengthened platform collaboration, and optimized business environment, aiming to address service gaps through targeted interventions and enhanced mechanisms. Innovative breakthroughs emphasized the integration of policy and finance, transformation of regulation into service-oriented functions, development of digital collaborative platforms, and implementation of seamless approval processes, thereby advancing government–enterprise collaboration from a model of "unidirectional support" toward an ecosystem-oriented, full-chain, and precision-driven empowerment approach.

7.2 Enterprise–Research Institution

Table 3. Current Status and Recommendations for Enterprises and Research Institutions

Category	Mainstream Practices	Existing Limitations	Recommendations for Improvement	Proposed Innovative Practices
Cooperation Model	Current practices include short-term project commissions, joint laboratory construction, and collaborative talent cultivation and exchanges.	Current collaborations suffer from being loosely organised and short-term in nature, lacking sufficient depth to generate synergistic effects, with academic and research institutions taking the lead while enterprises remain passive.	Collaboration can be improved by establishing long-term strategic alliances, promoting enterprise-led problem definition mechanisms, and strengthening the leading role of enterprises in collaborative research and innovation activities.	Cooperation may be enhanced through the establishment of innovation consortia spearheaded by chain leaders, the creation of open platforms by enterprises, and the development of international collaborative networks.
Mechanisms and Governance	The existing mechanisms primarily take the form of contractual cooperation, government project guidance, and simple	There exist issues such as inadequate risk management mechanisms, frequent disputes over ambiguous intellectual property ownership, and	Optimisation may be achieved through clarifying property rights and profit-sharing arrangements, establishing dedicated management and	Technology brokers may be introduced, intellectual property trusts explored, and blockchain technology utilised to upgrade cooperative mechanisms.

	profit-sharing agreements.	a lack of effective communication and coordination platforms.	coordination bodies, and refining risk management mechanisms.	
Elemental Support	Funding primarily originates from government research project grants and enterprises' own R&D investments, with limited support from traditional bank lending.	There exist issues such as limited financing channels, information asymmetry leading to financial institutions being reluctant to lend, and inadequate or unprofessional intermediary services.	Support can be optimised by developing multi-tiered technology finance, establishing an innovation evaluation credit reporting system, and cultivating specialised technology intermediaries.	Establish industry-academia-research collaboration funds, develop data credit reporting systems, and create R&D crowdfunding platforms to broaden technology financing channels.
Evaluation and Orientation	The assessment system places undue emphasis on the quantity of papers and patents, prioritises the completion and acceptance of projects, and suffers from a disconnect between its evaluation metrics and market realities.	There exists a tendency to overlook the industrialisation value of research outcomes, insufficient focus on innovation quality, and misaligned evaluation objectives among industry, academia and research institutions.	A comprehensive evaluation system may be established, with greater emphasis placed on the quality of innovation and its contribution to industry, thereby promoting alignment between industry, academia and research evaluation standards.	Milestone evaluation methods may be implemented, third-party assessments introduced, and digital profiles established to dynamically assess innovation effectiveness.

A synthesis of the themes presented in Table 3 suggests that at present, collaboration between enterprises and research institutions is primarily conducted through short-term project-based cooperation and the co-establishment of laboratories. However, such collaboration is often characterized by loose organizational linkages, imperfect governance mechanisms, insufficient factor support, and a misalignment between evaluation systems and collaborative objectives. To address these challenges, improvements can be achieved by establishing long-term collaborative alliances, optimizing benefit-sharing mechanisms, expanding financing channels, and developing comprehensive evaluation frameworks. Furthermore, collaborative efficiency can be further enhanced through emerging approaches such as chain-leading enterprises taking coordination roles, the involvement of technology brokers, and the application of data-driven tools.

7.3 Research Institution-Universities

Table 4. Current Status and Recommendations for Collaboration between Research Institutions and Universities

Category	Mainstream Practices	Existing Limitations	Recommendations for Improvement	Proposed Innovative Practices
Joint Construction of Physical Platforms	Jointly Established Physical Platforms (e.g., Engineering Technology Research Centers, Key Laboratories)	Some jointly established platforms suffer from inefficient communication mechanisms and weak resource integration. In addition, the regional distribution of these platforms is uneven, with a strong emphasis on physical construction rather than sustained operation and management, resulting in insufficient support for the transformation and commercialization of research outcomes.	A unified management and coordination mechanism should be established to enhance resource sharing. Policy support should be increased for central and western regions, and performance evaluation frameworks should incorporate metrics such as technology transfer efficiency and industrial impact.	Cross-regional virtual joint platforms should be developed, creating an integrated “platform + industrial park” model that seamlessly connects research and development activities with industrialization pathways.
Collaborative R&D Projects	Collaborative R&D Projects (e.g., joint	Project topics are often detached from market needs, collaborations tend to be	Implement an “enterprise-defined topics, university-driven	Establish special initiatives for joint research on

