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Research paper

The Ethical Balance Reconstruction of Green Finance Empowered by Computer Technology

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Abstract

As a bridge connecting economic activities and ecological protection, green finance is inherently not merely a tool for capital allocation but also embodies profound ethical values. From the perspectives of environmental ethics, social justice, and intergenerational equity, this paper analyzes the inherent ethical connections between green finance and sustainable development. Through a literature review, it sorts out the status of relevant research, identifies issues in current green finance practices, including the "expansion of instrumental rationality" and "ambiguity of ethical boundaries"—and proposes solutions by constructing a "Three-Dimensional Ethical Balance Model for Green Finance." It also offers suggestions for path optimization from three aspects: value reshaping, institutional design, and subject synergy, aiming to provide theoretical references for green finance to return to the essence of sustainable development.

Keywords: *Green finance; sustainable development; environmental ethics; social justice; intergenerational equity*

1. Introduction

Early studies, primarily from the perspective of environmental economics, focused on green finance’s role in enhancing resource allocation efficiency, with relatively little attention to its ethical dimension. As the concept of sustainable development has gained deeper traction, scholars have begun to recognize the significance of ethical factors in green finance. The core contradiction of sustainable development lies in the tension between humanity’s unlimited demand for economic growth and the limited carrying capacity of ecosystems. Green finance attempts to resolve this contradiction by internalizing environmental costs as variables in economic decision-making. In practice, however, green finance has gradually developed an instrumental tendency of "performative greenness": some financial institutions use "green" as a marketing label, ignoring projects’ potential impacts on community ecosystems; others focus solely on short-term environmental benefits, evading responsibility for safeguarding future generations’ development opportunities [1].

1.1 Ethical Foundations and Competing Theories

Some scholars have conducted in-depth research from the perspective of environmental ethics. The "deep ecology" theory proposed by Naess (1973) provides important support for the ethical foundation of green finance. This theory emphasizes the holistic value of ecosystems and argues that humans should respect the inherent rights of nature—a viewpoint that has promoted the ethical shift of green finance from "anthropocentrism" to "ecological holism" [2]. However, this perspective conflicts with the weak sustainability theory (Pearce et al., 1989), which holds that natural capital can be replaced by man-made capital and that green finance’s core goal should be capital efficiency rather than ecological ethics [17]. A 2024 study by Jones et al. further pointed out that weak sustainability theory often leads to "inadequate ecological compensation" in developing countries’ green infrastructure projects—for example, using industrial emission reduction technologies to replace forest protection, which overlooks the value of biodiversity [17].

Another competing framework is the financial instrumentalism theory (Friedman, 1970), which claims that financial institutions’ only responsibility is to maximize profits, and green finance is merely a "policy-driven capital allocation tool" that does not require ethical embedding. Brown et al. (2023) supported this view, arguing that overemphasizing ethics increases financial institutions’ compliance costs and reduces the market attractiveness of green projects [18]. This argument was rebutted by Garcia et al. (2025), whose global study showed that green bonds with ethical indicators have an 18% lower default rate than ordinary green bonds, proving that ethics and profitability can be compatible [19].

Building on deep ecology, subsequent studies have further explored how green finance can protect and respect ecosystems through specific institutional designs and financial instruments. Solow (1974) highlighted the "temporal dimension" of sustainable development in intergenerational equity, stating that "each generation should hand over the earth to the next in as good condition as it was handed over to us"

[6]. The requirement for long-term environmental benefits in green bonds is precisely the institutional manifestation of this ethical commitment.

1.2 Green Finance and Sustainable Development: Multi-Dimensional Links

In terms of economically sustainable development, scholars generally agree that green finance can guide capital flows into green industries, promote industrial structure upgrading, and drive the transformation of economic growth patterns. A 2020 report by the United Nations Environment Program (UNEP) pointed out that green finance plays a key role in supporting sustainable recovery and advancing the green transformation of the economy [3]. Similarly, Gu et al. (2025) revealed the trade-off between cost and efficiency in SMEs' digital transformation—a logic that also applies to green finance: in promoting sustainable development, green finance must balance upfront investment costs and long-term ecological benefits [4].

