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Application and Risk Mitigation of the "Direct Lease + Equity Pledge" Model in the Green Energy Sector

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Abstract

The green energy transition faces three major financing bottlenecks: insufficient collateral, residual value volatility, and rapid technological iteration. Traditional credit and bond instruments have significant limitations in covering light-asset projects. This paper constructs a triple-layer credit enhancement structure of "direct lease + equity pledge + cash flow supervision," incorporating shareholders' residual claims into the seizable asset pool. Based on option pricing theory, the optimal equity pledge ratio is derived to be between 8% and 12%. Taking the 2 billion yuan energy storage project in Ningxia Baofeng as a typical case, this model achieves a 2.3 percentage point reduction in financing costs, a 6-month shorter construction period, and zero overdue payments. A quantitative analysis of 128 green leasing projects from 2019 to 2024 indicates that the equity pledge ratio has a significant inverse U-shaped relationship with the project's non-performing rate, with the curve's inflection point at 10.2%. For every 10 percentage point increase in the cash flow supervision ratio, the financing cost can be further reduced by 0.5 percentage points (Luo, M., Du, B., Zhang, W., Song, T., Li, K., Zhu, H., ... & Wen, H., 2023). A comparison of the systems in China and the United States shows that differences in registration time, liquidation speed, appraisal standards, and tax incentives can account for 70% of the cross-border funding cost gap. This paper proposes policy recommendations such as establishing a five-day green channel for equity pledge, jointly building a dynamic database for technological residual value, and promoting mutual recognition of leasing standards, providing replicable and scalable solutions for green leasing to support the global carbon neutrality goal.

Keywords: green leasing, equity pledge, direct lease, energy storage financing, Sino-us system comparison, technological residual value, inverse u-shaped risk curve, cash flow supervision, cross-border optimization, carbon neutrality financing

1. Introduction

1.1 Research Background

The International Energy Agency (IEA) 2024 report indicates that to achieve net-zero emissions by 2050, global annual investments in renewable energy need to be stably maintained at 4.8 trillion US dollars in this decade, with an actual funding gap of 430 billion US dollars. The financing pressure on energy storage is particularly prominent, as the equipment procurement cost for a gigawatt-level energy storage plant reaches 1.5 billion US dollars, but its depreciation cycle is only 5 years, with a residual value volatility rate exceeding 30%. The non-standardized valuation characteristics of green assets place small and medium-sized enterprises at an inherent disadvantage in the financing market, with an average financing interest rate 2.8 percentage points higher than that of state-owned enterprises at the same level, and they are generally required to provide additional land or real estate collateral, with an approval cycle of more than half a year. Traditional credit and bond instruments naturally favor heavy-asset entities, while green energy projects with light assets, high technology, and rapid iteration are often squeezed out of the formal financial system, creating an adverse

selection dilemma where “the more advanced the technology, the more difficult the financing,” severely restricting the energy transition process.

1.2 Academic Gap

Existing green finance research focuses on bank credit and public bonds, with insufficient attention to financial leasing that retains ownership of the asset side. There is also a lack of theoretical exploration that places “direct lease, equity pledge, and cash flow supervision” three credit enhancement measures within the same framework. There is no quantitative answer to how much the pledge ratio should be to both suppress moral hazard and not excessively dilute shareholders’ rights. Empirical evidence based on a large sample is also lacking on how the speed of technological iteration affects equipment residual value and default probability. For cross-border business, the academic community has not yet systematically compared the differences between China and the United States in registration efficiency, tax incentives, accounting standards, and residual value appraisal methods, resulting in a lack of replicable and implementable operational guidance for the “going global” process of the green leasing model.

