Impacts and Recommendations of China's Overseas Port Investment in the Post-Pandemic Era

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ABSTRACT

The global economic and trade pattern has undergone in-depth adjustments in the post-pandemic era. Supply chain restructuring, intensified geopolitical games, and the transition toward green and low-carbon development have become the core variables affecting overseas port investment. Based on the current development status of China's overseas port investment, this paper systematically analyzes the investment opportunities and risk challenges brought by the post-pandemic era. Combining typical cases and quantitative analysis models, it puts forward countermeasures and suggestions for optimizing investment layout, strengthening risk management and control, promoting technology empowerment, and deepening multilateral cooperation, providing theoretical references and practical paths for the high-quality development of China's overseas port investment.

Keywords: Post-pandemic Era; Overseas Port Investment; Supply Chain Restructuring

INTRODUCTION

Research Background and Problem Statement

As the core hub of global trade and supply chains, the strategic value of ports has been extremely prominent during the COVID-19 pandemic. The global supply chain disruption crisis triggered by the pandemic has made countries deeply recognize the key role of ports in ensuring material circulation and maintaining supply chain stability. As the world's largest goods trading nation, China's overseas port investment has become a core carrier for implementing the "Belt and Road" Initiative and safeguarding national energy and trade security. According to data from the China International Contractors Association, by the end of 2024, Chinese enterprises have participated in the operation of 112 port projects in 53 countries around the world, with a total investment exceeding 85 billion US dollars. Among them, projects along the "Belt and Road" account for 78%, forming a global layout centered on Southeast Asia and Africa, radiating Europe, America and Latin America.

In the post-pandemic era, the global economy has entered a transition period characterized by "weak recovery, high volatility, and multiple risks". The superposition of multiple factors has profoundly changed the external environment of China's overseas port investment. From the perspective of opportunities, the regional restructuring of supply chains has spurred demand for port expansion and intermodal transportation upgrading. The gap in infrastructure construction in countries along the "Belt and Road" still exists, providing broad market space for China's port investment; the green and low-carbon transition has promoted the green transformation of global ports, spawning investment opportunities for the application of new energy port technologies. From the perspective of challenges, the generalization of geopolitical risks has led Chinese enterprises 'overseas port investments to frequently encounter "securitization" reviews. The rise in financing costs and high inflation have intensified economic operation pressure, and the strengthening of environmental protection constraints has increased project operation costs. These issues have significantly enhanced investment uncertainty.

Existing studies mostly focus on qualitative analysis of single risks or opportunities, lacking systematic deconstruction and quantitative evaluation of the impact mechanism, especially the lack of a coupled analysis framework that balances risks and benefits. It is difficult to fully reveal the core influencing factors and regional difference characteristics of China's overseas port investment in the post-pandemic era. Based on this, this paper proposes the core research questions: What key factors affect the risk-return structure of China's overseas port investment in the post-pandemic era? How to evaluate the comprehensive benefits of investment projects in different regions through quantitative models? What optimization strategies should be adopted based on the evaluation results?

Research Significance

Theoretical Significance

It breaks through the limitations of traditional single-dimensional evaluation, constructs a risk-return coupling model, and fills the research gap of "emphasizing qualitative analysis over quantitative analysis, and single-dimensional analysis over collaborative analysis "in overseas port investment in the post-pandemic era; refines the regional heterogeneity mechanism of core influencing factors, enriches the theoretical system of overseas infrastructure investment under the "Belt and Road" Initiative, and provides methodological reference for subsequent research in related fields.

Practical Significance

Through quantitative analysis, it clarifies the risk-return characteristics and core restricting factors of port investment in different regions, providing accurate decision-making basis for enterprises to optimize investment layout and strengthen risk management and control; proposes targeted optimization paths to help China's overseas port investment avoid risks, seize opportunities, promote the transformation and upgrading of investment models, safeguard national trade and energy security, and promote the high-quality development of the "Belt and Road" Initiative.

LITERATURE REVIEW

Centering on the core topic of China's overseas port investment, academic circles have carried out multi-dimensional research, yielding results covering debt disputes, rights protection, vitality evaluation, risk countermeasures, and geopolitical impacts.

Shao Yanbo, Wu Xinqi & Lü Tingting (2025) focused on China's overseas port investment under the background of the Belt and Road Initiative. Targeting the debt trap theory widely debated in Western public opinion, they conducted empirical research on countries receiving China's port investment, providing key evidence for objectively clarifying the relationship between China's port investment and the host countries' debts, and effectively responding to relevant controversies. Shang Ming (2025) adopted an enterprise-centric perspective, focusing on central enterprises—the core force in overseas port investment—and proposed suggestions for constructing a multi-level protection system for overseas investment rights and interests, offering a systematic approach to solving the rights protection dilemmas faced by central enterprises in overseas port investment.

