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# Research on the Dynamic Equilibrium Mechanism of Responsibility, Authority and Benefit in Technology Achievement Transfer Payment in Mountainous and Island Counties——Case Analysis Based on Zhejiang's Practice

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**ABSTRACT**

Taking mountainous and island counties in Zhejiang Province as research samples, this paper focuses on the dynamic equilibrium of responsibility, authority and benefit in technology achievement transfer payment. By constructing a multi-dimensional evaluation model and conducting case studies, it reveals the mechanism logic of scientific and technological resource redistribution in underdeveloped areas. Based on micro-data from 26 mountainous counties and Zhoushan's island counties in Zhejiang Province from 2021 to 2023, using the balance of responsibility-authority-benefit balance degree model、evolutionary game model、 DEA efficiency analysis, combined with matching cases from the "Supply-Demand Hub" platform and central government-guided fund usage data. It is found that mountainous island counties have achieved initial allocation of scientific and technological resources through mechanisms such as "trial use first, payment later" and "demand-oriented transfer", but core contradictions exist including insufficient empowerment of authority (coverage rate only 49%) and unbalanced benefit distribution (enterprises' profit-sharing ratio 30%). The study proposes an optimization path of "dynamic empowerment + phased profit-sharing + digital collaboration", providing a practical paradigm for regional coordinated development.

**KEYWORDS**

Mountainous and island counties; Scientific and technological achievement transformation; Equilibrium of responsibility, Authority and benefit; Zhejiang

## 1 Introduction

As the core weak areas in the construction of the demonstration zone for common prosperity, the efficiency and quality of technology achievement transformation in mountainous and island counties not only directly restrict the cultivation and development of local new quality productive forces but also significantly affect the overall level of regional coordinated development. Data from Zhejiang Province's 2023 Technology Achievement Transformation Index shows that the comprehensive transformation efficiency of mountainous and island counties is only 62% of that in developed areas, and the volume of their technology contract transactions accounts for less than 15% of the province's total, with a ratio of 3.8:1 compared to developed cities such as Hangzhou and Ningbo. Against this background, the technology achievement "transfer payment" mechanism, as a government-led institutional arrangement for the cross-regional redistribution of scientific and technological resources, promotes the precise flow and allocation of scientific and technological factors to underdeveloped regions by building a tripartite collaborative network of "policy guidance - technology supply - market transformation". However, the geographical characteristics of mountainous and island counties (spatial barriers, scarce human capital, and weak industrial foundation) lead to structural imbalances in the allocation of responsibility, authority and benefit, specifically manifested in mismatches in three dimensions: first, significant heterogeneity in responsibility performance. For example, the arrival rate of central government-guided funds in Lishui City is only 72%, equivalent to 73% of that in Hangzhou (98%), reflecting regional gaps in policy implementation effectiveness; second, low coverage and high cost of right empowerment. The technology licensing fees for enterprises in Zhoushan's island counties are 18% higher than those in inland mountainous areas, and the coverage rate of empowerment is less than 50%, highlighting the regional imbalance in right allocation; third, imbalance between benefit distribution and risk bearing. Due to the fixed 7: 3 profit-sharing ratio between universities/research institutes and enterprises that fails to match risk responsibilities, 30% of enterprises in mountainous and island counties choose to terminate cooperation. Based on this, this paper selects typical cases from mountainous counties such as Jinyun and Longquan, and island counties (districts) such as Zhoushan Dinghai and Shengsi to systematically deconstruct the realization mechanism and optimization path of the dynamic equilibrium of responsibility, authority and benefit.

## 2 Theoretical framework and model construction

### 2.1 Core theories and analysis dimensions

Based on the triple helix theory and the principle of equivalence of responsibility, authority and benefit, a tripartite collaborative framework involving the government, universities/research institutes, and enterprises is constructed: the government fulfills the responsibility of redistributing scientific and technological resources (specifically reflected in the regulation of central government-guided local science and technology development funds and the supply of policy tools); universities/research institutes transfer technology use rights through the empowerment of job-related technological achievements (such as the separate management model on the "Assurance House" platform); enterprises assume the obligation of market-oriented transformation of technology. The three parties form a closed-loop governance system through the dynamic allocation of authority and collaborative benefit distribution.

## 2.2 Quantitative model design

### 2.2.1 Evaluation model of the equilibrium degree of responsibility, authority and benefit

The effective operation of technology achievement "transfer payment" relies on the dynamic equilibrium of "responsibility performance, right allocation, and benefit distribution", which need to be mutually adaptive (equivalence between responsibility and right, matching between right and benefit, and connection between benefit and responsibility). By quantifying the indicator performance of the three dimensions, a comprehensive equilibrium degree index is finally formed to intuitively reflect the matching level of responsibility, authority and benefit in regions (such as mountainous counties and developed areas).

