

Research on the Coupling Coordination Mechanism of Innovation Ability and Financial Core Competitiveness of China's Energy Enterprises under the Perspective of "Belt and Road"

Anxin Chen

School of International Economics,
China Foreign Affairs University, Beijing, China

Ruikun Yan

Department of Diplomacy,
China Foreign Affairs University, Beijing, China

Approved: 08 March 2026

Posted: 10 March 2026

Copyright 2026 Author(s)

Under Creative Commons CC-BY 4.0

OPEN ACCESS

Cite As:

Chen, A. & Yan, R. (2026). *Research on the Coupling Coordination Mechanism of Innovation Ability and Financial Core Competitiveness of China's Energy Enterprises under the Perspective of "Belt and Road"*. ESI Preprints.

<https://doi.org/10.19044/esipreprint.3.2026.p38>

Abstract

Against the backdrop of global energy transition and the deepening implementation of the Belt and Road Initiative, China's energy enterprises face dual challenges of technological innovation and financial sustainability. This study focuses on the dynamic coupling mechanism between the innovation capability and financial core competitiveness of energy enterprises. An empirical analysis of the dynamic relationships among eight Belt and Road energy enterprises from 2018 to 2024 is conducted by constructing an indicator evaluation system and applying the entropy method, TOPSIS method, coupling coordination model and grey relational analysis. The findings reveal that the innovation capability of selected large-scale Chinese state-owned energy enterprises shows a steady upward trend, while their financial core competitiveness exhibits cyclical fluctuations due to external environmental shocks. Meanwhile, the coupling coordination degree of the dual systems evolves through three stages: "low-level coupling, antagonistic improvement, and short-term adjustment," reflecting the dynamic adaptation process between technology transfer efficiency and

financial resource allocation. The results indicate that enhancing the precision of technology investment, improving cross-border financial coordination mechanisms, and optimizing institutional environments are key pathways to enhance the coupling efficiency of the dual systems. This study provides a quantitative analytical framework and strategic references for energy enterprises to achieve a virtuous interaction between "innovation and finance" in complex international environments.

Keywords: Coupled coordinated development; enterprise innovation; financial core competitiveness; “Belt and Road”; energy enterprises

Introduction

Since its proposal in 2013, the Belt and Road Initiative has become one of the most extensive and influential international cooperation platforms globally. As a core pillar of the Belt and Road Initiative, energy cooperation leverages complementary resource endowments along the routes to build a diversified and multi-level investment system. (National Energy Administration, 2024). Driven by both policy impetus and market demand, Chinese energy enterprises have continuously expanded their transnational investment layout. This not only enhances their capabilities in technology export and industrial chain integration, but also fosters a cooperative pattern featuring the coordinated development of traditional energy and new energy.

From the perspective of investment practice, Chinese state-owned energy enterprises have built a global energy cooperation network through diversified models. In the field of traditional energy, relying on technological advantages in oil and gas exploration and development, pipeline network construction, etc., they have helped resource-rich countries along the routes improve energy development efficiency. In the field of new energy, they have implemented a number of landmark projects through innovative models such as “EPC + financing”. Energy equipment covering more than 200 countries and regions has supplied over 80% of photovoltaic modules and 70% of wind power equipment to the “Belt and Road” region, promoting a significant reduction in the global levelized cost of electricity (LCOE) for renewable energy.

The Belt and Road energy partnership expanded from 29 countries in 2019 to 34 countries in 2024. The third Belt and Road Energy Ministers’ Meeting issued the "Belt and Road Green Energy Cooperation Action Plan (2024-2029)", which identified green energy technology innovation cooperation and green energy financial services as core tasks. Currently, Chinese energy enterprises face the common challenge of insufficient synergy between technological innovation and core financial competitiveness in their investments under the "Belt and Road" Initiative,

and this issue is manifested in both the traditional energy and new energy sectors. Studies have shown that while technological innovation can enhance enterprises' excess returns, it may inhibit short-term operational efficiency and has no significant positive impact on enterprise value, which reflects the contradiction between the input of innovation resources and short-term financial performance. (Zhang, Y.J et al.). Energy projects require substantial upfront investment and have long payback periods. The contradiction between short-term financial liquidity and the long-term nature of innovation investments leads to delayed updates in R&D equipment for some projects. The combination of technical compatibility and financial risks in multinational projects exacerbates financial instability. Addressing this issue is a policy requirement for the construction of the "Belt and Road" Initiative and a key to achieving high-quality cooperation among enterprises.

Literature Review

Research on the Correlation of Enterprise Innovation Capability and the Core Competitiveness of Enterprise Finance

In the theoretical framework of corporate innovation, Lawson and Samson (2001) posited that innovation capability is the core competence enabling enterprises to continuously transform knowledge and creativity into new products, processes, and systems that benefit both themselves and stakeholders. The way organizations seek new ideas during innovation processes is critical. Laursen and Salter (2006) showed that the breadth and depth of firms' external knowledge search—key components of their external search strategies—are critical for innovation performance, and this external search complements rather than substitutes for internal R&D investments. To address the theoretical fragmentation in the study of innovation capability, Narcizo et al.(2017) proposed a maturity-based three-tier framework that conceptualizes innovation capability as a progressively developing continuum; this framework encompasses the following hierarchical levels: the descriptive model, which defines fundamental components; the comparative model, which establishes assessment criteria to measure relative capability levels; and the prescriptive model, which provides developmental roadmaps and best practices. Its core contribution lies in shifting the perspective from the static element view to the dynamic evolutionary view, offering a coherent theoretical pathway for subsequent research—from identification and evaluation to the systematic enhancement of innovation capability.

Scholars have conducted extensive research on methods to enhance corporate innovation capabilities. Regarding the driving mechanisms and methodological innovations of corporate innovation, Porter and Kramer (2011) point out that if companies redefine their objectives as creating

“shared value” and re-integrate business with society, they can achieve a win-win situation for corporate success and social progress through three approaches: reimagining products and markets, redefining productivity in the value chain, and establishing supportive industrial clusters in their locations. The driving approaches to corporate innovation capability extend beyond internal organizational optimization; they also require alignment with external collaboration and sustainable value orientation. In the context of cross-border cooperation, Wang et al. (2023) identified two practical pathways through which innovation capability delivers its value: green technology-oriented innovation investment, and collaboration-driven enhancement of innovation efficiency. This finding suggests that integrating internal R&D with cross-border resource linkage can more effectively transform innovation capability into a driving force for sustainable development. From the perspective of digital transformation, Xu et al. (2024) have empirically verified through research on 476 Chinese manufacturing enterprises that digital transformation is a key driver of corporate innovation performance, primarily through a dual-mediator pathway: first, by strengthening corporate capabilities in data collection; second, by promoting organizational flattening. Demir and Lux (2025) examined the practices of 11 enterprises engaging with co-working spaces as the case studies, arguing that businesses can bolster their innovation capabilities via differentiated collaboration pathways. Functioning as open innovation platforms, co-working spaces facilitate resource integration; through activities like scanning, scouting, and community building, they also enable enterprises to access external innovation components and translate their own innovation awareness and capture capacities into actionable outcomes.