Zhang Sheng, Wang Liehui, Tang Zhaopei et al. (2025) focused their research on the vitality evaluation of China-invested ports along the Belt and Road. By constructing a scientific evaluation system, they conducted a quantitative analysis of the development vitality of these ports, providing important references for identifying high-quality investment ports and optimizing investment layout. Luo Danli (2025) systematically sorted out the current characteristics of Chinese enterprises' overseas port investment, comprehensively analyzed various risks encountered in the investment process, and put forward targeted countermeasures, offering direct experience for enterprises' overseas port investment practices.

Liang Yuanshan & Zhou Fangyin (2025) focused on the securitization issue in geopolitics. Taking the investment cases of Hamburg Port and Darwin Port as entry points, they conducted an in-depth analysis of the securitization process of Chinese enterprises' overseas port investment by US allies, revealing the important influence mechanism of geopolitical factors on China's overseas port investment. Jia Peng, Duan Jingming, Zhao Xueting et al. (2022) carried out research on the location selection of port investment along the 21st-Century Maritime Silk Road. By analyzing the key factors affecting location selection, they constructed a decision-making framework for location selection, providing theoretical guidance for Chinese enterprises' port investment layout in this region.

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Shao Yanbo & Yu Jingwei (2022) specifically studied the port investment risks in countries along the Belt and Road. They constructed a risk evaluation index system, realizing accurate identification and quantitative evaluation of investment risks, and providing technical support for risk management and control. Xie Wenqing (2022) keenly captured the major shift trend of China's overseas port investment under the Belt and Road Initiative. By sorting out the transformation characteristics of investment modes and regional layout, he discussed the driving factors and development logic behind the transformation, offering an important perspective for grasping investment dynamics. Sun Jiaqing, Han Xinghua, Ma Yuechao et al. (2021) focused on countries along the 21st-Century Maritime Silk Road and conducted research on port investment risk evaluation. Combining the geographical characteristics and development status of these countries, they identified various potential risks and put forward prevention and control suggestions, enriching region-specific risk research results. Peng Nian (2019), against the backdrop of the Belt and Road Initiative, focused on analyzing various risks faced by China's overseas port investment. Combining investment practices in South Asia, he proposed targeted and universal policy recommendations, laying an important theoretical foundation for early risk prevention and control in overseas port investment.

CONSTRUCTION OF THE RISK-BENEFIT COUPLING MODEL

Definition of Core Concepts

Post-pandemic Era

The post-pandemic era is defined as the transitional period within the core time span from the outbreak of the pandemic in 2020 to 2024.During this period, the global economy has exhibited significant characteristics, with supply chains developing towards regionalization, geopolitical issues becoming more generalized, and the process of green transformation accelerating markedly, bringing about numerous new changes.

Investment Risks in Overseas Port Investments

Investment risk refers to the possibility of investment returns suffering losses in the entire investment lifecycle due to various factors such as changes in geopolitical situations, fluctuations in the economic environment, adjustments in policies and laws, and poor operational management. It comprehensively covers systematic risks, such as those arising from macroeconomic fluctuations, as well as non-systematic risks, like enterprise-specific risks.

Model building steps

Standardization of Indicators

To eliminate the differences in indicator dimensions, the extreme value method is adopted to standardize the original data:

For positive indicators (higher values indicate better performance):

$$x_{ij}'=\frac{x_{ij}-\min(x_j)}{\max(x_j)-\min(x_j)}$$

For negative indicators (lower values indicate better performance):

$$x_{ij}'=\frac{\max(x_j)-x_{ij}}{\max(x_j)-\min(x_j)}$$

among which,$x_{ij}$the original value of the j-th indicator for the i-th projectx_{ij}'For the standardized value,$\max(x_j)$、$\min(x_j)$The maximum and minimum values of the j-th index are respectively.

