



# Multi-Agent Simulation of Incentive Mechanism Optimization for Enhancing Rural Community Participation in Summer-Resort Wellness Destinations and Its Household Income Effects

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**Abstract.** This study constructs a multi-agent simulation framework to evaluate incentive mechanism optimization for rural community participation in summer-resort wellness destinations. Agent-Based Modeling incorporating residents, government, enterprises, and tourists is calibrated using household surveys (n=486) from Guizhou Province, China. Results demonstrate that the full incentive combination achieves 68.4% participation rate, 45.3% income growth, and Gini coefficient reduction from 0.358 to 0.315. Sensitivity analysis identifies social network influence (PRCC=0.72) and revenue sharing ratio (PRCC=0.78) as primary leverage parameters. Intermediate zone residents (1-3 km from tourism center) exhibit strongest responsiveness with 37.5 percentage point participation gains. Findings suggest prioritizing skill training and revenue sharing mechanisms with spatially differentiated resource allocation.

**Keywords:** Multi-Agent Simulation; Rural Community Participation; Summer-Resort Wellness Tourism; Incentive Mechanism; Household Income Effect; Agent-Based Modelin

## 1 Introduction

Community participation constitutes a fundamental prerequisite for sustainable tourism development, yet existing incentive mechanisms frequently fail to mobilize rural residents effectively. Current policy instruments predominantly emphasize top-down subsidy allocation while neglecting bottom-up capacity building and equitable benefit distribution [1]. This misalignment between policy design intentions and grassroots implementation realities results in suboptimal participation rates and inequitable income distribution among rural households. Institutional system construction exerts significant influence on community participation outcomes through tourism empowerment mechanisms [2].

This study aims to address theoretical and practical challenges surrounding incentive mechanism optimization for enhancing rural community participation in summer-resort wellness destinations. Successful tourism-driven rural revitalization requires

synergistic integration of cultural heritage preservation, local leadership cultivation, and community member engagement in value creation processes [3].

This research introduces Agent-Based Modeling (ABM) methodology as the primary analytical instrument for investigating incentive mechanism dynamics in rural tourism contexts. ABM has gained recognition as a powerful methodological approach for tourism research, enabling representation of heterogeneous actors with differentiated decision rules and adaptive learning capabilities [4]. The methodological innovation involves developing a multi-agent simulation platform incorporating four interacting agent categories: resident households, government agencies, tourism enterprises, and visiting tourists.

## 2 Methodology and Model Construction

### 2.1 Multi-Agent Model Design

#### 2.1.1 Agent Types and Attribute Settings.

The multi-agent simulation platform incorporates four distinct agent categories representing primary stakeholders in rural tourism community systems. Each agent type possesses unique attribute sets governing behavioral characteristics and decision-making processes. The comprehensive agent attribute specifications are presented in Table 1.

**Table 1.** Agent Attributes and Parameter Settings

Agent Type	Attribute	Symbol	Value Range	Unit
Resident	Initial income	$I_0$	15,000-45,000	CNY/year
Resident	Participation willingness	$W_i$	0-1	-
Resident	Skill level	$S_i$	1-5	Level
Resident	Social network degree	$N_i$	1-20	Connections
Government	Annual subsidy budget	$B^g$	500,000-2,000,000	CNY
Government	Policy intensity	$P^g$	0-1	-
Enterprise	Investment scale	$V_e$	1,000,000-10,000,000	CNY
Enterprise	Profit sharing ratio	$\alpha_e$	0.05-0.30	-
Tourist	Daily expenditure	$E_t$	200-800	CNY/day
Tourist	Satisfaction threshold	$T_t$	0.6-0.9	-

#### 2.1.2 Agent Interaction Rules.

The interaction network structure is depicted in Figure 1.