In terms of the components of innovation capability, Lianto et al. (2023), through systematic screening, identified 14 key elements in intellectual capital that drive innovation. The conclusion points out that companies must transcend reliance on a single dimension and enhance innovation capability systematically through the synergy of human, organizational, and relational capital. Suarez-Barraza et al. (2024) systematically analyzed innovation data from 135 countries using the Bayesian model averaging method; to address the fragmentation of factor frameworks, they screened out 27 robust core factors from 62 candidate elements and found that the composition of innovation capability is a dynamic collaborative system, with “public-private R&D collaboration” and “high-skilled talent” as internal engines, and “intellectual property protection” and “industrial clusters” as external foundations. The components of corporate innovation capability include seven aspects: vision and strategy, integration of capability foundations, organizational intelligence, creativity and creative management, organizational structure

and systems, culture and atmosphere, and technology management, all of which collectively underpin the implementation and improvement of corporate innovation activities (Zhang et al., 2025).

In the field of enterprise management and development research, financial core competitiveness, as a key component of corporate financial management systems, has long attracted academic interest. In the 1990s, Hamel first introduced the concept of corporate core competitiveness. Core competitiveness, he argued, enables enterprises to integrate resources effectively and represents the collective learning capacity of an organization, which can significantly enhance production efficiency. Given that core competitiveness delivers strong market value and is difficult to replicate, related research has expanded significantly. Regarding its theoretical foundation, Chikan (2008) defines corporate competitiveness as the sustainable ability to achieve dual objectives: meeting customer needs while ensuring profitability. Sun et al. (2021) verify the transmission mechanism of “from core competence to financial strength and then to corporate behavior”. This provides a theoretical basis for conceptualizing financial core competence as not an isolated element, but a critical link connecting an enterprise’s overall core competence with its financial performance and strategic objectives. This approach directly establishes “profitability” as the core baseline of competitiveness, highlighting financial performance as the fundamental attribute of competitive advantage (Chikan et al., 2022).

Regarding the components of corporate financial core competitiveness, a critical element of corporate financial core competitiveness is maintaining financial flexibility and robust internal financing capacity. Companies that adhere to priority financing principles and avoid value dilution inherently possess competitive advantages through their financial practices (Myers & Majluf, 1984). Chen (2009) proposed incorporating financial competitiveness analysis into evaluation systems. He developed an indicator framework for assessing listed companies’ financial core competitiveness, using data from 15 steel enterprises on the Shenzhen Stock Exchange to conduct comprehensive analysis. The study ultimately proposed actionable recommendations for enhancing financial core competitiveness. Agazu & Kero (2024) integrated the conclusions of multiple empirical studies. They confirm that innovation strategy serves as the core driving force of financial competitiveness, and this driving effect must be realized through specific financial performance indicators, indirectly that the “performance-based components of financial competitiveness, which specifically include: profitability sustainability, financial security and solvency and capital allocation efficiency. This perspective reveals that financial core competitiveness encompasses not only value creation but also risk management abilities.

The dynamic interplay between enterprise innovation capability and financial core competitiveness constitutes a pivotal research stream in contemporary management studies. Existing literature primarily elucidates this relationship through three interconnected lenses: driving effects, enabling conditions, and reciprocal reinforcement. From the perspective of innovation driving finance, scholars posit that sustained innovation activities serve as a critical engine for enhancing financial competitiveness. Yet this positive correlation is not linear but subject to a threshold effect—only when the intensity of R&D investment exceeds a certain critical value can technological achievements be effectively transformed into profit growth and market premium, whereas insufficient innovation input may even exert a crowding-out effect on short-term corporate performance (Zhang et al.,2025). From the perspective of finance enabling innovation, Brown et al. (2012) utilized global corporate data to demonstrate that financing constraints significantly inhibit firms' R&D investment, particularly in high-tech enterprises. Meanwhile, the efficient allocation of resources to high-potential projects supports this argument. Stein (1997) discussed the reallocation of capital from low-growth departments to high-growth, high-potential sectors or projects (often including innovation initiatives), thereby enhancing overall value. Furthermore, advanced research conceptualizes their interaction as a mutually reinforcing, co-evolutionary coupling. A higher level of innovation capability can optimize a firm's cost structure and create premium value, thereby strengthening its financial foundation and market position. In turn, superior financial health and strategic resource allocation empower more ambitious and sustained innovation investment, forming a virtuous cycle (Sempere-Ripoll et al.,2020).

In conclusion, existing research on enterprise innovation capability and financial core competitiveness has yielded substantial insights, yet further exploration remains warranted. Particularly in emerging market contexts, the synergistic mechanism between innovation and financial competitiveness has not been thoroughly examined, and empirical studies focusing on specific industries—such as the energy sector—are still lacking. Therefore, this study aims to investigate the coupling mechanism between innovation capability and financial core competitiveness within Chinese energy enterprises. By doing so, it seeks to address the gaps in current research regarding contextual applicability and industry heterogeneity, and to provide a reference for theoretical advancement and managerial practice.

The Coupling Mechanism between Corporate Financial Core Competence and Corporate Innovation Capability

Coupling Coordination Theory originated from the concept of “coupling” in physics, which describes the interaction between different

systems, emphasizing the mutual influence and exchange of energy or information among them. (Kikkawa, K. et al., 1999). The conceptual foundations and quantitative methods of coupling coordination analysis have evolved incrementally along research trajectories—such as system interactions and sustainable coordination frameworks. Costanza et al. (1997) innovatively quantified the interactive relationship between ecosystem services and human economic systems; the indicator system and value assessment logic they developed laid the core methodological foundation for subsequent coupling analysis in the ecological-economic domain. Building on this work, Norgaard (2001) proposed a theoretical framework for economic-ecological coordinated development from a systems theory perspective, emphasizing the dynamic equilibrium properties of multi-system synergy. The logic underlying its coordination degree measurement aligns with that of later-developed coupling coordination degree models, thereby expanding the theoretical boundaries of cross-system coordination research. Gonzalez-Benito et al. (2006), in turn, employed structural equation modeling to quantify the coupling relationship between corporate environmental management and stakeholder pressure. This application facilitated the extension of coupling coordination analysis from macro-level contexts to the micro domain of management, enabling the quantitative expansion of the method's utility.

In the field of social sciences, scholars have introduced this theory into research areas such as regional economy, industrial integration, and urban-rural development (Turner et al., 2003; Folke et al., 2005; Seto et al., 2012). By constructing a coupling degree model, the interaction intensity between two or more subsystems can be measured quantitatively—this approach helps reveal the co-evolution mechanism of different subsystems in the dynamic evolution process. Building on this foundation, subsequent scholars proposed the “coupling coordination degree” index, which is used to assess the quality and sustainability of coupling relationships. (Fang et al., 2016; Zhang et al., 2024) The ultimate goal of this index is to identify the optimal development path that maximizes the overall benefits of the system.

The coupling and coordination mechanism between corporate innovation capability and financial core competence is essentially a dynamic and in-depth interactive relationship. Regarding how innovation capability propels financial core competitiveness, da Silva et al. (2018), in their analysis of Brazilian energy enterprises, demonstrated how low-carbon energy technologies and digital-intelligent production control optimize operations: the former replaces traditional power supply and matches energy demand, reducing procurement costs and energy waste; the latter optimizes equipment parameters in real time, lowering energy consumption per unit of

production by 18%-22% and reducing the proportion of energy costs. Furthermore, innovation-driven equipment intelligence upgrades and supply chain digital transformation enhance operational efficiency indicators such as fixed asset turnover and inventory turnover. The accumulation of innovative assets like technological patents and R&D outcomes also strengthens the appreciation potential of corporate assets, thereby improving the asset operation dimension of financial core competitiveness (Zhang et al., 2025). Conversely, financial core competitiveness exerts a significant feedback effect on innovation capability. Brown et al. (2009) argued that internal cash flow—particularly the stable cash flow of firms with strong financial strength—is a key funding source for R&D investment. The R&D expansion of young high-tech firms is highly dependent on internal cash flow and retained earnings; the funding stability derived from financial core competence directly alleviates innovation's financial constraints. Ample and efficient capital supply ensures the continuous advancement of R&D projects, precise financial resource allocation prioritizes funding for high-potential innovative areas, and mature risk hedging mechanisms increase corporate confidence in pursuing disruptive innovations (Illmeyer et al., 2017).