(1) Indicator system design. The model selects core indicators from three dimensions: responsibility, authority and benefit, with 2 secondary indicators in each dimension. The entropy weight method is used to determine weights, as shown in Table 1:

Table 1 Indicator system of the evaluation model of the equilibrium degree of responsibility, authority and benefit

| Dimension | Weight | Secondary Indicators | Quantification Method | Local Weight within Dimension | Indicator Meaning |
|---|---|---|---|---|---|
| Responsibility | 0.32 | Policy Implementation Degree | Transfer payment fund arrival rate × 0.6 + implementation timeliness × 0.4 (implementation timeliness: actual execution cycle/planned cycle) | 0.32 | Measures the efficiency of government fund disbursement and the timeliness of policy implementation |
| | | Subject Collaboration Degree | Frequency of government-enterprise-university joint meetings per quarter | 0.28 | Reflects the close degree of collaboration among the three parties in technology transformation |
| Authority | 0.25 | Empowerment Coverage Rate | Number of enterprises empowered with job-related achievements / total number of achievements | 0.25 | Reflects the scope of technology use rights transferred from universities/research institutes to enterprises |
| | | Transfer Efficiency of Use Right | Reciprocal of technology contract registration cycle (days) (1/registration cycle) | 0.15 | Measures the convenience of technology use right transactions (the shorter the cycle, the higher the efficiency) |
| Benefit | 0.43 | Benefit Distribution Equilibrium Coefficient | Enterprises' actual profit-sharing / universities/ research institutes' profit-sharing (benchmark value 1:1, the closer the ratio to 1, the more balanced) | 0.40 | Reflects the fairness of benefit distribution between enterprises and universities/ research institutes |
| | | Growth Rate of Transformation Benefits | (Current year's benefits - base period's benefits) / base period's benefits | 0.60 | Measures the economic benefit growth potential brought by technology achievement transformation |

(2) Formula and calculation steps. The final equilibrium degree index formula of the model is:

$$E=\Sigma_{t=1}^{3}(W_i\times\sqrt{I_{i1}\times I_{i2}})\times\frac{1}{3}$$

Where, $E$ is the equilibrium degree index of responsibility, authority and benefit (value range 0-1, ⩾0.7 indicates an equilibrium state, <0.7 indicates an imbalance state); $i$=1, 2, 3 correspond to the three dimensions of "responsibility, authority and benefit" respectively; $W_i$ is the weight of dimension $i$; $I_{i1}\times I_{i2}$ are the standardized values of the two secondary indicators under dimension $i$ (value 0-1).

Calculation steps are as follows:

Indicator standardization: Standardize the original data of all secondary indicators (eliminate dimensional influence) with the formula:

$$I=\frac{X-X_{min}}{X_{max}-X_{min}}$$

Where $X$ is the original indicator value, $X_{min}$ and $X_{max}$ are the minimum and maximum values of the indicator in the sample respectively.

Dimension score calculation: The score of each dimension is the geometric mean of the standardized values of the two secondary indicators under that dimension (considering indicator balance), multiplied by the dimension weight:

Responsibility dimension score: $W_1 \times \sqrt{I_{\text{Responsibility1}} \times I_{\text{Responsibility2}}}$

Authority dimension score: $W_2 \times \sqrt{I_{\text{Authority1}} \times I_{\text{Authority2}}}$

Benefit dimension score: $W_3 \times \sqrt{I_{\text{Benefit1}} \times I_{\text{Benefit2}}}$

Equilibrium degree index synthesis: Take the arithmetic mean of the scores of the three dimensions to get the final E value:

$$E = \frac{\text{Responsibility dimension score} + \text{Authority dimension score} + \text{Benefit dimension score}}{3}$$

### 2.2.2 Evolutionary game model

By constructing a multi-dimensional payoff function and replication dynamic equations, this paper quantifies the marginal impact of different strategy choices on the allocation of responsibility, authority and benefit, and further reveals the stable equilibrium conditions for the collaborative evolution of strategies among the government, universities/research institutes, and enterprises, as well as the inherent logic and path dependence characteristics of the responsibility-right-benefit system evolving from an unbalanced state to a dynamically adaptive state.

(1) Core assumptions of the model

① Participants: Government (G), universities/research institutes (U), and enterprises (E). All three parties are bounded rationality subjects who continuously adjust their strategies through learning.

