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Empowerment Mechanism of Intangible Cultural Heritage Embedding on ESG Performance of Rural PPP Projects: Weight Decomposition and Cross-Type Comparative Analysis

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Abstract: Existing ESG evaluation research on rural PPP rarely separates cultural indicators for targeted mechanism analysis, yet entropy calculation based on 58 Guangdong rural PPP samples proves that intangible cultural heritage (S5) carries the highest weight (13.547%) among all 20 ESG indicators. To unpack the heterogeneous empowerment effect of cultural embedding across project categories, this paper divides samples into three groups: wetland park PPP, water ecological governance PPP, and rural sanitation PPP. This study adopts entropy weight decomposition to quantify the marginal contribution of S5 to overall ESG score, and uses TOPSIS coefficient inter-group difference test to compare performance gaps between projects with heritage layout and non-heritage layout. The results show that intangible cultural heritage embedding significantly lifts comprehensive ESG performance; wetland PPP gains the largest cultural premium, followed by water governance projects, while sanitation PPP shows weak cultural spillover. The channel test verifies that heritage embedding improves social trust and public participation (G5), and indirectly optimizes environmental operation input. This paper supplements the micro-mechanism of cultural elements in rural sustainable infrastructure and puts forward differentiated cultural embedding strategies for three types of PPP projects.

1. Introduction

Public-Private Partnership has become a core capital operation mode for rural ecological and public infrastructure under China's rural revitalization and cultural inheritance strategy [1]. Previous rural PPP ESG evaluation mostly integrated cultural indicators into social dimension without independent decomposition, ignoring the unique weight advantage of intangible cultural heritage (ICH) in field measurement[2]. Based on the full sample data of 58 rural PPP projects in Guangdong Province from 2024 to 2025, the entropy result of the prior study confirms that S5 (intangible cultural heritage preservation initiatives) ranks first with 13.547% weight, far exceeding energy

consumption and green coverage indicators[3]. This prominent data phenomenon creates an obvious research gap: current literature fails to explain the heterogeneous empowerment intensity of ICH embedding across different rural PPP types, nor quantify its internal transmission path to E/G dimensions [4].

Most existing cultural infrastructure PPP studies only take single cultural tourism cases without classified comparison of ecological, water and sanitation projects [5]. In addition, mainstream evaluation methods adopt total TOPSIS score without weight decomposition to isolate the independent marginal contribution of heritage indicators, leading to ambiguous policy targeting [6]. To fill these deficiencies, this paper carries out three core research tasks: first, decompose entropy weight to separate the marginal impact of S5 on comprehensive ESG performance; second, divide 58 samples into wetland, water governance and sanitation PPP groups to conduct inter-group TOPSIS coefficient difference test; third, identify the mediating channels through which ICH embedding improves environmental and governance scores. The findings provide classified cultural integration schemes for different rural PPP formats and enrich the theoretical logic of cultural empowerment in ESG rural infrastructure.

2. Literature Review

Overseas scholars have confirmed that cultural heritage layout can raise community recognition of rural public projects and reduce land acquisition conflicts [7]. Laura Vang Rasmussen et al. (2021) found heritage facilities bring stable social premium to wetland PPP yet did not compare sanitation and water projects [8]. European rural PPP clauses generally set mandatory cultural protection indicators but lack quantitative weight decomposition tools to measure cultural marginal effects [9]. Domestic research on rural cultural PPP focuses on tourism single case analysis, lacking large sample classified comparison of ecological governance projects [10]. Few studies combine entropy decomposition with grouped TOPSIS to isolate the independent driving force of ICH indicators, resulting in insufficient differentiated policy suggestions [11]. The above limitations constitute the core research motivation of this paper.

3. Research Design, Index and Data

3.1. ESG Index System (Consistent with Predecessor Full-Sample Framework)

The 20-indicator ESG system covering E/S/G three dimensions is retained, with S5 (Number of intangible cultural heritage preservation initiatives) as the core explanatory variable of this paper. Indicator attributes and measurement standards remain consistent with the full-sample research [12].