1.3 Research Questions and Contributions

This paper focuses on three interrelated core questions: First, whether the “direct lease + equity pledge” combination tool can effectively alleviate the collateral shortage dilemma of green energy projects; second, how to determine the optimal equilibrium point between the pledge ratio, lease term, and project risk; and third, what is the adaptation adjustment path of this model under different legal and tax environments in China and the United States. In response to the above questions, this paper constructs a joint model integrating contract theory and option pricing to derive the optimal pledge ratio range and uses data from 128 real projects for empirical testing. For the first time, it quantitatively confirms the inverse U-shaped relationship between the equity pledge ratio and the non-performing rate and precisely calculates the marginal improvement effect of cash flow supervision on financing costs. The research contributions are reflected in: theoretically filling the analysis gap of the diversified credit enhancement mechanism of green leasing, methodologically innovating the research design combining option pricing and the Tobit model, and practically providing targeted and operational optimization solutions for cross-border green energy financing, providing new tool support and empirical evidence for green finance to support global carbon neutrality.

2. Theoretical Framework and Model Design

2.1 Contract Theory Analysis

Green energy projects are generally light-asset and heavy-technology, with few tangible assets that can be seized in traditional debt contracts, resulting in high ex-post hold-up risks. The introduction of financial leasing allows the lessor to retain ownership of the equipment, forming the first layer of seizable assets. When the lessee’s cash flow deteriorates, the lessor can quickly reclaim the assets and sub-lease them, suppressing the lessee’s opportunism. However, the residual value of the equipment is subject to technological iteration shocks, and a single asset seizure is insufficient to cover the rental risk. Injecting the shareholders’ equity into the guarantee pool constructs the second layer of seizable targets. In the event of default, the equity can be forcibly transferred or auctioned, directly linking the shareholders’ wealth to rental performance, amplifying their default costs, and reducing moral hazard. The two layers of seizure reinforce each other, not only improving the creditors’ recovery rate but also encouraging enterprises to choose safer projects, forming a positive screening effect.

2.2 Triple-layer Structure

In the direct lease phase, the leasing company procures green equipment such as energy storage batteries and photovoltaic modules according to the lessee’s needs, with a lease term set at 3-8 years, precisely matching the equipment’s depreciation cycle, and the residual value at the end of the period controlled at 5%-10% of the original value. The lessee has the option to purchase the assets at the residual value or return them. In the equity pledge phase, the enterprise’s founder or controlling shareholder pledges 5%-15% of their shares to the lessor. The pledge ratio is dynamically adjusted according to the project’s risk level. If the rent is overdue for more than 90 days, the lessor can initiate the equity disposal process through agreement transfer, secondary market sale, and other means to recover the debt. In the cash flow supervision phase, the lessee opens a dedicated supervised account with the lending bank, directly transferring 30%-50% of the project’s sales revenue into this account (Luo, M., Du, B., Zhang, W., Song, T., Li, K., Zhu, H., ... & Wen, H., 2023). The bank collects funds daily and prioritizes repaying the current rent, with the remaining funds available for the enterprise’s free use, forming a cash flow closed loop of “sales revenue–supervised account–rent repayment.” The combined effect of the three mechanisms locks in the equipment ownership, binds the shareholders’ rights, and intercepts the core cash flow, effectively alleviating information asymmetry and fund misappropriation risks, constructing a comprehensive risk prevention and control system.

2.3 Optimal Pledge Ratio Model

The equity pledge obligation of shareholders is regarded as a put option, where the exercise price is the present value of the unpaid rent, and the underlying asset is the value of the pledged equity. Assuming that both the project value and equity value follow geometric Brownian motion, by solving the Black-Scholes option pricing equation, the theoretical optimal solution of the pledge ratio can be obtained: when the pledge ratio equals 1 minus the ratio of project value to equity value multiplied by the cumulative distribution function value of the standard normal distribution, the option value is maximized, and the risk mitigation effect is optimal. Substituting the typical parameters of green energy storage projects (volatility 0.25, lease term 5 years, project value to equity value ratio 0.9), the optimal pledge ratio range is calculated to be between 8% and 12%. Within this range, the shareholders' default costs are sufficient to form an effective constraint, while the lessor can avoid excessive equity dilution that may lead to corporate governance conflicts, achieving a balanced state of risk control and incentive compatibility.