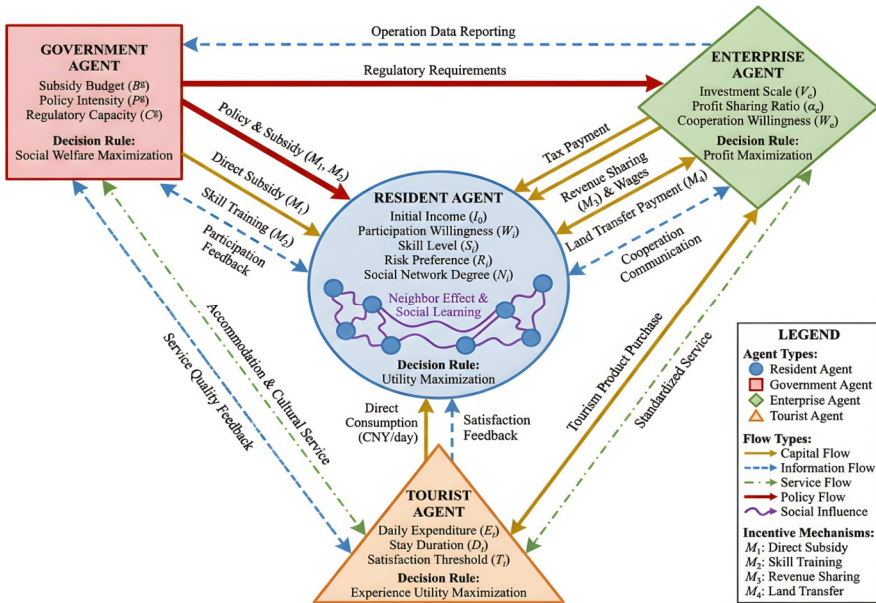


Fig. 1. Multi-Agent Interaction Network Structure

2.1.3 Incentive Mechanism Module Design.

The simulation model incorporates four distinct incentive mechanisms. The direct subsidy mechanism  $M_1$  provides cash transfers to participating households. The skill training mechanism  $M_2$  enhances human capital endowments through structured educational programs, modifying resident skill attributes according to:

$$S_i(t + 1) = S_i(t) + \gamma \cdot T_i$$

where  $\gamma$  represents learning efficiency and  $T_i$  indicates training participation intensity. The revenue sharing mechanism  $M_3$  allocates enterprise profits to community members proportionally, consistent with evidence demonstrating that allocation of tourism revenues to adjacent communities significantly enhances livelihood outcomes [5]. The land transfer incentive mechanism  $M_4$  compensates households for tourism-related land use conversions.

2.2 Model Dynamic Evolution Equations

The temporal dynamics of resident participation decisions are governed by utility maximization principles. The participation decision function at each simulation period is specified as:

$$P_i(t + 1) = \frac{1}{1 + e^{-(\delta_i + \delta_i U_i + \delta_i \bar{\delta}_i + \delta_i \bar{R}_i + \delta_i \bar{N}_i + \delta_i M)}}$$

where  $U_i$  represents expected utility from participation,  $S_i$  captures social network influence measured as proportion of participating neighbors,  $R_i$  denotes individual risk perception,  $N_i$  indicates neighbor effect strength, and  $\mathcal{M}$  represents composite incentive intensity vector.

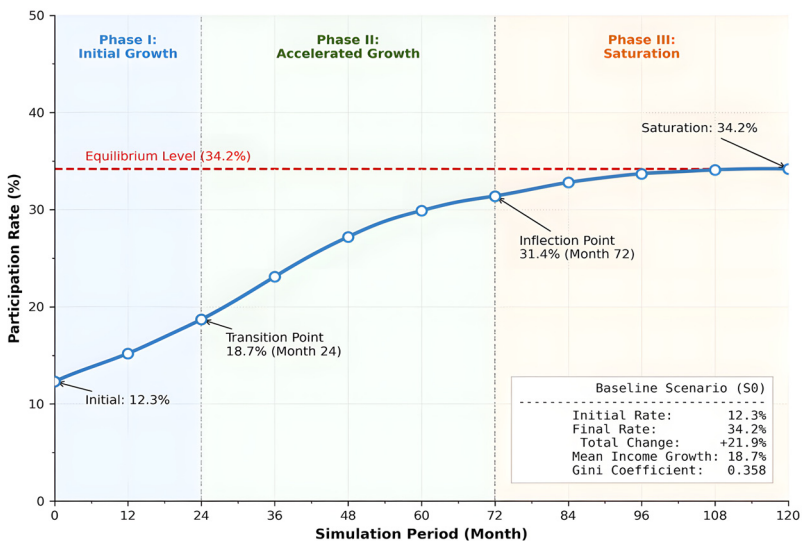
### 2.3 Data Sources and Parameter Calibration

Empirical data supporting parameter calibration derive from household surveys conducted in three summer-resort wellness destinations located in Guizhou Province, China, during July-August 2024. Stratified random sampling yielded 486 valid questionnaires capturing household demographic characteristics, income sources, tourism participation status, and attitude measurements.