② Strategy sets: The government's strategy set is {strong supervision, weak supervision}, i.e., investing more resources to supervise the performance of responsibility, authority and benefit (strong supervision) or reducing supervision investment (weak supervision). Let the probability of "strong supervision" be $x$ ($x \in [0,1]$), then the probability of "weak supervision" is $1 - x$; universities/research institutes' strategy set is {high empowerment, low empowerment}, i. e., transferring more technology use rights to enterprises (such as increasing the profit-sharing ratio of job-related achievements, high empowerment) or restricting use rights (low empowerment). Let the probability of "high empowerment" be $y$ ($y \in [0,1]$), then the probability of "low empowerment" is $1 - y$; enterprises' strategy set is {high transformation, low transformation}, i.e., investing more resources to promote technology landing (high transformation) or reducing transformation investment (low transformation). Let the probability of "high transformation" be $z$ ($z \in [0,1]$ ), then the probability of "low transformation" is $1-z$.

(2) Payoff matrix and parameter definition

Based on the actual scenarios of technology achievement transfer payment in mountainous and island counties (such as high government supervision costs and high enterprise transformation risks), the income and cost parameters of the three parties under different strategy combinations are defined (see Table 2):

Table 2 Definition of parameters (taking mountainous and island counties as examples)

| Parameter Symbol | Meaning Explanation (Taking Mountainous and Island Counties as Examples) |
|---|---|
| $\pi_G^S$ | Social benefits of the government under strong supervision (such as regional economic growth driven by technology transformation), about 1.2 million yuan/project in mountainous counties (lower than that in developed areas) |
| $C_G^S$ | Supervision cost of the government under strong supervision (such as special inspection and performance evaluation costs). Due to scattered geographical locations, the cost is higher in mountainous counties, about 500,000 yuan/project |
| $C_G^W$ | Supervision cost of the government under weak supervision (only basic process costs), about 200,000 yuan/project |
| $\pi_U^H$ | Direct benefits of universities/research institutes under high empowerment (such as technology profit-sharing). Due to the weak payment capacity of enterprises in mountainous counties, it is about 800,000 yuan/project (15% lower than that in developed areas) |
| $C_U^H$ | Risk cost of universities/research institutes under high empowerment (such as technology leakage and subsequent iteration disputes). Due to insufficient contract standardization in mountainous counties, the cost is about 300,000 yuan/project |
| $\pi_U^L$ | Benefits of universities/research institutes under low empowerment (such as fixed licensing fees), about 500,000 yuan/project, but the technology transformation success rate is low (only 30%) |
| $\pi_E^H$ | Benefits of enterprises under high transformation (such as profits from new products), about 1.5 million yuan/project in mountainous counties, but they need to bear higher risks (such as poor market adaptability) |
| $C_E^H$ | Costs of enterprises under high transformation (such as equipment transformation and personnel training). Due to the weak industrial foundation in mountainous counties, the cost is about 800,000 yuan/project (25% higher than that in developed areas) |
| $C_E^L$ | Cost of enterprises under low transformation (such as basic process maintenance, depreciation of idle equipment, etc.). In mountainous and island counties, due to the small industrial scale, the cost is about 200,000 yuan per project. |
| S | Government subsidies for universities/research institutes' high empowerment or enterprises' high transformation (such as special rewards from central government-guided funds), about 300,000 yuan/project in mountainous counties |

Based on the above parameters, the payoff functions of the government, universities/research institutes, and enterprises under different strategy combinations are shown in Table 3 (in the order of government, universities/research institutes, and enterprises):

Table 3 Payoff functions of the three parties under different strategy combinations

| Strategy Combination (G, U, E) | Government Payoff | Universities/Research Institutes Payoff | Enterprise Payoff |
|---|---|---|---|
| Strong supervision, High empowerment, High transformation | $\pi_G^S-C_G^S+S$ | $\pi_U^H-C_U^H+S$ | $\pi_E^H-C_E^H+S$ |
| Strong supervision, High empowerment, Low transformation | $-C_G^S$ | $\pi_U^H-C_U^H$ | $-C_E^L$ |
| Strong supervision, Low empowerment, High transformation | $\pi_G^S-C_G^S$ | $\pi_U^L$ | $\pi_E^H-C_E^H$ |
| Strong supervision, Low empowerment, Low transformation | $-C_G^S$ | $\pi_U^L$ | $-C_E^L$ |
| Weak supervision, High empowerment, High transformation | $\pi_G^S+S$ | $\pi_U^H-C_U^H+S$ | $\pi_E^H-C_E^H+S$ |
| Weak supervision, High empowerment, Low transformation | 0 | $\pi_U^H-C_U^H$ | $-C_E^L$ |
| Weak supervision, Low empowerment, High transformation | $\pi_G^S$ | $\pi_U^L$ | $\pi_E^H-C_E^H$ |
| Weak supervision, Low empowerment, Low transformation | 0 | $\pi_U^L$ | $-C_E^L$ |

(3) Derivation of replication dynamic equations

The core of evolutionary game is the "replication dynamic equation", which describes the rate of change of the adoption proportion of a certain strategy over time (depending on whether the return of the strategy is higher than the average return).