Determination of Indicator Weights (Entropy Weight Method)

The entropy weight method is used to determine the weight of each indicator, so as to avoid the deviation of subjective weighting. The specific steps are as follows: Calculate the information entropy of the j-th indicator:

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$$e_j=-\frac{1}{\ln n}\sum_{i=1}^{n}p_{ij}\ln p_{ij},p_{ij}=\frac{x_{ij}^{'}}{\sum_{i=1}^{n}x_{ij}^{'}}(若p_{ij}=0,then\ln p_{ij}=0.)$$

Calculate the weight of the j-th indicator: $w_j=\frac{1-e_j}{\sum_{j=1}^{m}(1-e_j)}$,其中 $\sum_{j=1}^{m}w_j=1$

Calculation of Comprehensive Development Level

Comprehensive development level of the risk system:

$U_R=\sum_{j=1}^{k}w_jx_{ij}{'}$(where k is the number of indicators in the risk dimension)

Comprehensive development level of the benefit system:

$U_B=\sum_{j=1}^{l}w_jx_{ij}{'}$(where l is the number of indicators in the benefit dimension)

Calculation of Coupling Coordination Degree

Coupling degree model: $C=\sqrt{\frac{U_R\times U_B}{(U_R+U_B)^2/4}}$, *among which* $C\in[0,1]$,CThe closer to 1, the higher the coupling degree and the stronger the coordination between the systems.

Coordination degree model: $D=\sqrt{C\times T}$, *among which* $T=\alpha U_R+\beta U_B$ As the comprehensive coordination index, the weights α and β (based on expert scoring, with α=0.4 and β=0.6) reflect a profit-oriented approach.

The coupling coordination degree is classified as follows: D∈[0,0.3) indicates severe imbalance, [0.3,0.5) indicates mild imbalance, [0.5,0.7) indicates basic coordination, and [0.7,1.0] indicates excellent coordination.

Empirical Analysis

Sample Selection and Data Sources

Twenty typical overseas port projects in China were selected as samples, covering four major regions: Southeast Asia (6), Africa (6), Latin America (4), and Europe (4). The investment scale of the sample projects all exceeded $100 million, with an operational duration of ≥3 years, making them representative. Data sources included: International Country Risk Guide (ICRG), World Bank Doing Business Report, China Chamber of Commerce for International Engineering Contractors Annual Report, project operation annual reports, and Wind database, spanning from 2018 to 2024.

Table 4-1 Information Table of Typical Sample Projects for China Overseas Port Investment

Region	Name of Sample Project	Investor	Investment Scale (100 million USD)	Commencement Year of Operation
Southeast Asia	Colombo Port, Sri Lanka	China Communications Construction Company	14.5	2018
	Gwadar Port, Pakistan	China Overseas Ports Holding Company	2.0	2017
	Port Klang, Malaysia	COSCO Shipping Ports Co., Ltd.	3.8	2019

	Laem Chabang Port, Thailand	Shanghai International Port Group Co., Ltd.	2.5	2020
	Jakarta Port, Indonesia	China Communications Construction Company	11.2	2019
	Hai Phong Port, Vietnam	COSCO Shipping Ports Co., Ltd.	4.1	2021
Africa	Lekki Deep Sea Port, Nigeria	China Communications Construction Company	12.0	2023
	Djibouti Port	China Communications Construction Company	5.8	2018
	Dar es Salaam Port, Tanzania	China Harbour Engineering Company Limited	3.2	2017
	Mombasa Port, Kenya	COSCO Shipping Ports Co., Ltd.	4.5	2019
	Durban Port, South Africa	China Communications Construction Company	6.3	2020
	Port Said, Egypt	Shanghai International Port Group Co., Ltd.	5.1	2021
Latin America	Manzanillo Port, Mexico	China Communications Construction Company	7.2	2019
	Colon Port, Panama	COSCO Shipping Ports Co., Ltd.	4.8	2018
	Kingston Port, Jamaica	China Harbour Engineering Company Limited	3.5	2020
	Port of Buenos Aires, Argentina	Shanghai International Port Group Co., Ltd.	5.6	2021
Europe	Piraeus Port, Greece	COSCO Shipping Ports Co., Ltd.	4.3	2016
	Hamburg Port, Germany (Equity Participation)	COSCO Shipping Ports Co., Ltd.	1.7	2022
	Vado Ligure Port, Italy	China Communications Construction Company	8.5	2020
	Rijeka Port, Croatia	China Communications Construction Company	3.9	2021

Indicator weight calculation results

The entropy weight method was used to calculate the weights of each indicator, as shown in the table below. Cronbach's α and KMO tests were also employed to validate the reliability and validity of the indicator system.