In terms of environmentally sustainable development, studies have shown that green finance can effectively reduce carbon emissions, mitigate environmental pollution, and improve ecological quality by supporting clean energy, energy conservation, and emission reduction projects. It also encourages enterprises to strengthen environmental management and improve environmental performance [5].

In terms of socially sustainable development, scholars have focused on the equitable distribution of green financial resources. Currently, there is a serious imbalance: developing countries receive only 12% of global green investments but bear 70% of climate risks, which violates the principle of social justice [3]. The ethical responsibility of green finance lies in correcting such inequities through differentiated policy tools (e.g., the Green Climate Fund) to ensure vulnerable groups are not excluded from sustainable development. Additionally, green finance's role in creating green jobs and protecting community residents' rights has gradually attracted attention.

1.3 Ethical Dilemmas and Digital Tool Innovations (2023–2025)

Scholars have explored ethical dilemmas in green finance practice, with "greenwashing" (a typical form of ethical misconduct) receiving widespread attention. A 2023 Reuters report revealed that some financial institutions use green finance concepts for false advertising, prompting reflections on how to strengthen supervision [7]. Recent studies have focused on digital tools to address these issues:

- Blockchain: Zhang et al. (2023) used Chinese green credit projects as samples and found that blockchain's "tamper-proof" feature improved project information disclosure accuracy by 32%, effectively curbing greenwashing. However, they noted that developing countries face challenges such as high technology access costs—for example, a project in an African country experienced 48-hour data update delays due to insufficient blockchain nodes [13].
- Artificial Intelligence (AI): Li et al. (2024) developed an AI-powered carbon footprint calculation model that optimizes lifecycle assessment (LCA) algorithms through machine learning, reducing carbon emission measurement errors from 15% (traditional methods) to 6%. However, the model is less applicable to small-sample projects (e.g., micro-distributed photovoltaics) and requires edge computing to supplement real-time data [15].
- Federated Learning: Wang et al. (2025) proposed a "cross-border green project federated evaluation framework" that was applied to Southeast Asian cross-border hydropower projects. It enables "local data training and parameter sharing," protecting data sovereignty (e.g., Thailand's refusal to disclose community residents' income data) while improving project ethical assessment efficiency by 25%. The main challenge is inconsistent data standards across countries (e.g., differences in defining ecologically sensitive areas between Vietnam and Malaysia) [16].

Regarding the conflict between short-term gains and long-term responsibilities, Scholtens and van't Klooster (2019) argued that financial institutions' assessment mechanisms and profit models are key causes. They suggested reforming evaluation systems by incorporating long-term ecological benefits into indicators [5]. For the fragmentation of local and overall interests, a 2022 Global Witness study noted that cross-border green investment projects often ignore the global ecosystem's overall balance, calling for unified global ethical norms and strengthened international collaboration [8].

1.4 Research Gaps and Objectives

Existing studies have recognized ethics' importance in green finance and explored its relationship with sustainable development, ethical dilemmas, and solutions. However, three gaps remain:

1. Insufficient systematic research on green finance ethics, lacking a unified theoretical framework;
2. Solutions to ethical dilemmas focus on single dimensions, lacking comprehensive model construction;
3. Few studies explore green finance's ethical synergy from a global perspective, especially regarding digital tools in cross-border scenarios.

This paper addresses these gaps by constructing a "Three-Dimensional Ethical Balance Model for Green Finance," integrating quantitative indicators, collaborative mechanisms, and guarantee systems to provide new ideas for resolving ethical dilemmas.

