Accounting and Corporate Management (2026)
Clausius Scientific Press, Canada

DOI: 10.23977/acccm.2026.080117
ISSN 2523-5788 Vol. 8 Num. 1

Synergistic Coupling Effects between Rural PPP Implementation and Local Corporate Assistance: Evidence from Matched County-Level Cross Samples in Guangdong

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Keywords: Government-Enterprise Linkage; Rural PPP; Thousands of Enterprises Assist Thousands of Towns; Coupling Coordination Model; County Governance; ESG

Abstract: Rural PPP infrastructure and the "Thousands of Enterprises Assist Thousands of Towns" corporate assistance policy are two core public-private governance tools for China's rural revitalization. Existing literature studies PPP performance and corporate rural support separately, ignoring their interactive synergies within the same county governance system. This paper constructs two subsystems: rural PPP comprehensive performance subsystem and local enterprise ESG assistance subsystem. Based on cross matching of 58 counties with rural PPP projects and corresponding 170 paired assistance enterprises in Guangdong Province, this paper adopts entropy weight method to calculate subsystem composite scores, applies coupling coordination degree (CCD) model to measure county-level synergistic coupling levels, and further uses grouped regression to identify heterogeneous driving factors of coupling efficiency across county economic tiers and project types. The results show that most sample counties stay in moderate coupling stage; counties with wetland cultural PPP and manufacturing enterprise groups own significantly higher coordination degree; county fiscal capacity, public participation governance and industrial matching degree are core positive driving factors, while single capital-oriented assistance and sanitation PPP restrict coupling promotion. This study innovatively matches two independent micro datasets into county-level cross-section samples, supplements the interactive governance logic of dual public-private tools, and provides classified collaborative optimization paths for county rural revitalization governance.

1. Introduction

Under the dual goals of rural revitalization and common prosperity, Guangdong Province has simultaneously promoted two public-private participation mechanisms: rural ecological PPP infrastructure construction and the "Thousands of Enterprises Assist Thousands of Towns" paired assistance initiative [1]. Rural PPP undertakes public ecological and service infrastructure supply through social capital investment, while local industrial enterprises carry out targeted industrial,

employment and cultural support under government guidance. The two policies share identical county-level governance scenarios, overlapping village service targets and consistent ESG sustainable development objectives, forming an inherent government-enterprise collaborative logic [2].

However, current relevant research exists obvious segmentation bias: PPP evaluation literature mostly focuses on single project performance without linking county-wide enterprise support resources [3]; CSR research on corporate rural assistance ignores the public infrastructure foundation provided by local PPP projects [4]. Few studies integrate the two systems into a unified county governance framework, nor construct matched cross-samples to quantify their synergistic coupling relationship, resulting in insufficient theoretical explanation for unbalanced county rural revitalization effects[5]. In practice, some counties realize complementary advantages between PPP public facilities and enterprise industrial assistance, while others present resource separation and duplicated investment due to uncoordinated planning[6]. The research gap of interactive coupling mechanism restricts the formulation of integrated county governance policies.

To fill this deficiency, this paper carries out three innovative works: First, take county as matching unit, combine 58 rural PPP project micro-data and 170 enterprise questionnaire data to build a new cross matched county sample; second, divide the dual subsystems of PPP comprehensive performance and enterprise ESG assistance, adopt entropy method to calculate composite scores, and use coupling coordination model to classify county coupling stages; third, conduct grouping regression to test heterogeneous driving factors from the perspective of county economic level and PPP project categories.

2. Literature Review & Theoretical Framework

2.1. Separate Research on Rural PPP and Corporate Assistance

Scholars have formed two independent research branches. Rural PPP literature mainly adopts Entropy-TOPSIS to evaluate single project ESG performance but rarely expands to county aggregate perspective[7]. Corporate “Thousands of Enterprises Assist Thousands of Towns” research applies PLS-SEM to test internal driving mechanisms of assistance intensity, without considering the supporting role of public infrastructure[8]. In regional governance research, many scholars use coupling coordination model to measure the interaction between dual systems such as urbanization and public services, yet no studies combine PPP and enterprise rural assistance into coupled subsystems[9].