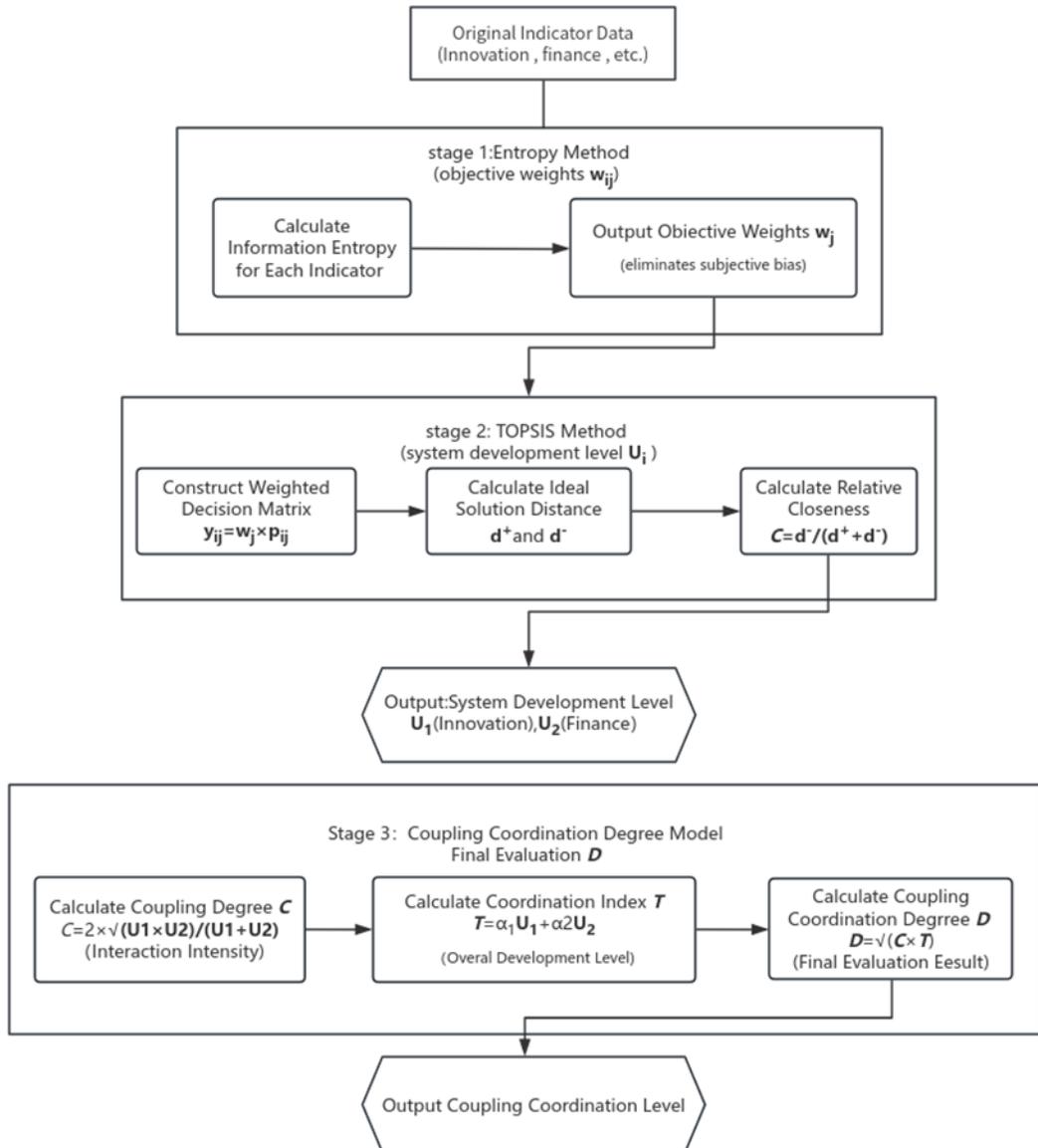
When the coupling between a firm's innovation capability and financial core competence exceeds a critical threshold, it generates systemic synergy. For Chinese energy enterprises, this threshold is even industry-specific, Yang & Zhang (2020) found that energy firms only achieve positive innovation-to-financial performance conversion when their R&D investment intensity crosses a critical value, otherwise redundant innovation input may squeeze profit margins. This synergy not only enables lower-cost resource acquisition and higher-efficiency value realization but also establishes a self-reinforcing cycle where innovation and finance mutually drive upgrades. (Guo, Z et al., 2022) Ultimately, this process constructs a unique market barrier centered on this synergistic advantage, forming a sustainable and hard-to-replicate competitive position. (Ren, Y & Li, B., 2023; Chen, J. et al., 2024).

Existing research on the coupling between innovation capability and financial competitiveness in China's energy enterprises exhibits significant gaps. Theoretically, it lacks a framework that integrates policy-driven dynamics and industry-specific traits, and fails to apply coupling coordination theory specifically to the innovation-finance interplay. Empirically, studies overlook the unique context of energy firms, such as their cost structures and long-cycle green innovation value logic. Methodologically, there is a mismatch in evaluation indicators and a reliance on static approaches, unable to capture the long-term, dynamic evolution of this relationship.

Research Methods

To systematically examine the coupling and coordinated development mechanism between innovation capability and financial core competitiveness of Chinese energy enterprises under the Belt and Road Initiative, this study establishes a structured research framework progressing through “indicator weighting-system evaluation-coupling analysis-driver identification.” First, the entropy method is adopted to objectively assign weights to evaluation indicators within the innovation and financial subsystems, thereby mitigating subjective bias and clarifying the relative importance of each indicator in the integrated assessment. Second, the TOPSIS method is applied to compute the annual comprehensive development levels of the two subsystems, which quantifies their relative developmental status by measuring proximity to the ideal solution. Subsequently, a coupling coordination degree model is employed to assess the interaction strength (coupling degree) between the two systems and their synergistic development level (coordination degree), thus elucidating the quality and phased characteristics of their dynamic interaction. Finally, gray relational analysis is used to identify key determinants affecting system coordination, thereby informing evidence-based policy recommendations.

Figure 1: Three-Stage Modeling Flowchart for Evaluating the Coupling Coordination of Innovation and Financial Systems



Note: Author’s own work.

Entropy Method

The entropy method constitutes a cardinal step in research on inter-system coupling and coordination, where it is utilized to objectively derive weights for the constituent evaluation indicators (Shannon, 1948). This

objective weighting establishes the basis for aggregating indicators into a composite measure of development for each system.

First, an initial matrix is constructed:

This represents X_{ij} the data of the j_{th} indicator in the i_{th} year.

Secondly, since the units of each index are different, it is necessary to standardize the index.

$$B_{ij} = \begin{cases} \frac{A_{ij} - \min(A_{ij})}{\max(A_{ij}) - \min(A_{ij})} & A_{ij} \text{ is positive indicator} \\ \frac{\max(A_{ij}) - A_{ij}}{\max(A_{ij}) - \min(A_{ij})} & A_{ij} \text{ is negative indicator} \end{cases}$$

Suppose there are i sample observations, with the maximum value being g , and j evaluation indicators, with the maximum value being h . A_{ij} represents the original measure indicator sequence, B_{ij} represents the standardized measure indicator sequence, and $\min(A_{ij})$ and $\max(A_{ij})$ are the minimum and maximum value, A_{ij} respectively.