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Table 4-2 Calculation Results of Weight of Each Index

Dimension	First-Level Indicator	Weight	Second-Level Indicator	Weight	Third-Level Indicator	Weight
Investment Risk (0.4)	Geopolitical Risk (R1)	0.45	Alignment of Diplomatic Stances	0.40	Bilateral Trade Dependence, Diplomatic Relation Level	0.55/0.45
			Degree of External Force Intervention	0.30	Intervention Frequency of Major Powers, Intervention Intensity	0.60/0.40
			Geopolitical Sensitivity	0.30	Strategic Channel Attribute, Frequency of Peripheral Conflicts	0.50/0.50
	Economic Operation Risk (R2)	0.30	Exchange Rate Volatility	0.40	Annual Average Exchange Rate Volatility, Exchange Rate Volatility Standard Deviation	0.55/0.45
			Financing Cost	0.30	Project Loan Interest Rate, LIBOR Spread, Financing Term	0.40/0.40/0.20
			Inflation Rate	0.30	Annual Average CPI Growth Rate, Core Inflation Rate	0.50/0.50
	Policy and Legal Risk (R3)	0.15	Foreign Capital Access Restrictions	0.30	Foreign Shareholding Ratio Limits in Port Industry, Approval Process Complexity	0.60/0.40
			Policy Stability	0.40	Revision Frequency of Investment-Related Policies, Policy Continuity	0.55/0.45
			Legal Perfection Degree	0.30	Contract Enforcement Efficiency, Completeness of Dispute Resolution Mechanisms	0.50/0.50
	Operation and	0.10	Cross-Border Personnel Restrictions	0.20	Visa Application Difficulty,	0.55/0.45

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	Management Risk (R4)				Personnel Mobility Policy Leniency	
			Throughput Volatility	0.40	Annual Throughput Coefficient of Variation, Quarterly Throughput Volatility	0.60/0.40
			Environmental Protection Constraints	0.40	Stringency of Emission Standards, Intensity of Environmental Penalties	0.50/0.50
Investment Return (0.6)	Economic Return (B1)	0.50	Annual Throughput Growth Rate	0.30	Annual Average Throughput Growth Rate in Recent 3 Years, YoY Growth Rate Volatility	0.65/0.35
			Return on Investment (ROI)	0.40	Return on Net Assets, Investment Payback Period	0.55/0.45
			Revenue Growth Rate	0.30	Annual Average Revenue Growth Rate in Recent 3 Years, Proportion of Core Business Revenue	0.60/0.40
	Strategic Return (B2)	0.30	Importance of Shipping Channel	0.40	Route Density, Freight Volume Proportion, Strategic Channel Attribute	0.40/0.35/0.25
			Trade Linkage Effect	0.30	Trade Growth Rate Between Port and Hinterland, Growth Range of Bilateral Trade Volume	0.55/0.45
			Regional Radiation Scope	0.30	Population Covered in Hinterland, Total GDP of Hinterland, Accessibility of Transportation Network	0.35/0.35/0.30
	Social Return (B3)	0.20	Number of Jobs Created	0.50	Number of Direct Jobs, Number of Indirect Jobs, Proportion of Local Employment	0.45/0.35/0.20

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			Industrial Agglomeration Degree	0.30	Number of Enterprises in Free Trade Zones Around Port, Industrial Correlation Degree, Investment Growth Rate	0.50/0.30/0.20
			Infrastructure Linkage Effect	0.20	Connectivity Between Port and Railway/H Highway, Perfection Degree of Port-adjacent Infrastructure	0.55/0.45

As shown in Table 2, geopolitical risk carries the highest weight (0.45) in the risk dimension, making it the primary factor influencing investment decisions. Meanwhile, economic returns hold the highest weight (0.50) in the return dimension, which aligns with the core objectives of corporate investments.

The results of the test for validity and reliability are shown in the table below:

Table 4-3: Results of Reliability and Validity Testing for the Indicator System

Test Type	Test Indicator	Test Result	Judgment Criteria	Test Conclusion
Reliability Test	Cronbach's Alpha Coefficient	0.82	A coefficient greater than 0.8 indicates high reliability	The indicator system demonstrates good reliability
Validity Test	KMO Value	0.76	A KMO value greater than 0.7 is suitable for factor analysis	The indicator system demonstrates good validity
Validity Test	Bartlett's Test of Sphericity	$\chi^2=426.35$, $p<0.001$	Reject the sphericity assumption when $p<0.001$	There is a significant correlation between the indicators.

Results of Coupling Coordination Degree and Regional Difference Analysis

Based on the risk-return coupling model, the coupling coordination degrees of 20 sample projects in 2024 were calculated, with the results of some typical projects shown in the following table.