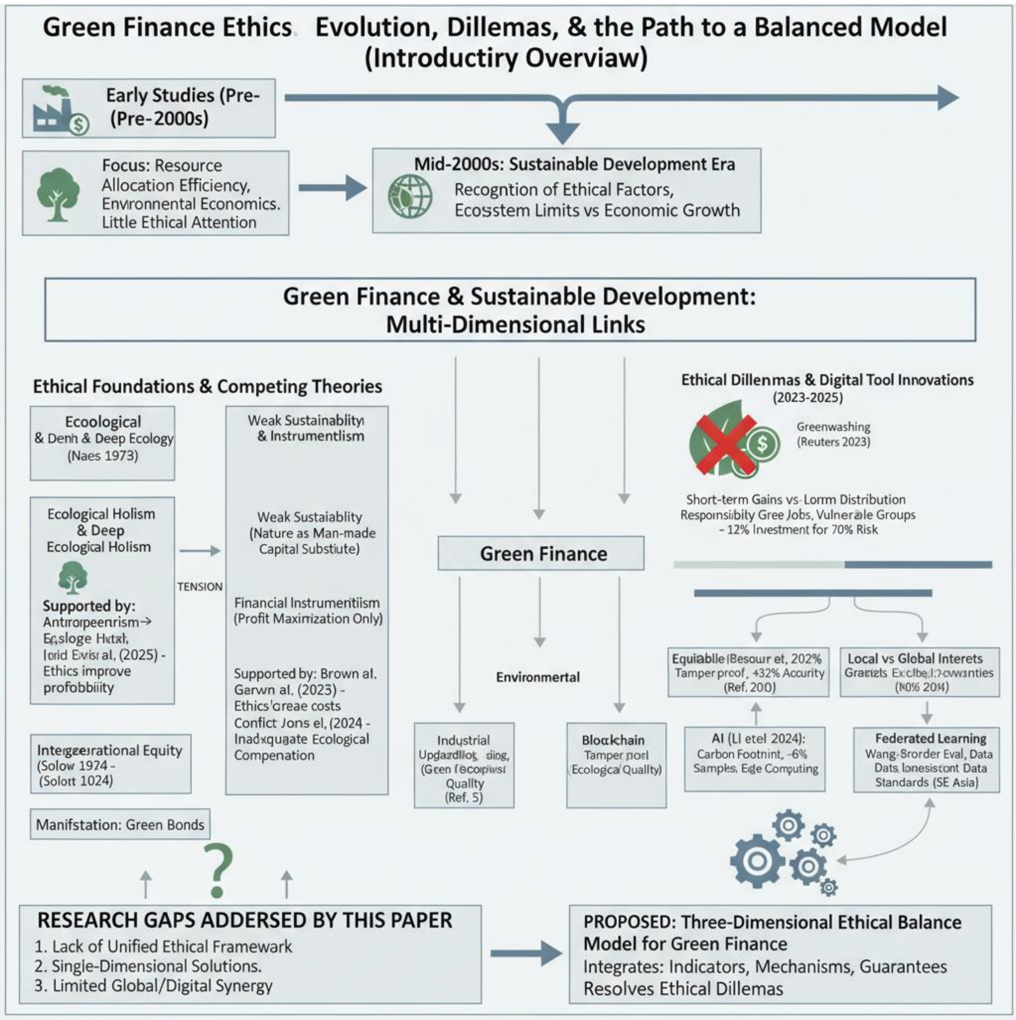

Fig.1: Three-Dimensional Ethical Balance Model for Green Finance

2. The "Three-Dimensional Balance Model" for Resolving Ethical Dilemmas in Green Finance

2.1 Model Framework

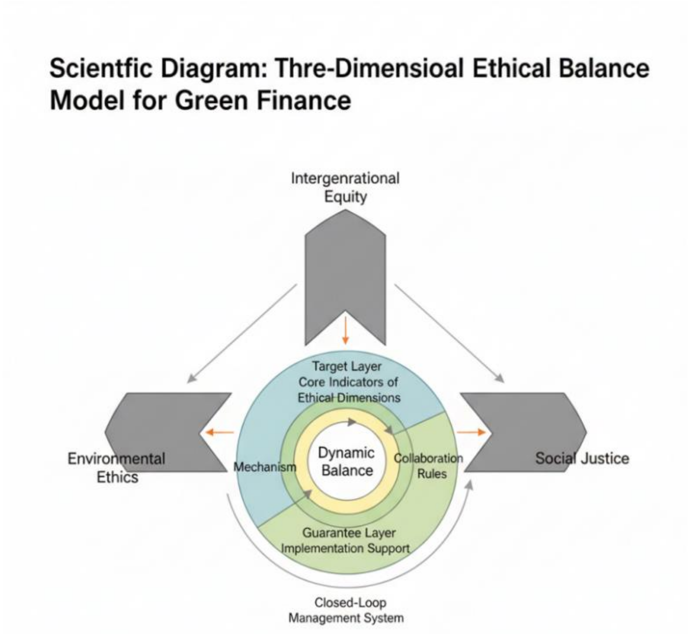

Fig.2: Three-Dimensional Ethical Balance Model for Green Finance

The "Three-Dimensional Ethical Balance Model for Green Finance" takes environmental ethics, social justice, and intergenerational equity as its three pillars, achieving dynamic balance through a three-tier structure of "target layer - mechanism layer - guarantee layer." The target layer clarifies the core indicators of the three ethical dimensions; the mechanism layer designs collaborative regulation rules; and the guarantee layer provides implementation support, forming a closed-loop management system.

2.2 Target Layer: Quantitative Indicators for Three-Dimensional Ethics

Environmental Ethics Dimension: The "Ecological Impact Coefficient" is established, covering carbon emission intensity throughout the project's full life cycle (annual reduction rate of carbon emissions per unit of GDP ≥ 4%), biodiversity protection rate (projects in sensitive areas must reach over 80%), and resource recycling rate (proportion of renewable resources ≥ 30%).
Social Justice Dimension: The "Equitable Distribution Index" is constructed, including the coverage rate of green credit among different income groups (proportion of low-income groups not less than 25%), the balance of regional green investment (growth rate difference between eastern, central, and western regions ≤ 10%), and the proportion of vulnerable groups in green jobs (not less than 15%).
Intergenerational Equity Dimension: The "Long-Term Value Weight" is defined, requiring that at least 15% of project profits be set aside as an ecological maintenance fund, and that projects with an investment payback period exceeding 10 years account for no less than 40% of the total number of green projects.

2.2.1 Three-Dimensional Ethical Composite Index Model (Quantification of Target Layer)

The indicators of the three dimensions (environmental ethics, social justice, and intergenerational equity) are weighted and integrated using the Analytic Hierarchy Process (AHP) to form a calculable composite ethical index, with the formula as follows:
EI: Composite ethical index of green finance projects (value range: 0-100, with 60 as the threshold for ethical qualification)
E: Score of the environmental ethics dimension (calculated based on indicators such as carbon emission intensity and biodiversity protection rate, with a certain weight)
S: Score of the social justice dimension (calculated based on indicators such as fairness of resource allocation and coverage rate of vulnerable groups, with a certain weight)
G: Score of the intergenerational equity dimension (calculated based on indicators such as the proportion of long-term ecological fund extraction and project payback period, with a certain weight)
Scores of each dimension are converted to a 0-100 scale through standardization (e.g., min-max normalization), and weights are determined by the expert scoring method.