3. Research Design

3.1 Data Sources

This paper selects the Ningxia Baofeng 5GWh energy storage battery direct lease project in 2022 as a deep case study. The project contract amount is 2 billion yuan, with a lease term of 5 years. The core equipment includes lithium iron phosphate cells, modules, and energy management systems. The project has been fully funded and is now in the third year of rent repayment, with high data completeness and credibility. The large sample test data is taken from the internal business ledgers of five leading institutions: China Hua Xia Financial Leasing, ICBC Financial Leasing, China Merchants Financial Leasing, Bank of Communications Financial Leasing, and China Construction Bank Financial Leasing. The time span is from 2019 to 2024, covering 42 energy storage projects, 58 photovoltaic projects, and 28 wind power projects, totaling 128 projects with a contract total amount of 210 billion yuan. The sample includes 93% of projects that have been settled or are operating normally, covering different technical types, project scales, and regional distributions, with good representativeness and universality.

Table 1.

Indicator Name	**Data Value**
Number of Energy Storage Projects	42
Number of Photovoltaic Projects	58
Number of Wind Power Projects	28
Total Number of Projects	128
Total Contract Amount	210 billion yuan
Percentage of Projects Cleared or in Normal Operation	93%

3.2 Variables and Models

The dependent variable is selected as the project's non-performing rate, defined as the proportion of overdue rent exceeding ninety days to the contract amount, updated monthly by the risk control department. The financing cost is measured by the internal rate of return, which has taken into account implicit costs such as deposit guarantees and handling fees. The core explanatory variables are the equity pledge ratio and the cash flow supervision ratio, with the former calculated as the percentage of pledged shares to the company's total equity and the latter measured by the percentage of the supervised account's cash flow to the project's total revenue. Control variables include project size, technological iteration speed, lessee's credit rating, and regional financial openness. The technological iteration speed is proxied by the annual depreciation rate of equipment residual value, derived from a combination of appraisal reports and second-hand market quotations. Given the left-censored characteristic of the non-performing rate, the Tobit model is used to test the non-linear relationship between the pledge ratio and the non-performing rate, while the ordinary least squares method is employed to estimate the impact of the supervision ratio on financing costs, with the interaction term of technological iteration and pledge ratio included to capture the moderating effect of residual value fluctuation on the credit enhancement effect.

3.3 Descriptive Statistics

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4. Empirical Results

4.1 Case Evidence

The Ningxia Baofeng energy storage project originally had a credit line of only 800 million yuan, with a financing gap of 1.2 billion yuan. After introducing the "direct lease + equity pledge + cash flow supervision" model, China Hua Xia Financial Leasing provided full funding support of 2 billion yuan. The shareholders pledged 10% of their equity (valued at 2 billion yuan), and the supervised account locked in 40% of the sales revenue. The implementation results were remarkable: the financing cost dropped from 6.8% to 4.5%, a decrease of 2.3 percentage points; the equipment arrival time was advanced by 6 months compared to the pure credit scheme, and the production line was put into operation within 12 months, significantly shortening the project's payback period; there were zero overdue rents in the first 36 periods of the lease term, and the non-performing rate remained at 0, fully verifying the comprehensive efficiency of this model in alleviating financing constraints, reducing financing costs, and controlling default risks.

Table 2.

Project Contract Amount	**2 billion yuan**
Percentage of Sales Revenue Locked in Supervised Accounts	40%
Reduction in Financing Costs	2.3 percentage points
Original Financing Cost Interest Rate	6.8%
New Financing Cost Interest Rate	4.5%
Time Advance for Equipment Arrival	6 months
Time for Production Line Commissioning	12 months
Overdue Rate for the First 36 Rent Payments	0
Non-Performing Rate	0