3.2. Sample Grouping Standard

All 58 Guangdong rural PPP projects are divided into three mutually exclusive categories:

- Group 1 Wetland Park PPP (14 samples): landscape, wetland ecological restoration with public leisure function;
- Group 2 Water Ecological Governance PPP (28 samples): river regulation, black odorous water remediation, rural water supply upgrading;
- Group 3 Rural Sanitation PPP (16 samples): solid waste treatment, centralized sewage station construction.

Within each group, further split into heritage-embedded subgroup (S5>0) and non-heritage subgroup (S5=0) for TOPSIS score difference test.

3.3. Methodology

3.3.1. Entropy Weight Decomposition

Based on the standard entropy calculation process, extract the partial derivative of comprehensive closeness coefficient Ci with respect to S5 normalized value, to quantify the marginal contribution of ICH indicator to total ESG performance, eliminating interference of E/G other indicators[13].

3.3.2. Grouped TOPSIS Comparative Test

Calculate Ci for heritage and non-heritage subgroups within each project type; adopt independent sample t-test to verify whether inter-group performance gap is statistically significant.

3.3.3. Mediating Channel Identification

Construct simple mediating model: ICH embedding (S5) → public participation (G5) → comprehensive ESG score, to test the social governance transmission path of cultural empowerment.

3.4. Data Source

Field survey data from Oct 2024–Mar 2025, 58 valid rural PPP projects across 12 Guangdong prefecture-level cities, complete indicator data including ICH investment, public participation frequency, green coverage and energy consumption .

4. Empirical Results

4.1. Entropy Weight Decomposition: Marginal Contribution of S5

After separating the marginal effect of S5 from other 19 indicators, the average marginal weight contribution of intangible cultural heritage to total ESG score of all samples reaches 12.81%. Grouped decomposition results (Table 1):

Table 1: Marginal Weight Contribution of S5 by Project Type

Project Category	Average Marginal Contribution of S5	Proportion of total social dimension weight
Wetland Park PPP	15.62%	45.18%
Water Ecological PPP	12.47%	36.21%
Rural Sanitation PPP	7.35%	21.06%

ICH marginal contribution ranks wetland > water governance > sanitation. Wetland projects rely on cultural exhibition, folk activity venues to realize heritage carrier function, so cultural indicators occupy dominant discrimination weight; sanitation projects focus on pollution treatment with limited cultural space layout, resulting in weak marginal effect of S5.

4.2. Inter-group TOPSIS Score Difference Test

Calculate average Ci of heritage/non-heritage subgroups in each category, paired t-test $p<0.05$ for all three groups, meaning cultural embedding significantly lifts comprehensive ESG performance (Table 2):

Table 2: Average TOPSIS Closeness Coefficient (Ci) Group Comparison

Category	Heritage Embedded Subgroup	Non-Heritage Subgroup	Score Gap	Significance p-value	Category
Wetland PPP	0.437	0.312	+0.125	0.001	Wetland PPP
Water Governance PPP	0.391	0.304	+0.087	0.004	Water Governance PPP
Sanitation PPP	0.336	0.289	+0.047	0.038	Sanitation PPP
Category	Heritage Embedded Subgroup	Non-Heritage Subgroup	Score Gap	Significance p-value	Category

Cultural premium (score gap) of wetland projects is 2.6 times that of sanitation PPP, verifying obvious heterogeneous empowerment effect across formats.

4.3. Mediating Channel Test Result

Mediating effect regression output: total effect of S5 on Ci $\beta=0.213$ ($p<0.001$); direct effect $\beta=0.086$ ($p<0.01$); mediating effect via G5 public participation $\beta=0.127$ ($p<0.001$). The mediating path accounts for 59.6% of total cultural empowerment effect. Intangible heritage activities increase village resident meeting frequency, raise public supervision willingness, optimize PPP governance transparency, and indirectly boost environmental operation standards.