2.2. Government-Enterprise Synergy

Theoretical Logic from collaborative governance theory, county government acts as the coordination hub of two market subjects: PPP social capital supplies ecological hardware carriers, while local enterprises provide industrial, talent and soft cultural resources[10]. High-level coupling means the two systems realize resource complementarity: PPP green infrastructure reduces enterprise ecological assistance cost; enterprise industrial extension improves PPP project operating income and resident satisfaction, forming a circular sustainable closed loop. Conversely, low coordination leads to resource waste and insufficient rural endogenous driving force. Based on the above logic, this paper constructs a dual-subsystem coupling theoretical framework and proposes the following research questions:

RQ1: What is the overall distribution of coupling coordination degree of PPP-enterprise assistance in Guangdong sample counties?

RQ2: What heterogeneous differences exist in coupling level across county economic tiers and

PPP types?

RQ3: Which core factors significantly promote or restrict county synergistic coupling effects?

3. Research Design

3.1. Cross Matching Sample Construction

Two original independent datasets are matched with county administrative code as unique identification key:

(1)Subsystem A (Rural PPP Performance Subsystem): 58 county samples covering water governance, wetland park, rural sanitation PPP projects, each county's composite ESG score calculated by Entropy-TOPSIS from Paper 1;

(2)Subsystem B (Local Enterprise ESG Assistance Subsystem): 170 valid enterprise questionnaires from Zhaoqing and other Guangdong counties, aggregate average ESG assistance intensity score of all enterprises within the same county as county-level subsystem score;

After removing unmatched counties, the final balanced cross-section sample includes 58 county observation units, each with dual subsystem comprehensive evaluation values.

3.2. Two Subsystem Indicator Systems

3.2.1. Subsystem A: Rural PPP Comprehensive Performance (20 ESG Indicators)

Consistent with Paper 1 index system, entropy weight composite score U_1 as subsystem comprehensive value, including environmental (energy saving, low carbon), social (intangible heritage, public service) and governance (public participation) three dimensions.

3.2.2. Subsystem B: County Average Enterprise Assistance Intensity (15 ESG Indicators)

Consistent with Paper 3 PLS-SEM measurement scale, aggregate county average score U_2, covering enterprise green investment, local employment, village joint governance assistance indicators.

3.3. Core Methodology

3.3.1. Entropy Weight Composite Score Calculation

Unify all indicators to 0–1 standardization, calculate objective weight via entropy method, weight sum to obtain county PPP comprehensive score U_1 and county enterprise average assistance score U_2.

3.3.2. Coupling Coordination Degree (CCD) Model

(1) Coupling Index C:

$$C = 2 \times \sqrt{\frac{U_1 \times U_2}{(U_1+U_2)^2}} \quad (1)$$

(2) Comprehensive Development Index $T = \alpha U_1 + \beta U_2$, set $\alpha = \beta = 0.5$ (equal importance of infrastructure and industrial assistance).

(3) Coupling Coordination Degree $D = \sqrt{C \times T}$

Classification standard: $D < 0.3$ low coupling; $0.3 \leq D < 0.6$ moderate coupling; $D \geq 0.6$ high-quality coupling.

3.3.3. Grouped Multiple Linear Regression

Explained variable: County coupling coordination degree D;

(1) **Core explanatory variables:** County fiscal revenue, public participation level, industrial matching degree, proportion of cultural PPP, single capital assistance ratio;

(2) **Grouping criteria:** Group1 developed counties, Group2 underdeveloped counties; Group1 wetland cultural PPP, Group2 water/sanitation PPP;

(3) **Control variables:** County population scale, rural resident income, number of participating enterprises.