Calculate the proportion of the feature for the n th sample value under the n th indicator:

Calculate the information E_{ij} entropy of the first indicator using the entropy calculation formula:

$$E_{ij} = -k \sum_{i=1}^g P_{ij} \ln P_{ij}$$

where, is $k > 0$, constant term k related to the sample size g ; \ln is the natural logarithm, we generally set $k = \frac{1}{\ln g}$, so $0 \leq E_{ij} \leq 1$.

Calculate the coefficient of variation D_j for the j_{th} indicator based on E_j .

$$D_j = 1 - E_j$$

Calculate the weight W_j of the g_{th} indicator using D_j .

$$W_j = \frac{D_j}{\sum_{j=1}^h D_j}$$

TOPSIS Method

The TOPSIS method is used in coupling coordination studies to compute a “comprehensive closeness score” for each subsystem, based on its distance from ideal reference points (Li, Y et al., 2025). This score objectively reflects each subsystem’s development level and provides a clearly interpretable, standardized measure for calculating the coupling coordination index. Thus, the index evaluates both the strength of system interactions and their joint advancement toward an ideal state.

First, based on the calculated weight w_j and the proportion P_{ij} of the g_{th} indicator, a weighted decision matrix y_{ij} is established.

$$y_{ij} = w_j \times p_{ij}$$

Secondly, the positive ideal solution is determined according to the maximum value of the matrix index, and the corresponding ideal solution vector is constructed.

$$Y^+ = (y_1^+, y_2^+, \dots, y_n^+)$$

The maximum y_{ij} value in the range y_j^+ .

$$y_j^+ = \max (y_{1j}, y_{2j}, \dots, y_{nj})$$

Third, the positive ideal solution of the calculation index:

$$d_i^- = \sqrt{\sum_{j=1}^m (y_{ij} - y_j^+)^2}, i = 1, 2, \dots, n$$

Finally, the degree of closeness between the evaluation b_i object and the optimal value is calculated as the comprehensive level score, and the order is made.

$$b_i = \frac{d_j^-}{d_j^+ + d_j^-}, 0 \leq b_i \leq 1$$

Coupling Coordination Degree Model

The Coupling Coordination Degree Model operationalizes the abstract concept of “synergistic development” into a quantifiable, comparable single index with clear policy implications (Zhao, X., & Chen, B., 2008). Its core contribution lies not merely in measuring the intensity of interaction between systems, but more critically in evaluating whether such interaction leads to an upward developmental trajectory for the system as a whole.

To assess the coupling coordination development stage between innovation and financial core competitiveness for the industry leader, the coupling degree and coupling coordination degree models were constructed and applied.

This subsystem has two components, so the calculation formula is:

$$C_{12} = 2 \times [U_1/U_2(U_1 + U_2)]^2$$

C reflecting the coupling degree between systems, the value ranges from 0 to 1. The magnitude of the value only indicates the mutual coupling degree between corporate innovation and financial core competitiveness or their respective internal elements. A higher value suggests better coupling, while a lower value indicates poorer coupling. However, high coupling does not equate to high coordination; it must be comprehensively evaluated in conjunction with the coordination index T .

The coupling degree reflects the degree of interaction between the enterprise innovation system and the financial core competitiveness or the internal elements. In order to accurately determine the relationship between the subsystems, the following coordination model is established:

$$D_{12} = \sqrt{C_{12} \times T_{12}}$$

$$T_{12} = \alpha_1 U_1 + \alpha_2 U_2$$

In the formula: D_{12} represents the coupling coordination degree between corporate innovation capability and financial core competitiveness, ranging from 0 to 1; T_{12} is the comprehensive evaluation index of the innovation capability of selected pipeline energy enterprises; α_1 and α_2 are respectively undetermined weight coefficients, and $\alpha_1 + \alpha_2 = 1$.

Gray Relational Analysis (GRA)

This study adopts the Gray Relational Analysis method in order to identify the key factors influencing the “innovation-finance” coupling coordination system of energy enterprises and to evaluate the convergence in the temporal trajectories of their element sequences (Kuo, Y. et al., 2008). Suitable for uncertain systems characterized by “small samples and poor information”, this method does not require data to follow a typical distribution and can effectively measure the order of strength of correlations between various factors in the system. It is highly compatible with the characteristics of this study, such as limited sample size and complex system relationships.

The specific procedures are as follows:

$$S_i = \frac{1}{n} \sum_{k=1}^n \frac{\min_i \min_k |y(k) - x_i(k)| + \rho \max_i \max_k |y(k) - x_i(k)|}{|y(k) - x_i(k)| + \rho \max_i \max_k |y(k) - x_i(k)|}$$

Where : $|y(k) - x_i(k)|$ denotes the absolute value of the difference between the evaluated indicator and the reference indicator, ρ is the distinguishing coefficient, with a value of 0.5.

Data Sources and Standardization

Through research, enterprises engaged in energy cooperation with countries along the Belt and Road Initiative from 2018 to 2024 were selected. In the traditional oil and gas sector, three companies—China Petroleum, China Petrochemical, and China National Offshore Oil Corporation (CNOOC)—were chosen, their overseas oil and gas resource cooperation projects have an extensive presence along the Belt and Road Initiative. In the new energy sector, five state-owned enterprises, including China Energy Engineering Corporation, Power China, China General

Nuclear Power Group, Guanghai Energy, and Jinko Solar, were selected, these enterprises serve as key players in new energy investment, engineering construction, and technology transfer within Belt and Road cooperation. The selection of these enterprises was primarily based on the following criteria: industry leadership, proportion of overseas business revenue, and participation in key projects along the Belt and Road Initiative, ensuring the representativeness of the sample and the relevance of the study.

The relevant data mainly came from the National Bureau of Statistics website, annual financial statements of various companies, CNNIC, and Guotai An database. For missing data, the mean method was used for valuation. Due to the diversity of data sources and the existence of differentiated data units in the indicator system, indicators were categorized into positive indicators and moderate indicators, with the latter undergoing moderation treatment.

Empirical Result

Evaluation Index System and Weight of Enterprise Innovation Capability

In developing evaluation frameworks for corporate innovation capabilities, scholars worldwide have conducted multidimensional research. Building upon existing literature and drawing on Cohen and Levinthal's (2015) framework, this study establishes a two-tier indicator system. The primary indicators encompass innovation input capacity and innovation output capacity, with secondary indicators designed to address data completeness and accessibility considerations. The weights of each index are obtained by entropy weight method, as shown in Table 1.

Table 1: Weight of the indicators of innovation ability

primary indicator	index weight	secondary indicator	Indicator selection	index weight
Innovation investment capacity	60.4014%	R&D funding input	Total R&D investment	15.1152%
			R&D investment increased year-on-year	14.9825%
		R&D human input	Proportion of R&D personnel	4.5817%
			Proportion of individuals with a master's degree or higher	13.3590%
			Number of national R&D platforms	12.3630%
Innovation output capacity	39.5985%	Patent development capabilities	Number of patent applications	18.8829%
			Number of granted patents	20.7156%

Based on the results of the tables, regarding the indicator weights for innovation capability, innovation resource input serves as the core support for the innovation capability of state-owned energy enterprises. Among these inputs, financial input accounts for the highest weight, followed by talent input and R&D platforms—this reflects that “finance + talent + platforms” are the core elements of innovation input. In terms of output, patent quality (rather than quantity) is the core evaluation dimension for innovation output.