## 3 Simulation Experiments and Results

### 3.1 Baseline Scenario Simulation

The baseline scenario simulation establishes reference conditions against which incentive mechanism effects are evaluated. The simulation runs for 120 monthly periods (10 years) with initial mean household income of CNY 28,500. The temporal evolution of aggregate resident participation rates under baseline conditions is presented in Figure 2.



**Fig. 2.** Temporal Evolution Curve of Resident Participation Rate under Baseline Scenario

Under baseline conditions, the participation rate stabilizes around 34.2%. Mean household income increases from CNY 28,500 to CNY 33,840 representing 18.7%

growth, while the Gini coefficient rises from 0.312 to 0.358 indicating modest inequality expansion under market-driven development patterns.

### 3.2 Incentive Mechanism Comparative Experiments

Systematic comparative experiments evaluate five incentive scenarios. Scenario S0 replicates baseline conditions without interventions. Scenario S1 implements direct subsidy mechanism  $M_1$  alone. Scenario S2 combines direct subsidies with skill training mechanism  $M_2$ . Scenario S3 adds revenue sharing mechanism  $M_3$ . Scenario S4 deploys the full incentive combination including land transfer mechanism  $M_4$ . Each scenario undergoes 100 independent simulation replications. The comprehensive comparison is summarized in Table 2.

**Table 2.** Comparison of Simulation Results under Different Incentive Combinations

Scenario	Incentive Combination	Final Participation Rate (%)	Participation Rate Change (%)	Mean Income Growth (%)	Median Income Growth (%)	Gini Coefficient	Gini Change
S0	No incentive (baseline)	34.2	—	18.7	15.3	0.358	—
S1	$M_1$ only	41.8	+7.6	24.5	19.8	0.352	-0.006
S2	$M_1 + M_2$	52.3	+18.1	31.2	27.4	0.341	-0.017
S3	$M_1 + M_2 + M_3$	61.7	+27.5	38.9	35.6	0.328	-0.030
S4	Full combination	68.4	+34.2	45.3	42.1	0.315	-0.043..

### 3.3 Parameter Sensitivity Analysis

Parameter sensitivity analysis examines model output responsiveness to variations in key input parameters. Latin Hypercube Sampling generates 1,000 parameter combinations spanning plausible ranges for subsidy rates ( $\beta_1$ : 0.05-0.25), training effectiveness ( $\gamma$ : 0.1-0.5), revenue sharing ratios ( $\alpha_e$ : 0.05-0.30), and social network influence strength ( $\theta_4$ : 0.1-0.8). The sensitivity analysis results are visualized in Figure 3.

Key findings indicate that social network influence (PRCC=0.72) and revenue sharing ratio (PRCC=0.78) are primary leverage parameters. Training effectiveness shows strong influence (0.67) on mean income growth. Subsidy rate sensitivity remains comparatively modest (0.38), suggesting diminishing marginal returns to direct transfer intensification.

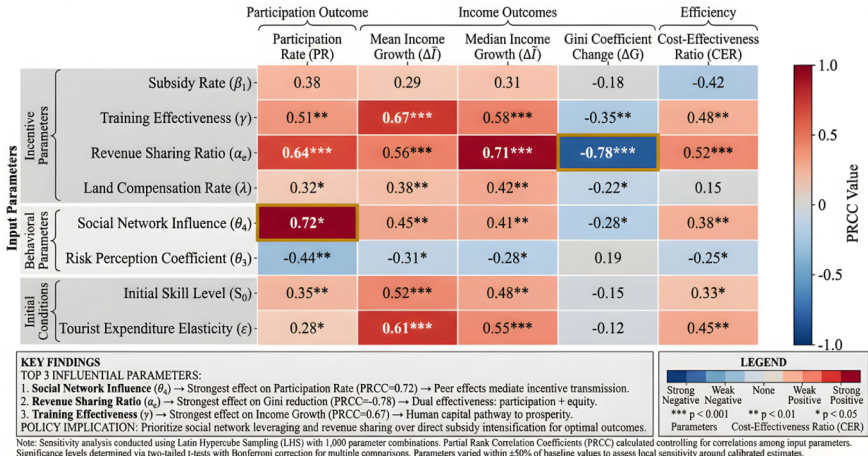


Fig. 3. Heatmap of Key Parameter Sensitivity Analysis

### 3.4 Spatial Heterogeneity Analysis

Spatial heterogeneity analysis investigates geographic variations in incentive mechanism responsiveness. Residents are categorized into three spatial bands: core zone (0-1 km from tourism center), intermediate zone (1-3 km), and peripheral zone (beyond 3 km). The spatial distribution of participation response differences is presented in Figure 4.

