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Transition Finance for the Low-Carbon Transition of High-Carbon Industries: Institutional Logic, Instrument Contracts, and Boundary Conditions

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Abstract: Transition finance is designed specifically to support the shift of high-carbon emission activities toward low-carbon and zero-carbon transitions. Its core function is to translate corporate emission reduction pathways into verifiable financing contracts. Grounded in the functional perspective of finance, contract theory, and information asymmetry theory, this study constructs a normative analytical framework for how transition finance supports the low-carbon transition of high-carbon industries. Mechanism analysis reveals that tightening external carbon constraints, stranded asset risks, and the shortage of traditional financial supply collectively drive the demand for verifiable financing pathways. Transition debt instruments rely on Key Performance Indicators (KPIs), interest rate adjustment mechanisms, and third-party verification to form a contractual closed loop. However, their effectiveness is constrained by carbon data quality, the maturity of technological routes, and the institutional environment of financial operations. Based on these insights, the study proposes policy design essentials from two perspectives: standard supply and incentive & constraint mechanisms, aiming to provide references for improving the transition finance system.

Keywords: Transition finance; High-carbon industries; Low-carbon transition; Instrument contracts; Boundary conditions

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1. Introduction

Steel, coal power, cement, and other high-carbon industries serve as both foundational pillars of the national economy and concentrated sectors of energy consumption and carbon emissions. However, under the binding constraints of carbon peaking and carbon neutrality goals, these industries can neither be phased out simply due to high emission intensity, nor can they remain stagnant by adhering to their existing development models. How to achieve a low-carbon transition while ensuring the security of industrial and supply chains has become a practical proposition that financial support for the green and low-carbon development of the real economy must address. In 2021, the *Guidelines on Fully, Accurately, and Comprehensively Implementing the New Development Philosophy to Achieve Carbon Peaking and Carbon Neutrality* explicitly called for building

a green, low-carbon, and circular economic system, providing an action basis for financial support for the transition of high-carbon industries [1].

From the perspective of financial functions, green finance is oriented toward static outcomes, primarily supporting technologies and projects that meet near "pure green" standards based on green catalogs, making it difficult for high-carbon activities in transition to enter the scope of support. Transition finance shifts the evaluation focus from outcomes to processes, emphasizing whether the pathways for high-carbon activities to transition to low-carbon or zero-carbon are credible. The two form functional complements rather than substitutes in terms of supported targets. Theoretical analyses indicate that transition finance is emerging as a parallel financial support paradigm alongside green finance [2]. Existing studies also suggest that the green finance system needs to extend its support scope to the low-carbon transition of brown assets [3]. At the policy level, the guidance issued by the People's Bank of China and six other departments calls for accelerating the development of transition finance standards and clarifying activity catalogs and disclosure requirements [4]. In terms of international experience, the 2022 G20 Transition Finance Framework established five pillars: defined standards, information disclosure, financial instruments, incentive mechanisms, and just transition [5], marking the entry of transition finance into the stage of institutionalized implementation.

The core argument is that the essence of transition finance is not green finance with relaxed conditions, but rather the transformation of high-carbon enterprises' emission reduction pathways into verifiable financing contracts. This study sequentially discusses three issues: institutional logic, instrument contracts, and boundary conditions, and provides key points for policy design.

2. Institutional generation logic

2.1. Hard constraints of carbon emissions

Carbon emission constraints are shifting from soft to hard constraints. In domestic practice, the coverage of the national carbon market continues to expand. The Ministry of Ecology and Environment included steel, cement, and aluminum smelting in the national carbon market in 2025, making emission costs explicit rather than implicit. However, in the first control year, quotas were allocated equally to actual emissions, meaning enterprises did not need to pay compliance costs; the financial impact of rigid constraints is mainly reflected in the surplus or deficit of quotas in subsequent years. At the same time, international trade rules are tightening in parallel. Starting from 2026, the EU Carbon Border Adjustment Mechanism (CBAM) will be formally implemented on high-carbon products such as steel, aluminum, and cement. Emission reduction performance directly affects market access and order acquisition, and the international competitiveness of high-carbon production capacity decreases as carbon intensity rises.

Domestic control methods are also undergoing transformation. The *Action Plan for Carbon Peaking Before 2030* issued by the State Council deploys improvements to the dual control system of energy consumption [6]. Building on this, the construction of a carbon emission dual control institutional system is gradually advancing. Further analysis indicates that clearly defining the ownership of carbon quotas and improving the allocation mechanism are key institutional conditions for transforming emission reduction responsibilities from advocacy to binding constraints [7]. Consequently, the cash flow expectations, asset valuations, and financing conditions of high-carbon industries are being systematically re-evaluated, making transition not an option but a necessity.

2.2. Stranded asset risks

Tightening carbon constraints directly impact the value basis of high-carbon assets, with their future earnings significantly impaired and stranded risks gradually becoming explicit. Some high-carbon assets are even shifting from high-quality assets to liabilities on the books.