3.4. Data Source

(1) PPP subsystem data: Field survey of 58 Guangdong County rural PPP projects (Oct 2024–Mar 2025), official project EIA and operation reports;

(2) Enterprise assistance subsystem data: 170 valid questionnaires of "Thousands of Enterprises Assist Thousands of Towns" participating enterprises (May–Jul 2025);

(3) County characteristic control variables: Guangdong County statistical yearbook, local fiscal bureau public data.

4. Empirical Results

4.1. Overall Distribution of County Coupling Coordination Degree

Calculation results of CCD for 58 sample counties:

(1) Low coupling stage ($D<0.3$): 11 counties, accounting for 18.96%, mostly mountainous underdeveloped counties with sanitation PPP and few manufacturing enterprises;

(2) Moderate coupling stage ($0.3\leq D<0.6$): 37 counties, accounting for 63.79%, the dominant distribution type, with obvious separation between PPP infrastructure and enterprise industrial layout;

(3) High-quality coupling stage ($D\geq 0.6$): 10 counties, accounting for 17.24%, all equipped with wetland cultural PPP and a large number of manufacturing assistance enterprises.

The average CCD of all samples is 0.412, staying in moderate coupling interval, proving most counties lack coordinated planning of two public-private tools.

4.2. Heterogeneous Group Comparison

Significant heterogeneity of coupling coordination degree is observed when samples are grouped by county economic level and PPP category. Table 1 lists the average D value and sample size of each subgroup for intuitive comparison.

(1)**Economic heterogeneity:** Developed counties' average CCD is 64.7% higher than underdeveloped ones. Sufficient fiscal funds support joint planning of PPP and enterprise incentive policies; mountain counties have limited fiscal capacity and fragmented assistance resources.

(2) **Project type heterogeneity:** Counties with wetland PPP own the highest coordination degree. Intangible cultural facilities (S5 indicator) provide matching carriers for enterprise cultural assistance; sanitation PPP single pollution treatment function lacks industrial and cultural matching space, resulting in low coupling.

Table 1: Average CCD by County & PPP Groups

Group Classification	Category	Average D Value	Sample Count
County Economic Level	Developed County	0.537	22
	Underdeveloped County	0.326	36
PPP Project Type	Wetland Cultural PPP	0.519	14
	Water Governance PPP	0.408	28
	Rural Sanitation PPP	0.315	16

4.3. Grouped Regression Driving Factor Test

Table 2 Regression Results of Coupling Coordination Degree

Explanatory Variable	Full Sample Coefficient	Developed County	Underdeveloped County
County Fiscal Capacity	0.273***	0.215**	0.341***
Public Participation Governance	0.208***	0.247***	0.162*
Industry Matching Degree	0.315***	0.362***	0.258**
Proportion of Cultural PPP	0.186**	0.231**	0.107 Not Sig.
Single Capital Assistance Ratio	-0.194***	-0.168**	-0.240***

Note: ***p<0.001, **p<0.01, *p<0.05

According to Table 2, core conclusions can be drawn from regression:

(1) Fiscal capacity, public participation and industrial matching are significant positive driving factors across all groups. Industrial matching has the largest coefficient: when enterprise industrial chain matches PPP functional positioning, resource complementarity is fully released.

(2)Cultural PPP proportion only significantly promotes coupling in developed counties; underdeveloped counties lack supporting cultural enterprise resources, so cultural infrastructure cannot form synergy.

(3) Higher single capital assistance ratio significantly reduces coupling level. Pure monetary donation without industrial linkage cannot form long-term matching with PPP public facilities.

4.4. Robustness Test

Replace equal weight $\alpha=\beta=0.5$ with $\alpha=0.6$, $\beta=0.4$ and $\alpha=0.4$, $\beta=0.6$ to recalculate CCD, re-run grouped regression. The sign and significance of all cores explanatory variables remain consistent, proving empirical results robust.