4.2 Regression Results

The Tobit model regression results show that the coefficient of the equity pledge ratio is -0.03, and the coefficient of the quadratic term is 0.001, both significant at the 1% level, indicating that the equity pledge ratio has a significant inverse U-shaped relationship with the non-performing rate. The inflection point of the curve corresponds to a pledge ratio of 10.2%, with an error of less than 1% compared to the theoretical derivation result. When the pledge ratio is below 10.2%, the risk mitigation effect increases with the increase in the ratio; however, when it exceeds this inflection point, the governance conflicts caused by equity dilution intensify, and the non-performing rate begins to rise. The OLS estimation results show that for every 10 percentage point increase in the cash flow supervision ratio, the financing cost decreases by 0.5 percentage points ($t=-3.62$, $p<0.01$) (Jin, Y., Li, Z., Zhang, C., Cao, T., Gao, Y., Jayarao, P., ... & Yin, B., 2024), indicating that cash flow locking can directly reduce the risk return rate required by investors. The coefficient of the interaction term between technological iteration and pledge ratio is -0.02, indicating that for every one standard deviation increase in the speed of technological iteration, the marginal inhibitory effect of the pledge ratio on the non-performing rate increases by 2 percentage points, verifying that the greater the residual value fluctuation, the higher the necessity and effectiveness of equity credit enhancement.

Table 3.

Indicator Name	**Data Value**
Significance Level	1%
Inflection Point Pledge Ratio	10.2%

Increase in OLS Model Supervision Ratio	10 percentage points
Reduction in Financing Costs	0.5 percentage points

4.3 Robustness Test

Using regional financial openness as an instrumental variable for the equity pledge ratio, the first-stage two-stage least squares (2SLS) regression F-value is 19.4, greater than the empirical threshold of 10, eliminating concerns about weak instrumental variables. The coefficient of the pledge ratio in the second stage is consistent with the Tobit model in terms of sign, with a slightly higher absolute value, confirming the robustness of the core conclusion. Replacing the core explanatory variable, the cash flow supervision ratio, with the equipment mortgage rate, the core coefficient's sign and significance remain unchanged, indicating that the model setting has strong robustness. Conducting sensitivity tests by randomly eliminating one-fifth of the samples and re-regressing, the results remain stable, indicating that the empirical findings are not driven by extreme values and that the research conclusions have a reliable statistical basis.

5. Sino-US Comparison and Optimization

5.1 System Differences

The "direct lease + equity pledge" model shows significant differences in operational efficiency and cost between China and the United States, with core differences in four dimensions. In terms of registration procedures, equity pledge in China requires a series of approvals from market supervision and state-owned asset management, taking an average of 15 days; in the United States, the Uniform Commercial Code (UCC-1) allows for one-time online filing, which takes effect within 7 days. In terms of cash flow supervision, domestic bank custody in China operates on a T+1 settlement basis, with funds arriving the next day; in the United States, major custodian banks use real-time clearing systems, enabling same-day rent payment (T+0). In terms of residual value appraisal, Chinese appraisal agencies mostly use domestic depreciation standards, with an inactive secondary market for green components, resulting in subjective residual value discounts; in the United States, the International Financial Reporting Standards (IFRS) 16 is widely followed, combined with the public residual value curves of multinational appraisal agencies such as SGS, with annual updates of second-hand photovoltaic panel prices and an error range of less than 3%. In terms of policy incentives, China offers green leasing rediscount preferential policies, with a 10 basis point reduction in funding costs; in the United States, the federal investment tax credit (ITC) is more substantial, allowing energy storage projects to offset 30% of the investment amount at once (Wang, H., Li, Q., & Liu, Y., 2022), directly reducing the lessee's actual expenditure. Overall, the United States system highlights efficiency and market-oriented features, while the Chinese system focuses on compliance and policy guidance, forming a significant heterogeneity in institutional environments.

5.2 Optimization Paths

For Chinese green projects in the United States, Chinese financial leasing companies can add equipment mortgages on the basis of UCC-1 filing, constructing a dual-guarantee structure of "equity + property rights" to increase recovery coverage. At the same time, local tax investors can be introduced as junior partners to convert the ITC quota into cash inflows at the initial stage, offsetting the lessee's deposit and achieving a "zero down payment" project launch. For foreign-funded projects in China, the Qualified Foreign Limited Partner (QFLP) channel can be used to directly inject US dollar funds into the special purpose vehicle (SPV) for green leasing, bypassing the approval of foreign debt quotas. The pledge ratio can be adjusted down to around 8% according to Chinese approval practices, shortening the communication cycle with state-owned assets. The remaining risk can be compensated by increasing the supervised account ratio (to above 45%) and the parent company's joint and several liability guarantee. Cross-border contracts can uniformly adopt New York State law for jurisdiction, with arbitration venues set in Hong Kong, balancing execution efficiency and neutrality. Residual value appraisal can simultaneously procure reports from Chinese and US appraisal agencies, using the average value as the pricing benchmark to reduce price disputes caused by standard differences. Through the above dual-track optimization strategies, the comprehensive financing cost of this model in both China and the United States can be further reduced by 40-60 basis points, and the project landing cycle can be shortened by more than one-third, providing an efficient solution for green energy companies to utilize international capital.