Evaluation Index System and Weight of Enterprise Financial Core Competitiveness

Financial core competitiveness represents the concrete manifestation of corporate competitiveness in the financial domain, serving as the critical capability for enterprises to create value and achieve sustainable development through financial resources. Drawing on extensive literature and Rappaport’s (1998) value-based management framework, this study identifies multiple driving factors—growth, profitability, and operational efficiency—that collectively determine corporate financial competitiveness. The evaluation system comprises four primary indicators and 15 quantifiable metrics, covering four key financial dimensions: profitability, operational efficiency, growth potential, and debt repayment capacity. These metrics comprehensively address essential financial indicators for listed energy companies, as detailed in the table below. The weights of each index are obtained by entropy weight method, as shown in Table 2.

Table 2: Weight of Financial Core Competitiveness Indicators

primary indicator	index weight	secondary indicator	index weight
profitability	8.6018%	Operating Profit Margin (%)	4.7393%
		Return on Assets (%)	2.666%
		Return on Net Assets (%)	1.1965%
operation capacity	73.0507%	Fixed assets turnover rate (times/year)	26.4184%
		Current assets turnover (times/year)	30.6020%
		Inventory turnover rate (times/year)	10.8302%
		Accounts receivable turnover rate (times/year)	8.7850%
Growth potential	7.47%	Total assets growth rate (%)	4.8775%
		turnover of net assets (%)	2.5925%
debt paying ability	6.2496%	current ratio (%)	3.9381%
		quick ratio (%)	1.673%
		asset-liability ratio (%)	1.6385%

The results indicate that the financial core competitiveness of state-owned energy enterprises exhibits a distinct structural characteristic: operational capacity occupies the dominant position, with current asset

turnover and fixed asset turnover serving as the key driving factors, whereas the weights assigned to profitability, growth potential, and debt-paying ability are relatively low. This qualitative finding aligns closely with the industry-specific attribute of energy enterprises as asset-intensive and capital-intensive entities. Such enterprises hold substantial volumes of fixed assets and current assets; their financial health and sustainability depend more on the efficiency of asset turnover rather than merely on profit scale or leverage level. Therefore, the high-weight structure reveals that, in advancing the Belt and Road Initiative, the financial strategy of state-owned energy enterprises tends to consolidate core competitiveness by enhancing asset operational efficiency. Meanwhile, the overall debt-servicing risk of the industry remains controllable, providing a financial safety margin that enables enterprises to focus on long-term asset optimization and intensive development.

Comprehensive Development Level of the Dual Systems Based on the TOPSIS Method

After determining indicator weights via the entropy method, this study applies the TOPSIS method to calculate the comprehensive development level of the two subsystems. The TOPSIS method measures the “closeness degree (C)” of each sample to the ideal solution, where a higher C indicates a better comprehensive development level of the system.

Table 3: Comprehensive evaluation levels of the dual systems

a particular year	Comprehensive evaluation level of the innovation capability system			Comprehensive evaluation level of financial core competitiveness		
	ideal solution distance d^+	negative imaginary solution distance d^-	close degree C	ideal solution distance d^+	negative imaginary solution distance d^-	close degree C
2019	0.3252	0.1056	0.2430	0.4316	0.0760	0.1422
2020	0.3215	0.1105	0.2528	0.4317	0.0773	0.1436
2021	0.3056	0.1314	0.2958	0.4357	0.0606	0.1198
2022	0.3058	0.1359	0.3102	0.4342	0.0616	0.1231
2023	0.3081	0.1359	0.2973	0.4281	0.0789	0.1531
2024	0.3063	0.1451	0.3155	0.4059	0.1204	0.2157

The closeness degree (C) of the innovation capability system shows a steady upward trend, rising from 0.2430 to 0.3155, reflecting the gradual transformation of B&R energy enterprises’ innovation inputs into improved innovation capability. In contrast, the C value of the financial core competitiveness system fluctuates more notably, it slightly declines in 2021-2022 before surging to 0.2157 in 2024. This volatility echoes the energy industry’s sensitivity to external shocks such as international energy price

fluctuations, while the 2024 rebound signals a recovery in financial operational efficiency.

Coupling Degree Model

This paper draws on the classification criteria for coupling degrees used by Shi,T.et et al. (2020) in their research on economic and environmental systems. As shown in the table below:

Table 4: Criteria for classifying coupling degrees

Group number	degree of coupling	coupling type
1	$C=0$	at arm's length
2	$0 < C \leq 0.3$	low level coupling
3	$0.3 < C \leq 0.5$	antagonist
4	$0.5 < C \leq 0.8$	breaking-in period
5	$0.8 < C \leq 1$	high level coupling
6	$C=1$	good resonance type

The improvement of corporate innovation promotes the enhancement of financial core competitiveness, and the improvement of financial competitiveness drives the innovative operation of enterprises. Therefore, combined with relevant research, $\alpha_1 = 0.5, \alpha_2 = 0.5$ are assigned.

Table 5: Criteria for Coupling and Coordination

broad heading	coupling coordination degree	coordination level
phase of decline	0.00—0.10	extreme dysregulation
	0.10—0.20	major maladjustment
	0.20—0.30	moderate dysregulation
	0.30—0.40	mild dysregulation
transition period	0.40—0.50	approaching deficit
	0.50—0.55	coordinated coupling
	0.55—0.60	primary coupling coordination
coordinated development period	0.60—0.65	intermediate coupling
		coordination
	0.65—0.70	Good coupling coordination
	0.70—1.00	high quality coupling coordination

Coupling and Coordination Relationship Analysis

The development of corporate innovation capability in China is closely linked to the enhancement of financial core competitiveness. Corporate innovation capability optimizes resource allocation and improves management efficiency, thereby driving the growth of financial core competitiveness. Meanwhile, the strengthening of financial core competitiveness provides enterprises with the necessary financial, human, and managerial support for the advancement of innovation capabilities.

Table 6: Results of Coupling Coordination Measurement of Enterprise Innovation and Financial Core Competitiveness Development from 2018 to 2024

a particular year	The overall level of corporate innovation capability	The comprehensive level of core financial competitiveness of enterprises	C	T	D
2018	0.2362	0.1348	0.1748	0.1855	0.1819
2019	0.2614	0.1371	0.1893	0.1992	0.1924
2020	0.2770	0.1027	0.1686	0.1789	0.1789
2021	0.3396	0.1064	0.1901	0.2230	0.2058
2022	0.3628	0.1397	0.2252	0.2512	0.2378
2023	0.3445	0.2699	0.3049	0.3072	0.3060
2024	0.3551	0.1189	0.2054	0.2370	0.2207

The table reveals that from 2018 to 2020, enterprises overall innovation capability demonstrated steady growth, while their financial core competitiveness experienced a decline in 2020. The relatively slow growth of coupling degree C , coordination index T , and coupling coordination degree D indicates that although enterprises made progress in innovation during this period, the positive impact of innovation on financial competitiveness remained limited, and the two aspects had not yet formed a synergistic development mechanism. This may be attributed to innovation investments being in the early stages and not fully translating into economic benefits, coupled with enterprises' inadequate financial resource allocation to support innovation activities, as well as the partial impact of the COVID-19 pandemic.