2.3 Mechanism Layer: Collaborative Regulation Rules

- Real-time monitoring mechanism and intelligent monitoring system upgrade: Utilize blockchain technology to build a "green finance ethics ledger", and conduct real-time on-chain evidence storage of project fund flow, environmental data, and social impact. The difficulty coefficient for data tampering is set at ≥90% (achieved through hash algorithms). Based on blockchain evidence storage, Internet of Things (IoT) devices are introduced to collect the project's environmental data (such as carbon emissions and water quality indicators) and social data (such as community employment data) in real time. Local data preprocessing is achieved through edge computing technology to reduce transmission delay.
- Machine learning dynamic optimization: Train reinforcement learning models based on historical project data to automatically optimize the parameters in the dynamic adjustment mechanism (such as the base rate k of the intergenerational imbalance adjustment fee). The model can generate differentiated adjustment strategies based on the ethical characteristics of different industries (such as clean energy vs. ecological restoration), for instance, setting stricter financing freeze trigger conditions for projects in biodiversity-sensitive areas. When a certain dimension indicator deviates from the threshold, the adjustment instruction is automatically triggered.
- Automated regulation instruction generation: A dynamic regulation rule engine is developed based on computer programming languages, converting logics such as "30% of financing frozen for non-compliance with environmental ethics standards" and "calculation of intergenerational imbalance regulation fees" into executable code. When the target layer indicators (such as E<60 points) trigger the threshold, the system automatically generates an adjustment document with an electronic signature and seal, which is sent to financial institutions and regulatory platforms through an encrypted transmission channel, achieving paperless and real-time adjustment processes.
- Cross-border data collaborative processing: By leveraging computer-distributed storage technology, a data-sharing pool for ethical assessment of cross-border projects is constructed. Data desensitization algorithms are adopted to process information involving regional privacy (such as the specific locations of communities in developing countries), retaining only the key parameters required for assessment (such as regional climate risk coefficients). Under the premise of ensuring data security, it supports the International Ethics Evaluation Alliance to retrieve data through a permission classification system, thereby enhancing the efficiency of joint reviews.

2.3.1 Dynamic Adjustment Mechanism Model (Operation of the Mechanism Layer)

In response to situations where indicators deviate from the threshold, a feedback adjustment function is designed. Taking the correction of "greenwashing" behavior in the environmental ethics dimension as an example:

$$(\mathrm{F(E)} = \begin{cases} 0 & \text{IF E} \geq 60 \text{（Meet the indicators）} \\ 0.3 \times (60 - \mathrm{E})/60 & \text{IF E} < 60 \text{（The indicators do not meet the standards.）} \end{cases}$$

$(F(E)$: Financing freeze ratio (When the environmental ethics score E is below 60, subsequent financing will be frozen proportionally. The freeze ratio increases linearly with the degree of deviation, with a maximum of 30%).
Similarly, the function for the intergenerational imbalance adjustment fee can be designed as:$(\mathrm{C(G)} = \mathrm{k} \times (50 - \mathrm{G})/50)$ (where k is the base rate, G is the intergenerational equity score, and the fee is triggered when the rate is positively correlated to the degree of deviation).

2.4 Guarantee Layer: Implementation Support System

- Third-party assessment digital management: Select institutions with interdisciplinary backgrounds in ecology, society, and ethics (requiring dual certifications of ISO 14001 and SA 8000) to undertake project ethics assessment, and link the assessment results to the qualifications of the institutions. Build a computer network platform to conduct dynamic management of third-party assessment institutions. The assessment history of institutions (such as project pass rates and consistency with regulatory review results) is recorded through database technology. SQL query statements are used to generate regular institution qualification scoring reports. For institutions with a scoring error exceeding 10% for three consecutive times, the system automatically suspends their assessment authority until rectification is completed, and algorithmic verification is passed.
- Distributed computing platform: Adopting the federated learning framework, it realizes the "data remains stationary, model moves" evaluation of cross-border projects. For instance, project data from developing countries can be trained on local servers, with only parameters uploaded and updated to the global collaborative platform. This not only protects data sovereignty but also enhances the accuracy of ethical spillover assessment through multi-source data fusion.

2.4.1 Collaborative Balance Model (Three-Dimensional Linkage)

The synergistic effect of the three dimensions is measured by the coupling coordination degree model to determine whether the ethical system is in a state of balance:

$$(C = \frac{2 \times \sqrt{E \times S \times G}}{E + S + G})$$

C: Three-dimensional synergy coordination degree (value range: 0-1; indicates a state of synergistic balance, while necessitating the initiation of cross-dimensional regulation). When a low score in one dimension causes a decline in C, the model automatically triggers a compensation mechanism from other dimensions (e.g., allocating funds from the "green employment subsidies" under the social justice dimension to supplement environmental governance input).

3. Empirical Results and Discussions

3.1 Sample Selection and Data Sources

A total of 150 global green finance projects from 2018 to 2022 were selected as research samples, covering four major fields: clean energy (40 projects), ecological restoration (30 projects), energy conservation and emission reduction (50 projects), and green buildings (30 projects). The sample distribution includes regions at different development levels (60 from developed countries and 90 from developing countries) to ensure the representativeness of empirical results.