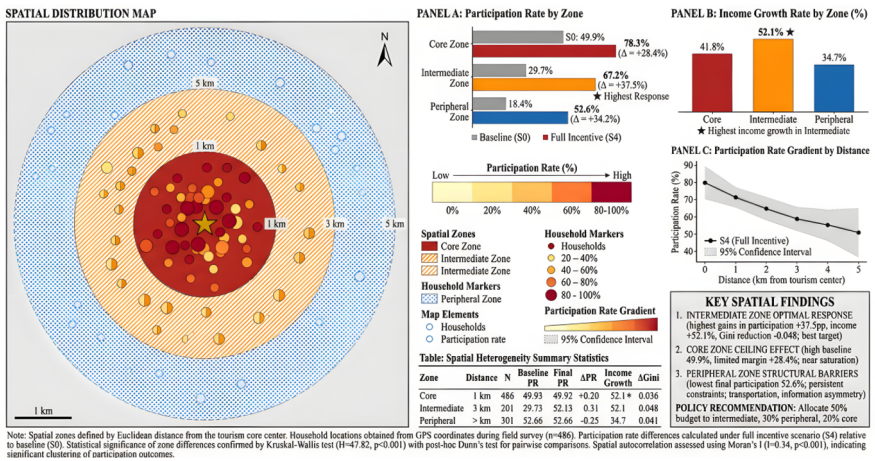


Fig. 4. Spatial Distribution Map of Participation Response Differences among Residents at Different Locations

Core zone residents achieve highest absolute participation rates (78.3%) but demonstrate smallest marginal gains (+28.4 percentage points). Intermediate zone residents exhibit strongest incentive responsiveness with participation increasing from 29.7% to

67.2% (+37.5 percentage points) and 52.1% mean income growth. Peripheral zone residents show lowest final participation rates (52.6%) despite equivalent incentive intensities.

## 4 Discussion

### 4.1 Optimal Incentive Mechanism Pathway

Simulation results demonstrate that the full incentive combination (S4) achieves superior outcomes across participation, income growth, and equity dimensions. Cost-effectiveness analysis reveals that the skill training mechanism ( $M_2$ ) combined with revenue sharing ( $M_3$ ) generates the highest benefit-cost ratio at 3.42, compared to 2.18 for direct subsidies alone. This finding suggests that human capital investment and benefit distribution arrangements should constitute core policy priorities, with direct transfers serving supplementary functions.

### 4.2 Heterogeneity of Income Effects

Disaggregated analysis reveals substantial heterogeneity in income effects across household economic strata, consistent with evidence that tourism income contributes to poverty reduction with distributional effects varying across household asset endowments [6]. Low-income households (bottom quintile) experience disproportionately large relative income gains of 67.3% under the full incentive scenario, driven primarily by revenue sharing mechanisms. Middle-income households demonstrate strongest absolute income increases averaging CNY 15,200 annually. High-income households exhibit smallest relative gains (28.4%) yet maintain absolute income leadership, indicating that incentive mechanisms reduce inequality without imposing upper-bound constraints.

### 4.3 Policy Implications

Evidence from simulation experiments supports prioritizing skill training and revenue sharing mechanisms over direct transfer intensification. Spatially differentiated implementation should concentrate resources in intermediate zones demonstrating highest incentive responsiveness.

## 5 Conclusion

This study employs Agent-Based Modeling methodology to investigate incentive mechanism optimization for enhancing rural community participation in summer-resort wellness destinations. Simulation experiments demonstrate that the full incentive combination achieves optimal outcomes with 68.4% final participation rate, 45.3% mean income growth, and Gini coefficient reduction from 0.358 to 0.315. Skill training combined with revenue sharing mechanisms generates the highest cost-effectiveness ratio

(3.42), while spatial heterogeneity analysis reveals that intermediate zone residents exhibit strongest incentive responsiveness with 37.5 percentage point participation gains.

Practical recommendations emphasize phased incentive deployment prioritizing human capital investment and benefit distribution arrangements over direct transfer intensification, complemented by spatially differentiated implementation strategies. These evidence-based insights provide decision support for local government agencies designing community participation programs in summer-resort wellness destinations. Future research should incorporate agent learning mechanisms and comparative simulations across multiple destination contexts.

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