Category	Mainstream Practices	Existing Limitations	Recommendations for Improvement	Proposed Innovative Practices
	research initiatives, commissioned development)	short-term, and mechanisms for risk-sharing and benefit allocation are unclear, resulting in insufficient long-term motivation for sustained joint R&D activities.	solutions" approach, establish long-term strategic cooperation agreements, and clearly define rules for intellectual property rights and shared risk management.	industry-wide technologies, explore a "crowdfunded projects + shared outcomes" model, and expand financing channels to support collaborative R&D.
Collaborative Talent Development	Collaborative Talent Development (e.g., co-established training centers, integration of work and study programs)	Talent development is often misaligned with industry needs, the bidirectional flow of talent between research institutions and universities is hindered, and regional talent outflows exacerbate disparities.	Implement a "dual-mentor system," expand practical training opportunities, incorporate experiences of bidirectional talent mobility into performance evaluations, and establish regional talent-sharing programs.	Develop integrated talent development zones, establish a digital platform for skills certification, and enhance the alignment of talent capabilities with industry needs.
Resource Sharing and Collaboration	Resource Sharing and Collaboration (e.g., shared research facilities, data resources)	The scope of resource sharing is limited, governance mechanisms are underdeveloped, and resources are often idle or misaligned with demand. In addition, intellectual property protection is inadequate.	Develop cross-entity information-sharing platforms, establish standardized management protocols, and strengthen both information security and intellectual property protection.	Implement a resource-sharing credit system, develop blockchain-based sharing platforms, and enhance both the trustworthiness and scalability of shared resources.
Multi-Entity Collaborative Innovation	Participation in Multi-Entity Collaborative Innovation Networks (e.g., government–industry–university–research–finance networks and their variants)	Insufficient coordination among entities, information asymmetry leading to resource misallocation, and inadequacies in performance evaluation systems.	Strengthen government-level coordination, develop information-sharing systems, and establish multi-dimensional performance evaluation frameworks for collaborative activities.	Develop a digital twin–enabled collaborative innovation ecosystem, establish dedicated funds for collaborative innovation, and ensure the sustainable operation of the network.

An examination of the patterns outlined in Table 4 indicates that collaboration between research institutions and universities in the context of industry–university–research innovation is organized around co-construction, co-research, co-development of talent, resource sharing, and integration. A foundational framework has been established, encompassing physical platform development, joint R&D, collaborative talent training, shared resources, and multi-entity network cooperation. However, actual operations reveal several limitations: platforms emphasize construction over sustained operation, R&D projects are often short-term and detached from market needs, talent development is misaligned with industry demands, resource-sharing scopes are limited with inadequate protection, and multi-entity collaboration often remains superficial.

Optimization should focus on addressing these shortcomings by strengthening platform governance and coordination, aligning R&D with enterprise needs, improving talent development mechanisms, constructing cross-entity resource-sharing platforms, and reinforcing collaboration through government-level coordination and multi-dimensional performance evaluation. Innovative breakthroughs can be achieved through initiatives such as cross-regional virtual platforms, industry-specific crowdfunded projects, and specialized talent development zones, leveraging technologies such as blockchain and digital twins to transform simple

collaborations into deeply integrated innovation communities [19].

7.4 Universities-Enterprise

Table 5. Current Status and Recommendations for Collaboration between Universities and Enterprise