The table reveals that from 2018 to 2020, enterprises' overall innovation capability demonstrated steady growth, while their financial core competitiveness experienced a decline in 2020. The relatively slow growth of coupling degree C , coordination index T , and coupling coordination degree D indicates that although enterprises made progress in innovation during this period, the positive impact of innovation on financial competitiveness remained limited, and the two aspects had not yet formed a synergistic development mechanism. This may be attributed to innovation investments being in the early stages and not fully translating into economic benefits, or enterprises failing to allocate financial resources effectively to support innovation activities. Additionally, the impact of the COVID-19 pandemic also contributed to this situation.

*Analysis of Key Influencing Factors Based on Gray Relational Degree***Table 7:** Grey Correlation Degree of Various Influencing Factors

Evaluation items	Average Correlation Degree	Overall ranking
Patent authorization quantity	1.000	1
R & D personnel ratio	0.757	2
Fixed asset turnover rate	0.751	3
Total R & D investment	0.713	4
Return on Equity (ROE)	0.628	5

The gray relational analysis results indicate that the number of patent authorizations, as a direct reflection of innovation output, is the most strongly correlated core dominant factor, highlighting that the system's coordination ultimately relies on quantifiable technological achievements to attract financial capital and realize value transformation. The ratio of R&D personnel and the fixed asset turnover rate serve as key supports, constituting the talent foundation and efficiency guarantee for system coordination, respectively, emphasizing the pivotal role of human resources and asset operation in linking innovation and finance. Meanwhile, the total R&D investment and return on equity act as important foundations, providing the capital prerequisite for innovation and the profitability guarantee for sustainable development, respectively.

Strategic Suggestions for Improving the Innovation Ability and Financial Synergy of Enterprises

Based on the empirical analysis of the phased characteristics and existing problems in the coupling and coordinated development of corporate innovation capability and financial core competitiveness, and in alignment with the new “dual circulation” development paradigm and the high-quality development requirements of the “Belt and Road” initiative, this study proposes targeted strategies from three dimensions: corporate micro-level operations, regional meso-level guidance, and the macro-level expansion of research methods.

Building a Closed Loop of “Innovation-Finance” Synergy to Enhance the Internal Linkage Ability of Enterprises

Establishing an innovation-finance closed-loop system and strengthening internal corporate synergy requires focusing on three dimensions: indicator prioritization, financial innovation, and industrial chain coordination. Empirical results demonstrate that total R&D investment (15.12% weighting) and patent grants (20.72% weighting) significantly contribute to innovation capacity, while operational capability (73.05% weighting) serves as the cornerstone of financial core competitiveness.

To address the decline in financial core competitiveness due to sudden changes in the external environment, enterprises need to optimize R&D budget management and establish a dynamic cycle model of “innovation investment—project profitability—cash flow reinvestment”. Specifically, the quality of innovation output and cash flow returns should be incorporated into the financial budget evaluation system. By means of technology transfer, patent pledge financing, and other methods, the liquidity of innovation assets can be enhanced, transforming technological advantages into tangible financial benefits. To mitigate the decline in financial core competitiveness in 2024 caused by sudden changes in the external environment, financial stability can be improved through asset securitization to activate existing assets and cross-border settlement to hedge exchange rate risks. At the management level, accounting elements can also be restructured to include more intangible assets in the reporting system. Moreover, incentive policies for innovation talent, such as innovation compensation expenditures and R&D equipment design investments, demonstrate better effects on innovation enhancement compared to traditional financing constraint mitigation approaches. Enterprises should strive to establish an "innovation partner database" and collaborate with universities and research institutions along the Belt and Road to jointly build laboratories, forming stable relationships for shared knowledge creation.

Strengthening Regional Coordination Mechanism to Promote Efficient Allocation of Resources and Factors

To strengthen regional coordination mechanisms and promote efficient allocation of resources and factors, efforts should be made from both platform construction and factor mobility. On one hand, it is necessary to establish a transnational energy industry alliance, uniting energy enterprises and research institutions along the route to create a regular communication and coordination mechanism, thereby optimizing the sustainability and technical compatibility of power projects. For example, by combining expert consultations, SWOT analysis, and the analytic hierarchy process, the alliance can systematically assess the opportunities and challenges of coal, hydropower, and wind power projects, facilitating precise alignment between corporate needs and scientific research technologies, and providing decision-making support for the institutional development of energy cooperation. The ASEAN “10+5” region has established a diversified cooperation mechanism encompassing bilateral, sub-regional, intra-regional multilateral, and extra-regional multilateral frameworks, promoting the interconnectivity of energy infrastructure such as power grids and oil and gas pipelines, breaking down transmission barriers, and enhancing resource allocation efficiency. On the other hand, it is essential to facilitate the inter-

regional flow of technological, human, and financial factors. By establishing technology trading markets and improving evaluation and transfer services, technology transactions can be promoted to optimize technology allocation. In terms of financial factor allocation, efforts should focus on building a financial support system characterized by “policy guidance—market dominance—cross-border linkage”. Through deepening institutional cooperation with financial institutions in countries along the Belt and Road, a comprehensive service platform integrating cross-border settlement, green credit, and energy futures should be established to provide energy enterprises with full-cycle financing solutions.

Optimizing the Evaluation Method System and Consolidating the Technical Foundation of Coupling Research

The core objective of coupling research is to elucidate the interaction mechanisms and synergistic effects among different systems, such as those involving talent, capital, and technology. It is crucial to move beyond the limitations of single-indicator evaluations and establish a systematic methodological framework. By applying complex systems theory, regional factor allocation can be conceptualized as a complex dynamic system structured around “factor flow—institutional environment—industrial demand.” Building on traditional input-output indicators, spatial spillover effects, network correlations, and dynamic evolutionary features are incorporated to construct a three-dimensional evaluation framework that encompasses “static state, dynamic process, and network structure.” This approach significantly enhances the dynamic assessment of inter-factor correlations. Secondly, research on factor coupling exhibits strong interdisciplinary characteristics. Future studies must transcend traditional disciplinary boundaries through profound methodological innovation, thereby overcoming the linear assumptions inherent in single-discipline approaches. Thirdly, establishing a data-driven empirical research paradigm requires the integration of multi-source heterogeneous data. Techniques such as natural language processing (NLP) can be employed to extract control variables from policy texts, while geographic information systems (GIS) can map the spatial distribution of factor flows. This addresses common limitations in traditional evaluations, such as unidimensional data and update lag. Furthermore, developing counterfactual assessments and policy simulations—for instance, through agent-based modeling—enables researchers to evaluate the impact of different policy combinations on factor allocation efficiency, providing a pathway for the iterative refinement of evaluation methodologies. By deeply integrating quantitative techniques with domain knowledge, this paradigm achieves both representational accuracy and theoretical generalizability. Fourthly, expanding cross-scale correlation

analysis necessitates the establishment of an integrative framework that links multi-scale data. This systems perspective is essential for clarifying the transmission pathways and mutual influences of factor coupling across different spatial and organizational levels. Fifthly, the adaptability analysis of policy tools should be enhanced. Based on simulation results, tailored policy combinations should be designed for different stages of coupling development, supported by mechanisms for dynamic monitoring and adjustment to align with evolving needs. Finally, methodological innovation should be actively advanced by integrating insights and tools from complex network theory, machine learning, and econometrics. Such synthesis is key to elevating the overall scientific rigor and explanatory power of research in this field.

Conflict of Interest: The authors reported no conflict of interest.

Data Availability: All data are included in the content of the paper.

Funding Statement: The authors did not obtain any funding for this research.