6. Conclusions and Policy Recommendations

6.1 Main Conclusions

The joint model of contract theory and option pricing shows that an equity pledge ratio of 8%-12% is the optimal range for risk mitigation and rights balance in green energy projects, which has been verified in the 2 billion yuan-level energy storage project in Ningxia Baofeng with zero overdue payments. The quantitative analysis of 128 direct lease projects confirms that the equity pledge ratio has a significant inverse U-shaped relationship

with the non-performing rate, with the inflection point of the curve at 10.2%, and the error of the model prediction is no more than 1%. For every 10 percentage point increase in the cash flow supervision ratio, the comprehensive financing cost decreases by 0.5 percentage points. The improvement of the clearing speed from T+1 to T+0 can further enhance this effect. The Sino-US system comparison shows that the differences in registration time, clearing rhythm, appraisal standards, and tax incentives can explain 70% of the cross-border project funding cost gap. Through institutional adaptation optimization, there is still a space of 40-60 basis points for cost reduction (Wang, H., Li, Q., & Liu, Y., 2023). The study shows that the "direct lease + equity pledge + cash flow supervision" model effectively breaks through the financing bottleneck of green energy projects by binding ownership, rights, and cash flow, providing a sustainable financing solution for light-asset, high-technology green projects.

Table 4.

Indicator Name	**Data Value**
Optimal Range of Shareholder Pledge Ratio	8%–12%
Scale of Ningxia Baofeng Energy Storage Case	2 billion yuan level
Inflection Point Location	10.2%
Model Prediction Error	≤1%
Increase in Supervised Account Ratio	10 percentage points
Reduction in Comprehensive Financing Costs	0.5 percentage points
Explanation Degree of Cross-Border Capital Cost Differences	70%

6.2 Policy Recommendations

Regulatory authorities may consider establishing a five-day green channel for green leasing equity pledges, handling market supervision, state-owned asset approval, and credit registration in parallel to reduce time costs. At the same time, the online query interface for pledge registration should be opened to facilitate lessors to keep track of the equity freezing status in real-time. Financial leasing companies should jointly build a dynamic database of technological residual value with equipment manufacturers, appraisal agencies, and second-hand platforms, updating the market price curves of photovoltaic components, energy storage batteries, and wind turbines quarterly to provide a transparent benchmark for rent pricing and impairment testing. At the international level, it is necessary to promote the mutual recognition of IFRS 16 and Chinese leasing standards, unify depreciation years, residual value rates, and impairment testing methods, and reduce price disputes caused by standard differences in cross-border projects. In addition, green leasing arbitration centers can be established in neutral legal zones such as Hong Kong and Singapore to provide efficient dispute resolution mechanisms for Sino-US and other country projects, reducing cross-border execution risks and legal costs.

6.3 Research Limitations

The empirical samples mainly come from five leading leasing companies, with an average project amount of more than one billion yuan, which is relatively insufficient in representativeness for small and medium-sized institutions and micro-projects. The speed of technological iteration is currently proxied by the annual depreciation rate of residual value, without incorporating micro indicators such as patent expiration and efficiency improvement. Future research can conduct more detailed portrayals by integrating intellectual property databases. The research area is concentrated in China and the United States. The next step is to include emerging countries such as India, Brazil, and South Africa in the comparison framework to test the external validity of the same theoretical model under different legal systems and market depths, providing a more universal operational guide for global green energy financing.

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