4.4. Heterogeneous Supplementary Analysis

Multi-phase sub-sample test: for multi-cycle wetland and water PPP, continuous ICH investment in later phases can maintain stable cultural premium; sanitation projects lack space to add heritage facilities in operation period, so cultural empowerment shows single-stage diminishing marginal return.

5. Discussion

5.1. Mechanism of ICH Cultural Empowerment

This study's mediating regression identifies a two-path transmission logic: intangible cultural heritage (ICH) embedding lifts rural PPP ESG performance via "cultural resource input → social upgrading → total performance growth".

The direct channel refers to cultural value appreciation. By integrating folk crafts, traditional water conservancy culture and local customs into PPP construction and operation, projects break single ecological remediation functions and gain cultural inheritance value. The full-sample entropy results show the ICH indicator (S5) weights 13.547% — the highest among all 20 ESG items — demonstrating obvious cultural performance premiums across projects [14].

The indirect channel works through resident participation and governance optimization. Operators building heritage halls and folk venues offer villagers stable activity spaces and demand expression channels, boosting their recognition and willingness to join project supervision and joint governance, thus lifting the high-weight governance indicator G5. Mediation tests confirm over half

of ICH's performance improvement takes effect through public participation, which acts as the core transmission mediator.

Such dual-channel effects vary sharply by PPP category. Wetland parks feature vast open spaces well-suited for heritage venues, yielding the strongest cultural and governance premiums. River and black-Odor water governance PPPs only have narrow waterfront belts for small cultural installations, generating moderate empowerment. Sanitation PPPs with enclosed sewage and waste facilities lack public activity areas; few villagers visit, so ICH layout barely creates cultural or participatory gains [15].

5.2. Category Heterogeneity Theoretical Explanation

The heterogeneous effect roots in three dimensions: spatial carrying capacity, resident activity frequency, cultural scene matching degree. Wetland PPP has maximum matching degree between infrastructure function and folk cultural display, so S5 marginal contribution is highest; sanitation infrastructure is closed functional facilities with low resident daily activity frequency, weak cultural spillover effect [16]. This classification difference provides targeted cultural embedding standards for government PPP approval.

6. Conclusions and Differentiated Policy Suggestions

6.1. Core Conclusions

(1) Intangible cultural heritage embedding is the most powerful single social indicator driving rural PPP ESG performance, with average marginal contribution 12.81% across all samples.

(2) Significant heterogeneous empowerment exists among three project types: wetland park PPP obtains the largest cultural performance premium, water ecological governance ranks second, rural sanitation PPP gains weak cultural promotion effect.

(3) Public participation acts as a key mediating variable, more than half of ICH's total empowerment effect transmits through improving village stakeholder engagement.

(4) Multi-phase wetland and water projects can sustain cultural premium via phased heritage investment, while sanitation projects show diminishing cultural marginal returns.

6.2. Classified Operation Suggestions

(1) Wetland Park PPP: Mandatorily set intangible cultural heritage exhibition, folk activity venues in planning stage, allocate 4%–6% total investment to cultural construction, take S5 as core scoring indicator in tender evaluation.

(2) Water Ecological Governance PPP: Combine waterfront green belts with local folk culture sculpture, traditional water conservancy heritage display, set small-scale cultural activity platforms to enhance resident recognition.

(3) Rural Sanitation PPP: Avoid large cultural construction investment; adopt soft embedding mode such as rural environmental protection folk custom publicity, limit heritage layout auxiliary investment within 1% of total cost.

6.3. Research Limitation and Future Outlook

This paper only adopts cross-sectional data of Guangdong Province; subsequent research can expand cross-provincial samples to compare regional cultural resource endowment differences; further research can integrate spatial entropy decomposition to analyse geographical differentiation

of ICH empowerment effect.

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