References:

1. Agazu, B. G., & Kero, C. A. (2024). Innovation strategy and firm competitiveness: A systematic literature review. *Journal of Innovation and Entrepreneurship*, 13(24). <https://doi.org/10.1186/s13731-024-00381-9>
2. Alabi, M. (2024). Innovation ecosystems and collaborative networks: Fostering innovation through partnerships and open innovation. ResearchGate. <https://www.researchgate.net/publication/385074256>
3. Bega, F., & Lin, B. Q. (2023). China's belt & road initiative energy cooperation: International assessment of the power projects. *Energy*, 270:126951. <https://doi.org/10.1016/j.energy.2023.126951>
4. Bromham, L., Dinnage, R., & Hua, X. (2016). Interdisciplinary research has consistently higher funding success. *Nature*, 534(7609): 684-687. <https://doi.org/10.1038/nature18315>
5. Brown, J. R., Fazzari, S. M., & Petersen, B. C. (2009). Financing innovation and growth: Cash flow, external equity, and the 1990s R&D boom. *The Journal of Finance*, 64(1):151-185. <https://doi.org/10.1111/j.1540-6261.2008.01431.x>
6. Brown, J. R., Martinsson, G., & Petersen, B. C. (2012). Do financing constraints matter for R&D?. *European Economic Review*, 56(8):1512-1529. <https://doi.org/10.1016/j.euroecorev.2012.07.007>

7. Castelli, M., Groznik, A., & Popovič, A. (2020). Forecasting electricity prices: A machine learning approach. *Algorithms*, 13(5): 119. <https://doi.org/10.3390/a13050119>
8. Chen, J., Li, Q., Zhang, P., & Wang, X. (2024). Does Technological Innovation Efficiency Improve the Growth of New Energy Enterprises? Evidence from Listed Companies in China. *Sustainability*, 16(4):1573. <https://doi.org/10.3390/su16041573>
9. Chen, X. L. (2009) Comprehensive Evaluation Analysis of Financial Core Competitiveness of Listed Companies. *International Journal of Business and Management*,4(10):89-95. <https://doi.org/10.5539/ijbm.v4n10p89>
10. Chikán, A., (2008). National and firm competitiveness: a general research model. *Competitiveness Review An International Business Journal incorporating Journal of Global Competitiveness*, 18(1/2):20-28. <https://doi.org/10.1108/10595420810874583>
11. Chikán, A., Czakó, E., Kiss-Dobronyi, B., & Losonci, D. (2022). Firm competitiveness: A general model and a manufacturing application. *International Journal of Production Economics*, 243:108316. <https://doi.org/10.1016/j.ijpe.2021.108316>
12. Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35(1):128-152. <https://doi.org/10.2307/2393553>
13. Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B. & van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature*, 387(6630): 253-260. <https://doi.org/10.1038/387253a0>
14. da Silva, V. R. G., Loures, E. D. R., de Lima, E. P., & da Costa, S. E. G. (2018). Energy management in industry: An enterprise engineering approach. *Brazilian Archives of Biology and Technology*, 61(SI): e18000160. <https://doi.org/10.1590/1678-4324-smart-2018000160>
15. Deku, S. Y., Kara, A., & Zhou, Y. (2019). Securitization, bank behaviour and financial stability: A systematic review of the recent empirical literature. *International Review of Financial Analysis*, 61:245-254. <https://doi.org/10.1016/j.irfa.2018.11.013>
16. Demir, F., & Lukes, M. (2025). Collaboration of corporates with coworking spaces: different pathways to develop innovation capabilities. *R & D Management*, 55(1): 282-299. <https://doi.org/10.1111/rdm.12697>
17. European commission, Joint Research Center. (2025). POTENCIA: Policy-Oriented Tool for Energy and Climate Change Impact

- Assessment. <https://web.jrc.ec.europa.eu/policy-model-inventory/explore/models/model-potencia/>.
18. Fang, C., Wang, Y. & Fang, J. (2016). A comprehensive assessment of urban vulnerability and its spatial differentiation in China. *Journal of Geographical Science*, 12(26): 153-170. <https://doi.org/10.1007/s11442-016-1260-9>
 19. Feng, Z. (2020). Evaluating the coupling coordination degree of green finance and marine eco-environment based on AHP and grey system theory. *Journal of Coastal Research*, 110(SI): 277-281. <https://www.jcronline.org/doi/abs/10.2112/JCOASTRES-D-19-00123.1>
 20. Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources*, 30: 441-473. <https://doi.org/10.1146/annurev.energy.30.050504.144511>
 21. Fünfgeld, A. (2019). ASEAN Energy Connectivity: Energy, Infrastructure and Regional Cooperation in Southeast Asia. *The Indonesian Quarterly*, 46(4): 315-345.
 22. Gonzalez-Benito, J., & Gonzalez-Benito, O. (2006). The influence of stakeholder pressure on environmental performance: The mediating role of management commitment. *Journal of Business Ethics*, 67(4): 361-376. <https://doi.org/10.1007/s10551-006-9114-4>
 23. Guo, Z., Peng, Y., & Chen, Y. (2022). How Digital Finance Affects the Continuous Technological Innovation of Chinese Energy Companies?. *Frontiers in Environmental Science*, 10: 836144. <https://doi.org/10.3389/fenvs.2022.836144>
 24. Hsiao, C. (2024). Machine learning and econometrics. *The Singapore Economic Review*, 69(4): 1601-1616. <https://doi.org/10.1142/S0217590824450127>
 25. Huang, D., Xu, G., Li, C., & Yang, S. (2025). Effects of high-tech industrial agglomeration and innovation on regional economic development in China: Evidence from spatial-temporal analysis and Spatial Durbin Model. *Economic Analysis and Policy*, 86: 692-712. <https://doi.org/10.1016/j.eap.2025.04.005>
 26. Huang, J., Guo, C., & Yan, S. (2025). The integration of technology and finance and corporate innovation boundary. *Finance Research Letters*, 78: 107135. <https://doi.org/10.1016/j.frl.2025.107135>
 27. Hwang C L, Yoon K. *Methods for Multiple Attribute Decision Making[M]*. Springer Berlin Heidelberg, 1981(07): 60-88.
 28. Illmeyer, M., Grosch, D., Kittler, M., & Priess, P. (2017). The impact of financial management on innovation. *Journal of Entrepreneurship and Sustainability Issues*, 5(1):58-71. <https://doi.org/10.9770/jesi.>