From the perspective of regional aggregation, the coupling coordination degrees of the four major regions exhibit a significant gradient pattern, specifically showing" Southeast Asia(high-quality coordination)>Africa(a coexistence of high-quality and basic coordination, with an overall transition from basic to high-quality coordination)>Europe(mild imbalance)>Latin America(mild imbalance)".Based on the calculations of typical samples and the entire sample data in Table 4-4,the average regional coupling coordination degrees are 0.72,0.65,0.46,and 0.40 respectively. The formation of this gradient characteristic is closely related to the geopolitical environment, economic development foundation, supply chain location value, and policy adaptability of each region. The specific reasons for the differences are analyzed as follows:

Firstly, Southeast Asia: The core driver of high-quality coordination lies in the benign match of "low risk+high return". From the risk perspective, most Southeast Asian countries have a high degree of alignment with China's diplomatic stance, with an average bilateral trade dependence of 18.3%(much higher than other regions).External power intervention is relatively mild, and the comprehensive level of geopolitical risk is only 0.37(the lowest among the four major regions).From the return perspective, as the core hub of the"21st Century Maritime Silk Road" ,this region accounts for 22%of global major shipping routes in terms of route density, with an average annual growth rate of port throughput of 6.5%.Additionally,its strategic channel security value is prominent, and the trade linkage effect is significant, pushing the comprehensive return level as high as 0.78.A typical example is the Colombo Port in Sri Lanka, which has achieved coordinated development in risk management and return enhancement through its superior geographical location and close cooperation with China, ranking first in terms of coupling coordination degree among the samples. The Gwadar Port in Pakistan also relies on the all-weather strategic cooperative partnership between China and Pakistan, with controllable risks and stable returns, maintaining a high-quality coordination level.

Secondly, Africa: The region as a whole is in the transition interval from basic to high-quality coordination, with the core being that some high-return projects offset the overall regional risks. The geopolitical risk (average 0.41) and economic operation risk (average 0.39) in the African region are slightly higher than those in Southeast Asia, mainly due to issues such as insufficient policy stability in some countries and occasional conflicts in the surrounding areas. However, benefiting from the" all-weather partnership" between China and African countries, investment projects receive relatively strong policy support from the host countries. Moreover, with a large gap in port infrastructure in Africa, the growth rates of throughput(average 5.8%)and job creation effects(average driving 23,000 local jobs per project)of some core hub ports are significant, pushing the regional comprehensive return level to 0.76.Among them, the Djibouti Port, relying on its core location advantage on the Red Sea strategic channel, achieves a comprehensive return level of 0.78 and a coordination degree of 0.70,reaching a high-quality coordination level and becoming a regional benchmark. Although the Lekki Deepwater Port in Nigeria faces certain exchange rate fluctuations and financing cost pressures, it still achieves a coordination degree of 0.68,in the basic coordination range, due to its radiation capacity to the West African hinterland. These two ports jointly drive the regional average coordination degree up to 0.65.

Thirdly, Europe: The core issue of mild imbalance lies in the dual constraints of "high risk+limited return". The geopolitical risk in the European region presents structural characteristics. On the one hand, countries such as Germany and Croatia are members of the EU or NATO and are deeply affected by the US-led "securitization" reviews, with an average external power intervention degree of 0.62(the highest among the four major regions).On the other hand, local port operation standards in Europe are stringent, and environmental protection constraints are strong(the average score for emission standard strictness is 85,much higher than other regions),pushing up operational management risks, with a regional comprehensive risk level reaching 0.58.

In terms of returns, the European port market is saturated, and investment projects are mostly carried out in the form of equity participation with limited control rights. However, benefiting from the region's mature trade system, the comprehensive return level reaches 0.66,slightly higher than that in the Latin American region. Nevertheless, the high-risk level still significantly suppresses the coupling coordination effect, resulting in an average regional coordination degree of only 0.46, in the mild imbalance range.

A typical example is the Hamburg Port in Germany (equity participation), which has seen a slowdown in project progress due to the impact of EU foreign investment review policies. Although its return level reaches 0.65,its comprehensive risk level is as high as 0.62,ultimately resulting in a coordination degree of only 0.48.The Piraeus Port in Greece has relatively better risk management effects(comprehensive risk level 0.55)due to the deep cooperation foundation between China and Greece, with a coordination degree of 0.45,slightly lower than that of the Hamburg Port, confirming the core characteristic of risk-dominated coordination levels in the European region.