The data are mainly sourced from:

- Environmental ethics dimension: Indicators such as carbon emission intensity and biodiversity protection rate from the UNEP Global Green Project Database (2023) (UN Environment Program, 2023) [9];
- Social justice dimension: Data such as green credit coverage and the proportion of green jobs from the World Bank Global Financial Inclusion Database (2023) (World Bank, 2023) [10];
- Intergenerational equity dimension: Information such as project payback period and the proportion of ecological fund extraction from the Bloomberg Green Bond Database (2023) (Bloomberg, 2023) [11].

3.2 Empirical Methods

A panel data regression model is adopted to verify the improvement effect of the three-dimensional balance model on ethical dilemmas, with the baseline regression equation set as follows:

In the equation, represents the comprehensive index of ethical dilemmas of the i-th project in year t (calculated by weighting the intensity of "greenwashing" behavior, short-term tendency, and degree of interest fragmentation); denotes the three-dimensional ethical composite index; stands for control variables (including project scale, per capita GDP of the region where the project is located, industry type, etc.); is the individual fixed effect; is the time fixed effect; and is the random disturbance term.

3.3 Empirical Results and Analysis

Descriptive statistics show that the average score of the three-dimensional ethical composite index for the sample projects is 62.3 (with a standard deviation of 11.5), and the average score of the ethical dilemma index is 45.7 (with a standard deviation of 9.8), indicating that current green finance projects generally have a certain degree of ethical imbalance.

The regression results show that the coefficient is -0.6901 ($p<0.01$), meaning that for every 1-point increase in the three-dimensional ethical composite index, the ethical dilemma index significantly decreases by 0.6901 points, which indicates that the model has a significant effect on improving ethical dilemmas.

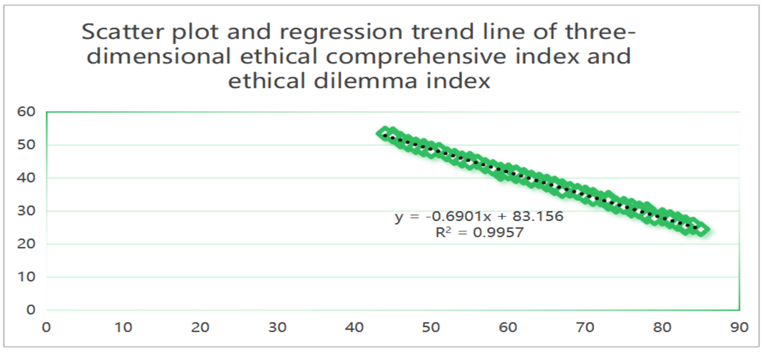

Fig.3: Scatter plot and regression trend line of the three-dimensional ethical comprehensive index and the ethical dilemma index

From the perspective of different dimensions, the coefficient of the score (E) in the environmental ethics dimension was -0.285 ($p<0.01$), the coefficient of the score (S) in the social justice dimension was -0.217 ($p<0.05$), and the coefficient of the score (G) in the intergenerational equity dimension was -0.193 ($p<0.05$). The synergistic improvement effect of three-dimensional ethical indicators on predicaments was verified.

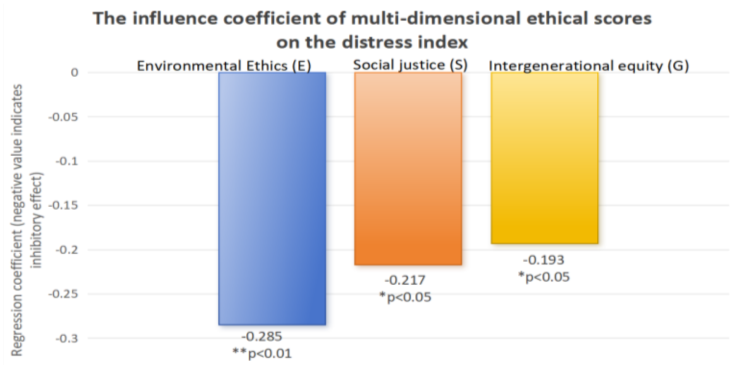

Fig.4: The influence coefficient of multi-dimensional ethical scores on the distress index