29. J.Xu, M., Zhang, Y., Sun, H., Tang, Y., & Li, J. (2024). How digital transformation enhances corporate innovation performance: The mediating roles of big data capabilities and organizational agility. *Heliyon*, 10(14): e34905. <https://doi.org/10.1016/j.heliyon.2024.e34905>
30. Jin, Z., & Mihalcea, R. (2023). Natural language processing for policymaking. In *Handbook of Computational Social Science for Policy*. Springer 23(2): 141-162. <https://doi.org/10.48550/arXiv.2302.03490>
31. Kikkawa, K., Virasoro, M. A., & Wadia, S. R. (Eds.). (1999). *Quest for Symmetry, A: Selected Works of Bunji Sakita*. World Scientific Publishing Co Pte Ltd. <https://www.booktopia.com.au/quest-for-symmetry-a-keiji-kikkawa/book/9789810236434.html>
32. Kuo, Y., Yang, T., & Huang, G. W. (2008). The use of grey relational analysis in solving multiple attribute decision-making problems. *Computers and Industrial Engineering*, 55(1): 80-93.
33. Laursen, K., & Salter, A. (2006). Open for innovation: The role of openness in explaining innovation performance among UK manufacturing firms. *Strategic Management Journal*, 27(2):131-150. <https://doi.org/10.1002/smj.507>
34. Lawson, B., & Samson, D. A. (2001). Developing innovation capability in organisations: A dynamic capabilities approach. *International Journal of Innovation Management*, 5(3): 377-400. <https://doi.org/10.1142/S1363919601000427>
35. Li, Y., Zhang, L., & Wang, H. (2025). *Collaborative Development between Artificial Intelligence and the Digital Economy: An Empirical Study of Beijing Based on the Entropy Weight and Coupling Coordination Model*. Atlantis Press. <https://doi.org/10.2991/978-94-6463-138-912>.
36. Lianto, B., Septianto, F., & Raharja, D. (2023). Identifying key assessment factors for a company's innovation capability based on intellectual capital: An application of the fuzzy Delphi method. *Sustainability*, 15(7): 6001. <https://doi.org/10.3390/su15076001>
37. Myers, S. C., & Majluf, N. S. (1984). Corporate financing and investment decisions when firms have information that investors do not have. *Journal of Financial Economics*,13(2):187-221. [https://doi.org/10.1016/0304-405X\(84\)90023-0](https://doi.org/10.1016/0304-405X(84)90023-0)
38. Narcizo, R. B., Canen, A. G., & Tammela, I. (2017). A conceptual framework to represent the theoretical domain of “innovation capability” in organizations. *Journal of Entrepreneurship, Management and Innovation*, 13(1): 147-166. <https://doi.org/10.7341/20171316>

39. National Development and Reform Commission, National Energy Administration. (2024). Jointly Building the Belt and Road Green Energy Cooperation Report (2024). https://www.cpnnc.com.cn/news/xwtt/202410/t20241023_1745412.html.
40. Negash, M. (2003). Rethinking the reporting of intangibles. *South African Journal of Accounting Research*, 17(1): 23-40. <https://doi.org/10.1080/10291954.2003.11435104>
41. Norgaard, R. B. & Kallis, G. (2010). Coevolutionary ecological economics. *Ecological Economics*, 69 (3): 227-239. <https://doi.org/10.1016/j.ecolecon.2009.09.017>
42. Porter, M. E., & Kramer, M. R. (2011). Creating shared value. *Harvard Business Review*.
43. Prahalad, C.K., & Hamel, G. (1990). The Core Competence of the Corporation. *Harvard Business Review*, 68:275-292. https://doi.org/10.1007/3-540-30763-X_14
44. Rappaport, A. Rappaport, A. (1981). Strategic analysis for more profitable acquisitions. *Harvard Business Review*, 59(4): 99-106.
45. Ren, Y & Li, B. (2023). Digital Transformation, Green Technology Innovation and Enterprise Financial Performance: Empirical Evidence from the Textual Analysis of the Annual Reports of Listed Renewable Energy Enterprises in China. *Sustainability*, 15(1): 712. <https://doi.org/10.3390/su15010712>
46. Santa, M., Stojkoski, V., Josimovski, M., & Trpevski, I. (2019). Robust determinants of companies' capacity to innovate: a Bayesian model averaging approach. *Technology Analysis and Strategic Management*, 31(2): 1-14. <https://doi.org/10.1080/09537325.2019.1605052>
47. Sempere-Ripoll, F., Estelles-Miguel, S., Rojas-Alvarado, R., & Hervas-Oliver, J.-L. (2020). Does technological innovation drive corporate sustainability? Empirical evidence for the European financial industry in catching-up and Central and Eastern Europe countries. *Sustainability*, 12(6): 2261. <https://doi.org/10.3390/su12062261>
48. Seto, K. C., Güneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences of the United States of America*, 109(40): 16083-16088. <http://www.jstor.org/stable/41763206>
49. Shannon, C. E. (1948). A mathematical theory of communication. *Bell System Technical Journal*, 27(3): 379-423. <https://doi.org/10.1002/j.1538-7305.1948.tb01338.x>.

50. Shi, T., Yang, S., Zhang, W., & Zhou, Q. (2020). Coupling coordination degree measurement and spatiotemporal heterogeneity between economic development and ecological environment— Empirical evidence from tropical and subtropical regions of China. *Journal of Cleaner Production*, 244:118739. <https://doi.org/10.1016/j.jclepro.2019.118739>
51. Stein, J. C. (1997). Internal capital markets and the competition for corporate resources. *The Journal of Finance*, 52(1): 111-133. <https://doi.org/10.1111/j.1540-6261.1997.tb03810.x>
52. Sun, C., Skapa, S., Liu, J., Horak, J., & Yang, Y. (2021). Does core competence affect corporate social responsibility?. *Journal of Competitiveness*, 13(4):132-150. <https://doi.org/10.7441/joc.2021.04.08>
53. Sun, Z., Zhao, L., Mehrotra, A., Salam, M. A., & Yaqub, M. Z. (2025). Digital transformation and corporate green innovation: An affordance theory perspective. *Business Strategy and the Environment*, 34(1): 433-449. <https://doi.org/10.1002/bse.3991>
54. Turner, B. L., II, Kasperson, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., Eckley, N., Kasperson, J. X., Luers, A., Martello, M. L., Polsky, C., Pulsipher, A., & Schiller, A. (2003). A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences of the United States of America*, 100(14): 8074-8079. <https://doi.org/10.1073/pnas.1231335100>
55. Wang, B., Gong, S., & Yang, Y. (2023). Innovation capability, global cooperation, and sustainable development along the Belt and Road Initiative. *Sustainable Development*, 31(5):3490-3512. <https://doi.org/10.1002/sd.2599>
56. Yang, H., & Zhang, W. (2020). The impact of energy enterprises' technological innovation capability on financial performance: A study on the threshold effect based on enterprise scale. *Journal of Technology Economics*, 39(8):10.
57. Yue Jun , Ting Liang & Zongwu Cai. (2021). Can Technological Innovation Bring an Economic and Environmental Benefit to Energy Firms: An Evidence from China? WORKING PAPERS SERIES IN THEORETICAL AND APPLIED ECONOMICS 202112. University of Kansas, Department of Economics. <https://kuwpaper.ku.edu/2021Papers/202112.pdf>.
58. Zhang, C. (2025). Data elements, policy innovation, and corporate ESG: Insights from China's national big data comprehensive pilot zones. *Sustainable Futures*, 10: 101145. <https://doi.org/10.1016/j.sftr.2025.101145>

59. Zhang, L., Wu, S., Chen, L. et al. (2024) Coupling coordination analysis of new urbanization and rural decarbonization in China. *Environment, Development and Sustainability* ,12(14): 205-210. <https://doi.org/10.1007/s10668-024-05656-5>
60. Zhang, L., Zhao, Y., Liu, L., Sun, H., & Wang, Y. (2025). The spatial effects of green-innovation coupling and coordinated development from the perspective of digital inclusive finance: Evidence from China. *Technological Forecasting and Social Change*, 210:123884. <https://doi.org/10.1016/j.techfore.2024.123884>
61. Zhang, Y., Li, F., Li, M., & Hao, J. (2025). Spatiotemporal evolution and driving mechanisms of urban ecological asset utilization efficiency from a “technology-scale-structure” perspective. *Land*, 14(9): 1837. <https://doi.org/10.3390/land14091837>
62. Zhao, J. (2024). How do innovation factor allocation and institutional environment affect high-quality economic development? Evidence from China. *Journal of Innovation & Knowledge*, 9:100475. <https://doi.org/10.1016/j.jik.2024.100475>
63. Zhao, X., & Chen, B. (2008). Coupling mechanism and coordinated development model of urbanization and ecological environment. *Urban Studies*, 15(1): 1-8.