Fourthly, Latin America: The main reason for mild imbalance is that excessive geopolitical risks suppress return potential. The geopolitical risk(average 0.83)in the Latin American region ranks first among the four major regions, with relatively large fluctuations in diplomatic relations between some countries and China and frequent external interventions due to the influence of the US "Monroe Doctrine". At the economic level, Latin American countries have severe exchange rate fluctuations (with an average annual volatility of 12.5%) and high inflation (with an average CPI growth rate of 8.3%), highlighting economic operation risks. Under these dual pressures, the regional comprehensive risk level is significantly higher than that in other regions. In terms of returns, Latin American ports mostly serve intra-regional trade and have weak trade linkages with China, with limited route density (average accounting for 15%of regional total routes) and hinterland radiation capacity, and a comprehensive return level of only 0.43, unable to offset high risk pressures, resulting in an average regional coordination degree of only 0.40, the lowest among the four major regions. The Manzanillo Port in Mexico is subject to the constraints of the rules of the North American Free Trade Agreement, limiting the operational autonomy of Chinese investors, with a comprehensive risk level as high as 0.85 and a return level of only 0.42,resulting in a coordination degree of 0.38.The Colon Port in Panama, relying on its strategic location advantage of the Panama Canal, has its return level increased to 0.45 and its risk level slightly decreased to 0.82,with a coordination degree of 0.41,which is better than that of the Manzanillo Port but still in the mild imbalance range.

In addition, from the perspective of intra-regional differences, there are also significant divergences in the coupling coordination degrees of different projects within the same region, and these divergence characteristics are highly consistent with the core influencing factors of the region. In Southeast Asia, the Gwadar Port in Pakistan(coordination degree 0.71)has a slightly lower coordination degree than the Colombo Port in Sri Lanka (coordination degree 0.73) due to a slightly inferior depth of geopolitical strategic collaboration, but both maintain high-quality coordination. In Africa, the Djibouti Port (coordination degree 0.70, high-quality coordination) has a significantly higher coordination degree than the Lekki Deepwater Port in Nigeria (coordination degree 0.68, basic coordination) due to its core strategic channel advantage, reflecting the role of location value in enhancing coordination levels.

In Europe, the Hamburg Port in Germany (coordination degree 0.48) has a slightly higher coordination degree than the Piraeus Port in Greece (coordination degree 0.45) due to a slightly higher return level, although it has higher risks, confirming the limited effect of "return compensating for risk" in the European region. In Latin America, the Colon Port in Panama (coordination degree 0.41) achieves a higher coordination degree than the Manzanillo Port in Mexico (coordination degree 0.38) by relying on its canal location to increase returns.

These intra-regional differences further confirm the regional heterogeneity of core influencing factors-Southeast Asia and Africa are mainly driven by return-driven differences, while Europe and Latin America are mainly driven by risk-driven differences, providing a precise basis for subsequent optimization of investment layouts.

Table 4-4 Calculation Results of Coupling Coordination Degree for Typical Projects

Region	Project Name	Comprehensive Risk Level(\(U_R\))	Comprehensive Return Level(\(U_B\))	Coupling Degree (C)	Coordination Degree (D)	Coordination Grade
Southeast Asia	Colombo Port, Sri Lanka	0.35	0.82	0.81	0.73	High-quality Coordination
Southeast Asia	Gwadar Port, Pakistan	0.38	0.79	0.79	0.71	High-quality Coordination
Africa	Lekki Deep Sea Port, Nigeria	0.42	0.75	0.77	0.68	Basic Coordination
Africa	Djibouti Port	0.39	0.78	0.78	0.70	High-quality Coordination
Latin America	Manzanillo Port, Mexico	0.85	0.42	0.62	0.38	Mild Imbalance

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Latin America	Colon Port, Panama	0.82	0.45	0.64	0.41	Mild Imbalance
Europe	Piraeus Port, Greece	0.55	0.68	0.76	0.45	Mild Imbalance
Europe	Hamburg Port, Germany (Equity Participation)	0.62	0.65	0.77	0.48	Mild Imbalance

As shown in Table 4 and Figure 1: 1. Significant regional disparities: Southeast Asia has the highest average coupling coordination degree (0.72), followed by Africa (0.65), while Latin America (0.40) and Europe (0.46) are relatively lower; 2. Diversified causes of imbalance: Latin American projects experience imbalance due to excessively high geopolitical risks (mean U_R 0.83), whereas European projects face imbalance due to low profit levels (mean U_B 0.66) and high risks (mean U_R 0.58); 3. Characteristics of high-quality coordinated projects: All exhibit the features of "low risk + high returns", such as Colombo Port and Djibouti Port, which leverage the "Belt and Road" dividends, maintain controllable geopolitical risks, and simultaneously enhance profit levels through the "port-industry-city integration" model.