Asset stranding weakens corporate financing capacity through two channels: First, the collateral channel, where shrinking valuations of high-carbon assets reduce eligible collateral, narrowing the space for indirect financing. Second, the maturity channel, where banks compress medium- and long-term credit lines, forcing enterprises to support long-cycle transformations with short-term funds, exacerbating maturity mismatches and hindering transition investments.

For the financial system, the concentrated exposure to high-carbon assets means the transmission of transition risks to credit risks. If banks cannot promptly identify and revalue their high-carbon asset exposures, asset quality will gradually come under pressure as the transition progresses. Surveys of institutional investors also indicate that climate risk is widely regarded as a significant investment risk and has entered asset allocation decisions [8]. From this perspective, high-carbon assets face not only regulatory discounts but also long-term capital flight driven by shifting investor preferences.

2.3. Supply shortage of traditional finance

While the demand side is under pressure, there is a structural supply shortage on the capital supply side. Green finance catalogs determine eligibility based on outcomes; only projects close to "pure green" can receive support from green credit and green bonds. High-carbon activities in transition are excluded due to high emission intensity. The problem is that despite the continuous expansion of green finance support, the funding gap for high-carbon transitions has not narrowed in tandem.

Transition projects require large investments, have long cycles, and high uncertainty, with risk premiums lacking effective risk-sharing and compensation arrangements, resulting in high capital costs. Empirical studies confirm that the transition financing of high-carbon industries still faces multiple constraints, including the absence of standards, single instruments, and insufficient incentives [9].

This supply shortage has given rise to an institutional demand for verifiable financing pathways. On the one hand, corporate emission reduction commitments need to be translated into measurable, reportable, and verifiable (MRV) targets and pathways to gain the trust of financiers. On the other hand, transition activities are highly specialized and costly to identify, requiring financial institutions to rely on catalogs, linkage clauses, and due diligence templates to reduce business uncertainty. This provides institutional space for transition finance as an independent financial instrument.

3. Instrument contract structure

3.1. Spectrum of transition debt instruments

Transition debt instruments constitute the cornerstone of current transition finance. Transition loans started the earliest and are the most widely used. Some local authorities have issued business management regulations, embedding carbon performance evaluation into the entire process of pre-loan, mid-loan, and post-loan. In the market, some banks have embedded carbon emission reduction calculation tools into the three stages of loan assessment, dynamically linking interest rates with emission reduction targets. This marks the shift of transition loans from simple labeling to substantive linking. Transition insurance and transition funds, as well as other

equity instruments, are also being explored, providing new channels for risk sharing.

Transition bonds connect with the capital market to meet the long-term capital needs of enterprise transformation and upgrading. The issuance scale continues to expand, making them an important channel for direct financing for high-carbon enterprises. Sustainability-linked loans (SLLs) and sustainability-linked bonds (SLBs) do not specify the use of raised funds, but instead link financing costs with performance targets to constrain issuer behavior, providing options for enterprises with flexible fund uses.

3.2. Setting of key performance indicators

The foundation of contractual effectiveness lies in the credible setting of Key Performance Indicators (KPIs). Indicators should first be quantifiable. Physical indicators such as energy consumption per unit of product and carbon emission intensity are more verifiable than abstract commitments. The base year and accounting boundaries should also be clarified to avoid fluctuating standards that cause the contract to lose its evaluation benchmark.

The baseline should refer to industry energy efficiency benchmarks and national baseline levels, making the target challenging yet realistic. If the target is too low, the contract degenerates into a low-cost financing channel; if too high, it induces default expectations and damages the sustainability of the instrument.

Indicator design must also prevent carbon lock-in. Some projects can achieve short-term compliance through partial equipment upgrades, but lock in high-carbon processes over a longer cycle, forming a “fake transition” that is actually delay disguised as transformation. The G20 Transition Finance Framework lists disclosure as one of its pillars, requiring transition entities to publish complete transition plans aligned with long-term zero-carbon pathways [5]. Indicator design should serve long-term pathways rather than reward local whitewashing.

3.3. Contract execution and verification mechanism

The enforceability of contracts relies on a dual arrangement of internal financial constraints and external verification safeguards. At the internal level, achieving performance targets triggers interest rate reductions, constituting positive incentives; target breaches trigger interest rate increases, using financial costs to constrain commitment fulfillment; in cases of major environmental breaches of trust, financial institutions can cancel transition qualifications and recall funds early. Some banks also add positive incentive clauses, increasing credit lines for enterprises that achieve phased carbon reduction targets on schedule, expanding penalty arrangements from pure punishment to incentive compatibility.

At the external level, pre-loan relies on industry due diligence templates to evaluate enterprise transition strategies, energy consumption status, and fund uses; mid-loan relies on carbon accounts to continuously track carbon emission data and the completion of phased targets; post-loan involves third-party institutions conducting annual verification and linking results with reward and punishment clauses. Thus, verification is no longer a formal stamp, but a dynamic check embedded in business processes.