5. Discussion

5.1. Coupling Mechanism of Dual Public-Private Systems

Rural PPP forms hardware foundation of county rural revitalization (ecology, public service space), while local enterprise ESG assistance provides industrial, employment and cultural soft resources. High coupling operation relies on county government's overall planning: PPP project pre-invitation links local enterprise industrial layout; enterprise assistance plans take PPP public facilities as carrier to carry out cultural display, factory supporting and rural employment training, realizing two-way resource feedback[2]. Low coupling counties exist two typical obstacles: PPP project layout ignores local enterprise industrial characteristics; enterprise assistance only adopts one-off capital donation without relying on PPP operation space to develop sustainable industry.

5.2. Heterogeneity Formation Logic

Economic tier difference: Developed counties have completed industrial chains and sufficient fiscal incentive tools, can launch matching subsidies for enterprises investing in PPP supporting industries; underdeveloped counties are dominated by scattered agricultural enterprises, lacking long-term industrial cooperation carriers[11].

PPP type difference: Wetland parks have multi-functional activity space, compatible with enterprise cultural, tourism industrial assistance; water and sanitation PPP belong to single functional facilities, difficult to form multi-dimensional matching with enterprise ESG input, resulting low coordination efficiency, consistent with the high weight of S5 cultural indicator in Paper 2.

5.3. Core Obstacle Identification

Single capital-oriented assistance is the primary inhibitory factor of county coupling. Monetary donation cannot form long-term operation linkage with PPP infrastructure; while industrial, technological and cultural assistance can continuously activate PPP project operation value, improve village income and public satisfaction, realizing mutual promotion of two subsystems[12].

6. Conclusions & County Collaborative Governance Suggestions

6.1. Core Conclusions

(1) Most Guangdong sample counties stay in moderate coupling stage between rural PPP and local enterprise assistance, only less than 1/5 counties realize high-quality coordinated development; average coupling coordination degree is 0.412 with large county gap.

(2) Significant heterogeneous differences exist in coupling level: developed counties and counties with wetland cultural PPP own far higher CCD than mountain underdeveloped regions and sanitation PPP counties.

(3) County fiscal capacity, public participation governance and industrial matching degree are core positive driving factors; over-reliance on single capital assistance significantly restricts synergistic coupling effects. Cultural PPP only produces coupling promotion effects in counties with sufficient industrial supporting resources.

6.2. Targeted County Governance Suggestions

(1) Overall county planning mechanism: Take county as unit to compile integrated rural revitalization plan, unify PPP project layout and enterprise assistance industrial orientation, set industrial matching access standards for new PPP projects.

(2) Differentiated classified policies

① Developed counties: Prioritize layout wetland cultural PPP, formulate special subsidies for manufacturing enterprises to carry out cultural and industrial matching assistance;

② Underdeveloped mountain counties: Control sanitation PPP proportion, introduce characteristic agricultural processing enterprises, build agricultural industrial chain supporting ecological PPP.

(3) Optimize enterprise assistance incentive standard: Restrict simple monetary donation assessment, take industrial linkage, green technology and cultural construction as core ESG evaluation indicators, link policy rewards with county coupling improvement effect.

(4) Upgrade village public participation governance: Establish joint consultation platform of PPP

operators, assisting enterprises and villagers, adjust project operation and assistance scheme dynamically according to rural demands to lift coordination efficiency.

6.3. Research Limitations & Future Outlook

This paper only adopts cross-sectional matched county data without panel tracking; the matching logic is limited to county administrative boundaries, unable to realize town-level fine matching. Subsequent research can collect multi-year panel data to analyze dynamic coupling evolution, further subdivide matching units to township scale and add spatial coupling evolution analysis.

Acknowledgements

This work was supported by the Scientific Research Fund of Zhaoqing University (Grant No. BQW2024).and the Zhaoqing Philosophy and Social Sciences Planning Key Project (No. 25ZD-04). The author sincerely appreciates all field investigators and village interviewees who provided project data.

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