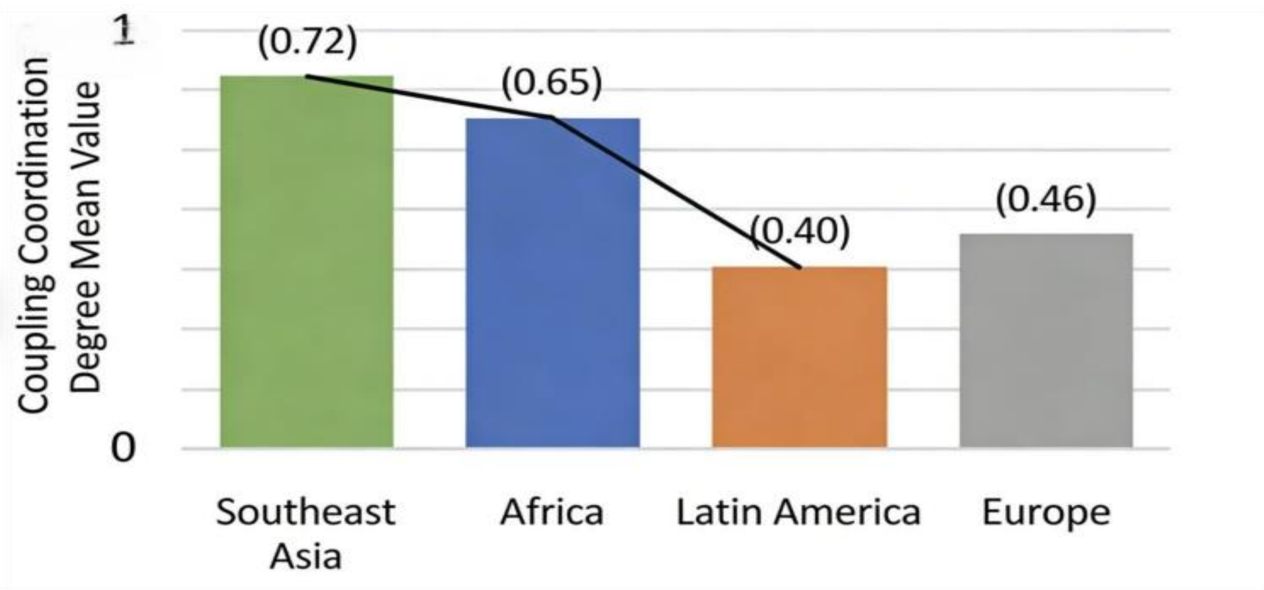

Figure 1 Comparison of Mean Coupling Coordination Degrees Among Four Major Regions

Model robustness test

To validate the reliability of the model results, a robustness test was conducted using the indicator substitution method. The "degree of external force intervention" in "geopolitical risk" was replaced with "the degree of alliance between the host country and major powers," and the coupling coordination degree was recalculated. The test results showed that the correlation coefficient between the adjusted indicators and the original results remained at 0.92 ($p<0.001$), and the regional coordination ranking (Southeast Asia> Africa> Europe> Latin America) remained unchanged, indicating strong robustness of the model results.

INTERPRETATION OF RESULT

Difference Characteristics of Regional Coupling Coordination Degree

The empirical results show that the coupling coordination degree of the four regions is significantly different, and the specific characteristics are as follows:

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Table 5-1

Region	Mean Value of Comprehensive Risk Level (U_R)	Mean Value of Comprehensive Return Level (U_B)	Mean Value of Coupling Degree (C)	Mean Value of Coordination Degree (D)	Average Coordination Grade
Southeast Asia	0.36	0.81	0.80	0.72	High-quality Coordination
Africa	0.41	0.76	0.77	0.65	Basic Coordination
Latin America	0.83	0.43	0.63	0.40	Mild Imbalance
Europe	0.58	0.66	0.77	0.46	Mild Imbalance

Overall, the coordination degree follows a descending trend: Southeast Asia> Africa> Europe> Latin America. Moreover, the risk-return profiles vary significantly across regions: Southeast Asia exhibits "low risk + high return", Africa shows "moderate low risk + moderate high return", Latin America displays "high risk + low return", while Europe features "moderate risk + moderate return".

Regional Heterogeneity Mechanism of Core Influencing Factors

Southeast Asia: Low Risk and High Return of Synergistic

The core driving factors for Southeast Asia's leading regional coordination include: First, controllable geopolitical risks, with high alignment in diplomatic stance with China (average score of 0.85 across three indicators), a bilateral trade dependence average of 0.12, and low external interference (average score of 0.28), providing a stable environment for investment; Second, outstanding economic returns, as a core hub of the global supply chain, the sample projects achieve an average annual throughput growth rate of 8.2%, with an average return on investment (ROI) of 8.5%, significantly higher than other regions; Third, synergy between strategic benefits and social benefits, leveraging strategic corridors like the Strait of Malacca, with high route density (average score of 0.78), while the "port-industry-city integration" model promotes industrial clustering, creating an average of 12,000 jobs per project.