Empirical evidence from the bond market shows that green bond issuance can produce significant market incentive effects and reduce stock price crash risk [10]. Flammer’s study based on the international market also shows that green bond issuance significantly improves issuers’ environmental performance. It can be seen that the more complete the linking clauses and verification closed-loop, the easier transition commitments are trusted by the market, and the more financing costs can reflect environmental performance differences.

4. Boundary constraints

4.1. Granularity of carbon emission data

Transition contracts are rooted in data; a weak data foundation directly undermines contract credibility. Insufficient granularity and poor comparability of corporate carbon emission data make it difficult for financial institutions to compare the environmental performance of different enterprises. Industry accounting methodologies have not yet been unified, leading to discrepancies in cross-institutional and cross-regional recognition. Limited disclosure by unlisted enterprises and SMEs further compresses the applicable boundary of contracts; the quantity of disclosure does not equate to disclosure quality. Domestic empirical studies also find that the expansion of ESG disclosure quantity may even increase the cost of debt financing, and that disclosure quality is the key to pricing differences. Research from the climate risk dimension further indicates that targeted risk disclosure helps curb corporate greenwashing. Data granularity thus constitutes the first boundary of transition finance: no matter how sophisticated the contract clauses are, they will fall flat without credible data support.

4.2. Maturity of technological routes

The second boundary stems from the technology itself. Deep emission reduction pathways such as hydrogen metallurgy and carbon capture, utilization, and storage (CCUS) are still in the demonstration stage, with limited commercialization. If financing support is detached from technology maturity, it can easily lead to a technological misstep, creating a disconnect between capital investment and emission reduction effects. Emission reduction costs vary significantly across industries and regions, making it difficult for unified instrument parameters to achieve full coverage. Contract design must respect the objective pace of technological routes and allow time flexibility for deep emission reduction.

4.3. Institutional environment of financial operations

The third boundary lies in the institutional environment of financial operations. On the government side, regional environmental law enforcement standards are not unified, local finance and employment form path dependence on high-carbon industries, and the exit of backward production capacity is sluggish, eroding the authenticity of transition performance. On the institutional side, banks lack awareness of transition risks; accountability pressure amplifies the fear of lending; climate risk pricing tools are lagging; and interdisciplinary talents with industry knowledge, carbon accounting, and financial skills are scarce. Investor behavior research also finds that if institutional investors' green attention lacks effective constraints, it may induce strategic greenwashing by enterprises, making investor constraints a crucial component of transition governance.

5. Key points of policy design

5.1. Institutional building of standard supply

Substantial progress has been made in the construction of transition finance standards. Relevant transition finance standards led by the People's Bank of China (PBC) have been piloted in multiple regions, with continuous expansion of the pilot scope and advancement of financial industry standard development; based on this, many localities have established local catalogs and project databases. The policy focus should shift from issuing catalogs to three tasks: First, unify national standards, regulate the connection between local catalogs and industry standards, promote mutual recognition of cross-regional standards, and prevent the fragmentation

of rules from raising transaction costs. Second, refine the frequency, granularity, and exemption arrangements of information disclosure, and urge issuers of linked products to disclose annual progress of KPIs and third-party verification. Third, regulate third-party assessment and verification businesses, and establish interest avoidance and accountability mechanisms. Research on regulatory effects also indicates that government environmental regulation can simultaneously curb greenwashing and promote genuine green transition, demonstrating that strict regulation and transition finance are not mutually exclusive.

5.2. Design of incentive and constraint instruments

Incentive instruments need to work in tandem with standard supply. In terms of monetary policy, in early 2026, the PBC expanded its carbon emission reduction support tools to include energy-saving renovations, green upgrades, and low-carbon energy transitions, and simultaneously lowered the interest rates of relevant structural monetary policy tools. The institutional implication of its extension from "pure green" to transition areas should not be underestimated. In terms of fiscal policy, interest subsidies and certification fee subsidies should be provided for transition loans and bonds to leverage the role of fiscal funds in mobilizing social capital. In terms of risk sharing, local governments can establish transition risk compensation funds, incorporate transition business into the assessment and evaluation of financial institutions, refine due diligence exemptions into operable business procedures, and alleviate banks' fear of lending.

6. Conclusion

The 15th Five-Year Plan period is a critical juncture for the comprehensive green transition of China's economic and social development. The low-carbon transition of high-carbon industries not only bears the heavy responsibility of reshaping the industrial structure but also serves as a necessary pathway for financial support for the high-quality development of the real economy. The above analysis shows that transition finance is not a relaxed version of green finance, but rather a verifiable emission reduction commitment contract. Institutional logic answers why transition finance is needed; instrument contracts answer how it operates; boundary conditions answer where the mechanism fails; and policy design answers how to correct such failures. Looking ahead, equity-based transition instruments, retroactive financing arrangements, and just transition indicators deserve in-depth research. The institutional vision of transition finance must also balance employment, regional development, and social equity. As China's transition finance standard system matures, transition finance is expected to build a bridge between incremental substitution and stock transformation, providing more solid financial support for high-quality development.

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Disclosure statement

The authors declare no conflict of interest.

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