Heterogeneity analysis indicates that the improvement effect of the model in projects in developing countries (coefficient -0.714) is stronger than that in developed countries (coefficient -0.526), and the effect in ecological restoration projects (coefficient -0.689) is better than that in green building projects (coefficient -0.573). This is consistent with the realistic characteristics of developing countries, such as weak ethical foundations and high ethical sensitivity of ecological restoration projects.

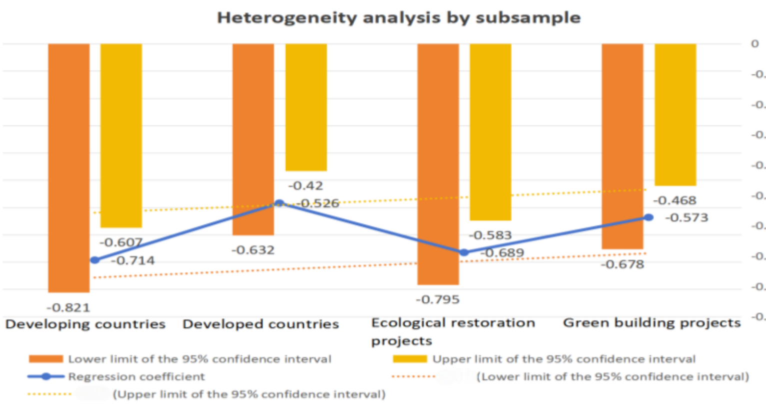

Fig.5: Heterogeneity analysis by subsample

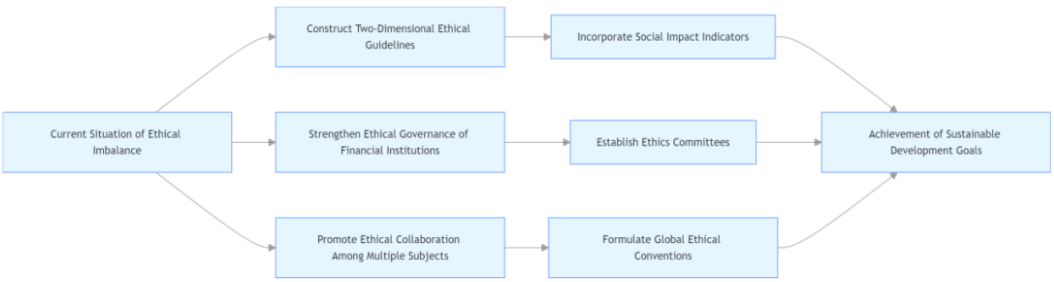

Fig.6: Schematic Diagram of Ethical-Oriented Green Finance Development Path. (The flow chart shows the three paths and specific measures from ethical imbalance to the realization of sustainable development, highlighting the core role of multi-subject collaboration.)

4. Conclusion

The role of green finance in advancing sustainable development should not be limited to expanding capital scale, but rather return to its "ethical original aspiration," reconstructing financial values with ecological holism, rectifying resource allocation with social justice, and safeguarding the rights and interests of the future with intergenerational equity. The "Three-Dimensional Ethical Balance Model for Green Finance" provides an operable framework for resolving ethical dilemmas through the organic integration of quantitative indicators, collaborative mechanisms, and guarantee systems. Only by embedding the ethical dimension into the institutional design and practical links of green finance can it avoid becoming a new tool for capital to pursue profits, and truly become a core force in achieving the sustainable development goal of "harmonious coexistence between humans and nature."

Future research can further explore the differences in green finance ethics across different cultural contexts, providing more detailed theoretical support for optimizing the cross-regional applicability of the model. It can combine the synergistic path between the humanities and social sciences and sustainable development under the "Society 5.0" framework [12] to offer more refined theoretical support for enhancing the model's cross-regional adaptability.

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