Africa: Economic Operational Risks Restricting the Release of Benefits

The African region's regional coordination level is marginally lower than that of Southeast Asia, primarily constrained by elevated operational risks. Firstly, the region faces severe exchange rate volatility: the average standard deviation of currency-to-RMB exchange rates for sampled projects in the past three years reached 0.15, significantly higher than Southeast Asia's 0.08, thereby increasing foreign exchange loss risks. Secondly, weak infrastructure foundations and substantial fluctuations in port throughput (average coefficient of variation 0.12) undermine revenue stability. Nevertheless, the region's strategic advantages are pronounced. Projects like Djibouti Port and Egypt's Port Said, leveraging the Red Sea-Suez Canal shipping corridor, demonstrate a trade linkage coefficient average of 0.82, serving as pivotal drivers for regional coordination.

Latin America: Geopolitical Risks Dominating the Imbalance Pattern

Latin America exhibits the lowest regional coordination, with geopolitical risks spiraling out of control as the core challenge. Three key factors contribute to this: First, intense external interference (0.85 average), as some countries in the region maintain close geopolitical ties with the U.S., subjecting Chinese port investments to security-focused scrutiny. A notable case is the Mexico City Port project in Manzanillo, which was forced to adjust its equity structure under U.S. pressure. Second, policy instability, with an average of 2.3 policy revisions per year over the past three years—significantly higher than other regions. Third, subpar economic returns, where sample projects show only 3.5% annual throughput growth and 3.8% average ROI, creating a 'high-risk, low-return' dilemma.

The Insufficiency of the Balance between Medium Risk and Medium Return in European Region

The European region exhibits a mildly imbalanced coordination level, stemming not from isolated risk factors but systemic equilibrium deficiencies. On the risk side, the EU's stringent environmental standards drive up operational costs, with sample projects allocating 15%-20% of budgets to environmental upgrades, resulting in high compliance risks (average 0.65). On the return side, Europe's port market is highly competitive, predominantly mature ports with limited throughput growth potential (average annual growth rate 2.8%), yielding an average ROI of merely 4.2%. Furthermore, some countries harbor ideological biases against Chinese investments, coupled with cumbersome approval processes (average approval duration 18 months), further exacerbating systemic imbalances.

The Relationship between Coupling Degree and Coordination Degree

The average coupling degree across four major regions (0.63-0.80) indicates strong regional synergy, with Southeast Asia (0.80), Africa (0.77), and Europe (0.77) showing comparable levels. This demonstrates that while risk-return systems exhibit high intrinsic interaction, their coordination varies significantly. The findings validate the coupling coordination model's core principle: coordination depends not only on inter-system synergy (coupling degree) but also on the system's overall development level (comprehensive coordination index T). Although Latin America achieved a coupling degree of 0.63, its excessively high risk and low return systems resulted in a T-index of 0.58, leading to suboptimal coordination. In contrast, Southeast Asia leveraged its "low-risk + high-return" system combination to achieve both high coupling and coordination.

CONCLUSION

The main conclusions indicate that in the post-pandemic era, China's overseas port investments exhibit significant regional disparities. The Southeast Asian and African regions demonstrate higher average coupling coordination levels, indicating favorable development trends, while Latin America and Europe are in a mildly uncoordinated state due to factors such as geopolitical risks and profit levels. The three core influencing factors have clear and significant mechanisms: supply chain restructuring positively enhances investment returns, geopolitical competition intensifies investment risks, and green transformation increases risks in the short term but boosts returns in the long term. Technological empowerment, model innovation, and multilateral cooperation are key pathways to improving coupling coordination levels. The indicator system and coupling model demonstrate good reliability and validity, with credible measurement results. Based on this, optimization paths include: optimizing regional layouts by focusing on high-coordination areas and cautiously expanding into high-risk regions; strengthening risk management by establishing a dynamic prevention and control system across the entire chain; promoting technological innovation to enhance coupling coordination levels through technological empowerment; and building a collaborative ecosystem to deepen multilateral cooperation and model innovation. However, this study has limitations such as limited sample size and subjective determination of model weights. Future research could expand the sample scope, adopt machine learning methods to optimize weight determination, and further investigate the impact of different investment models on coupling coordination levels, providing more precise theoretical support for model innovation.

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