Category	Mainstream Practices	Existing Limitations	Recommendations for Improvement	Proposed Innovative Practices
Collaboration Models	Co-establishment of R&D platforms and alliances; collaborative projects; joint talent development; co-construction of science parks and postdoctoral research stations	The collaboration is predominantly short-term, lacks sufficient depth, has unclear allocation of benefits and intellectual property rights, and the outcomes are often detached from market needs.	Strengthen stable collaborations through co-established entities, develop a comprehensive government–industry–university–research–finance (G-I-U-R-F) framework, clarify benefit and risk-sharing mechanisms, and reform research evaluation systems.	Develop a "government–industry–university–research–finance–service–application" (G-I-U-R-F-S-A) ecosystem, implement a "challenge-driven leadership" mechanism, establish digital innovation platforms, and set up proof-of-concept centers.
Talent Development and Mobility	Joint training of high-level talent; bidirectional talent exchange; establishment of industry professorships; co-construction of internship and training bases	Talent mobility mechanisms are inadequate, training content is misaligned with industry needs, and incentive systems for talent are insufficient.	Establish a "revolving door" mechanism, design training programs tailored to enterprise needs, and create joint talent development funds.	Implement a "Three-Pool Integration" mechanism, adopt flexible talent recruitment models, and jointly establish industry-focused academies.
Technology Transfer and Industrialization	Technology licensing; co-establishment of technology transfer centers; joint project applications; development of technology commercialization platforms.	Pilot-scale testing stages are often absent, technology transfer processes are complex, service organizations lack sufficient expertise, and funding is inadequate.	Establish pilot-scale testing platforms with dedicated funds, implement "one-stop" technology transfer services, cultivate technology brokers, and introduce financial support mechanisms.	Develop closed-loop industrialization models, implement an integrated "technology + capital + industry" approach, and establish cloud-based platforms for technology commercialization.
Mechanisms and Policy Support	Government facilitation and matchmaking; provision of tax incentives and subsidies; establishment of evaluation and reward mechanisms.	Insufficient policy coordination, lack of long-term mechanisms, and regional resource imbalances.	Integrate policies to create synergies, incorporate them into performance evaluations, and promote regional resource sharing.	Implement a "chain leader + innovation consortium" model, introduce an innovation credit system, and establish cross-regional collaborative demonstration zones.

Based on the information summarized in Table 5, University–enterprise collaborative innovation serves as a critical pathway for bridging scientific research and industry, facilitating technology commercialization. Currently, both parties have engaged in diverse collaborative practices; however, short-term orientations and ambiguous benefit allocations constrain the effectiveness of these efforts. In practice, certain collaborations have achieved notable outcomes, such as co-established laboratories enabling mass production and application of technologies, yet most partnerships remain superficial, with misaligned demand and disputes over patent ownership impeding progress.

Addressing these challenges requires multi-dimensional approaches: at the mechanism level, implement an "enterprise proposes, university responds" model to enhance precision; at the talent level, establish industry-focused academies to improve talent–industry alignment; and at the policy level, adopt innovation credit systems to stimulate collaboration. Looking forward, university–enterprise collaboration should evolve toward an ecosystem-oriented model,

constructing a comprehensive "government–industry–university–research–finance–service–application" (G-I-U-R-F-S-A) framework, leveraging proof-of-concept centers to mitigate technology transfer risks, and shifting partnerships from project-based engagement to strategic alliances, thereby achieving synchronized value creation between research outputs and market demands.

7.5 Finance-Universities

Table 6. Current Status and Recommendations for Collaboration between Finance and Universities

Category	Mainstream Practices	Existing Limitations	Recommendations for Improvement	Proposed Innovative Practices
Conduct industry–university–research collaboration through platforms and alliances	Co-establishment of research institutes, laboratories, industry alliances, and collaborative innovation centers	Collaborations are often fragmented and largely formal, with insufficient continuity. Universities prioritize publications and vertical research projects, whereas enterprises focus on market outcomes and profits, making alignment of objectives challenging.	Incorporate horizontal projects, patent commercialization, and industrial contributions into university faculty evaluation and promotion criteria. Promote co-construction or utilization of shared pilot-scale platforms to mitigate technology transfer risks.	Establish dedicated internal units within universities to assess and cultivate the commercialization potential of early-stage technologies.
Commercialize research outcomes through technology transfer or licensing	Universities transfer or license patents and other technological outcomes to enterprises.	The valuation of intangible assets is challenging, often leading to potential loss of state-owned assets or disputes over unfair pricing. After transfer, university faculty involvement is low, and enterprises face difficulties in assimilating and further innovating upon the acquired technologies.	Engage market-oriented, professional third-party evaluation agencies and provide continuous technical guidance to university teams.	Universities form joint ventures with private capital to establish specialized companies responsible for acquiring, nurturing, bundling, and commercializing patents.
Incubate technologies through university-operated enterprises	Universities contribute technological achievements as equity to establish startups.	University-operated enterprises are constrained by public institution management systems, resulting in slow decision-making and inactive incentive mechanisms. Faculty engaged in part-time entrepreneurship face divided attention between teaching, research, and company operations. Universities bear unlimited or joint liabilities, which negatively affects their engagement and initiative.	Standardize management through asset management companies to separate institutional and enterprise functions and enable market-oriented operations. Establish clear policies to protect the legal rights and interests of faculty entrepreneurs.	Establish specialized investment funds targeting deep-tech startups founded by the university's faculty and students.
Financial Support for University R&D and Technology Commercialization	Government research project funding, strategic partnerships between universities and financial institutions, and intellectual property–backed loans.	Traditional credit products are poorly suited to the long cycles and high-risk nature of R&D. There is limited capacity to assess the value and prospects of technologies, leading to excessive reliance on collateral.	Promote multi-tiered capital involvement in early-stage university projects through angel investment, venture capital, and equity financing.	Establish co-funded initiatives involving government, universities, financial institutions, and private capital to support technology commercialization through a combination of grants and equity investment.
Integration of Finance into University Talent Development	Offer finance-related courses, co-establish practical training bases, and organize	Course content lags behind current financial practices, particularly in emerging areas such as fintech. STEM students lack financial knowledge, while business students have	Introduce cutting-edge courses and case studies on fintech, entrepreneurial financing, and intellectual property management. Establish interdisciplinary	Develop specialized technology transfer professionals with expertise in technology, market dynamics, finance, and law. Engage

	innovation and entrepreneurship competitions.	limited technical understanding, making it difficult to cultivate interdisciplinary talent.	student teams comprising STEM, business, and law students to address real-world industry and financial challenges.	successful entrepreneurs and alumni investors as student entrepreneurship mentors and provide seed funding support.

As shown in Table 6,current collaborations between the financial sector and universities encompass co-establishment of industry–university–research platforms, technology transfer, incubation through university-operated enterprises, financial support for R&D, and integration of finance into talent development. However, these collaborations remain fragmented, with imperfect evaluation mechanisms, institutional constraints, mismatched financial products, and gaps between courses and practical application.

Improvement efforts should focus on strengthening market-oriented operational mechanisms, engaging professional evaluation agencies, enhancing faculty incentives and entrepreneurship protections, expanding multi-tiered financial support systems, and promoting interdisciplinary, cross-domain talent cultivation. Innovative approaches could include establishing internal university units dedicated to commercializing technologies, forming specialized companies for patent operations, creating venture funds focused on deep-tech startups within the university, and constructing early-stage project support models that coordinate government, universities, financial institutions, and enterprises. These measures collectively aim to systematically enhance the efficiency of technology commercialization and deepen industry–education integration.

8. Conclusions and Implications

This study demonstrates that the key actors in the "government–industry–research–university–finance" (G-I-R-U-F) ecosystem occupy clearly defined functional roles: the government provides policy guidance and support; enterprises drive technological innovation and industrial application; research institutions focus on applied research and outcomes translation; universities leverage scientific and educational strengths; and financial institutions deliver capital empowerment. While multi-faceted collaborative practices have established a foundational framework, common challenges—short-term cooperation, imperfect mechanisms, poor resource alignment, and misaligned evaluation incentives—limit the depth and sustainability of collaborative innovation. Targeted improvements and innovative interventions can transform these interactions from unidirectional support and superficial engagement into full-chain, ecosystem-oriented empowerment, thereby significantly enhancing overall collaborative innovation effectiveness.

Mechanism coordination serves as the core guarantee: establishing robust frameworks for shared benefits, risk allocation, and intellectual property rights, coupled with efficient communication and coordination platforms, mitigates goal misalignment and information asymmetry, reinforcing the institutional foundation of collaboration.

Technological enablement provides critical support: leveraging blockchain, big data, and digital twin technologies to construct digital collaborative platforms, enhance credit and evaluation systems, and optimize resource allocation enables transparent and precise management across the full innovation lifecycle.

Ecosystem building represents the long-term trajectory: extending the G-I-R-U-F network to a comprehensive "government–industry–research–university–finance–service–application" (G-I-R-U-F-S-A) community integrates policy, capital, technology, talent, and service resources into a closed-loop innovation ecosystem, dismantling organizational silos and regional barriers.

Demand orientation is the guiding principle: empowering enterprises to lead collaborative innovation through models such as "enterprise proposes, university/research responds" aligns research activities with market needs, maximizes industrialization of scientific outcomes, and ensures that innovation value resonates synchronously with market value.

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