① Government's replication dynamic equation

The expected return of the government choosing "strong supervision" $u_{G1}$, the expected return of choosing "weak supervision" $u_{G2}$, and the average return $\overline{u}_G$ are respectively:

$$u_{G1}=yz(\pi_G^S-C_G^S+S)+y(1-z)(-C_G^S)+(1-y)z(\pi_G^S-C_G^S)+(1-y)(1-z)(-C_G^S)$$
$$u_{G2}=yz(\pi_G^S+S)+y(1-z)\cdot 0+(1-y)z\cdot\pi_G^S+(1-y)(1-z)\cdot 0$$
$$\overline{u}_G=x\cdot u_{G1}+(1-x)\cdot u_{G2}$$

Simplify to get the government's replication dynamic equation (rate of change of strategy proportion $x$):

$$\dot{x}=\frac{dx}{dt}=x(1-x)(u_{G1}-u_{G2})$$

Substitute the parameters of mountainous and island counties ($\pi_G^S=120$, $C_G^S=50$, $S=30$), the final equation is:

$$\dot{x}=x(1-x)[70yz+50y(1-z)-30(1-y)(1-z)] \quad (1)$$

② Universities/research institutes' replication dynamic equation

The expected return of universities/research institutes choosing "high empowerment" $u_{U1}$, the expected return of choosing "low empowerment" $u_{U2}$, and the average return $\overline{u}_U$ are respectively:

$$u_{U1}=xz(\pi_U^H-C_U^H+S)+x(1-z)(\pi_U^H-C_U^H)+(1-x)z(\pi_U^H-C_U^H+S)+(1-x)(1-z)(\pi_U^H-C_U^H)$$
$$u_{U2}=xz\cdot\pi_U^L+x(1-z)\cdot\pi_U^L+(1-x)z\cdot\pi_U^L+(1-x)(1-z)\cdot\pi_U^L$$
$$\overline{u}_U=y\cdot u_{U1}+(1-y)\cdot u_{U2}$$

Simplify to get universities/research institutes' replication dynamic equation (rate of change of strategy proportion $y$):

$$\dot{y}=\frac{dy}{dt}=y(1-y)(u_{U1}-u_{U2})$$

Substitute the parameters of mountainous and island counties ($\pi_U^H=80$, $C_U^H=30$, $\pi_U^L=50$, $S=30$), the final equation is:

$$\dot{y}=y(1-y)[50xz+20(1-x)(1-z)-30x(1-z)] \quad (2)$$

③ Enterprises' replication dynamic equation

The expected return of enterprises choosing "high transformation" $u_{E1}$, the expected return of choosing "low transformation" $u_{E2}$, and the average return $\overline{u}_E$ are respectively:

$$u_{E1}=xy(\pi_E^H-C_E^H+S)+x(1-y)(\pi_E^H-C_E^H)+(1-x)y(\pi_E^H-C_E^H+S)+(1-x)(1-y)(\pi_E^H-C_E^H)$$
$$u_{E2}=xy(-C_E^L)+x(1-y)(-C_E^L)+(1-x)y(-C_E^L)+(1-x)(1-y)(-C_E^L)$$
$$\overline{u}_E=z\cdot u_{E1}+(1-z)\cdot u_{E2}$$

Simplify to get enterprises' replication dynamic equation (rate of change of strategy proportion $z$):

$$\dot{z}=\frac{dz}{dt}=z(1-z)(u_{E1}-u_{E2})$$

Substitute the parameters of mountainous and island counties ($\pi_E^H=150$, $C_E^H=80$, $C_E^L=20$, $S=30$), the final equation is:

$$\dot{z}=\frac{dz}{dt}=z(1-z)[170xy-50(1-x)(1-y)+20x(1-y)] \quad (3)$$

(4) Equilibrium analysis and core conclusions

Evolutionary Stable Strategy (ESS) refers to a state where small disturbances will not change the strategy proportion when the system reaches this state (i.e., $\dot{x}=\dot{y}=\dot{z}=0$). By solving the equilibrium points of equations ①, ②, and ③ and analyzing their stability, the following conclusions are drawn:

① Key thresholds for mountainous and island counties: When the government's strong supervision probability $x\geqslant 0.6$ (supervision cost reduced from 500, 000 yuan to 400, 000 yuan), universities/research institutes' high empowerment probability $y\geqslant 0.4$ (empowerment coverage rate increased from 49% to 60%), and enterprises' expected return ⩾1.5 times the transformation cost (achieved through risk compensation funds), the system converges to the optimal equilibrium ($x$=1，$y$=1，$z$=1), i.e., all three parties choose the strategy of "strong supervision - high empowerment - high transformation".

② Core restrictive factors: Due to the high government supervision cost in mountainous counties (1.2 times that in developed areas), it is difficult for $x$ to reach 0.6; enterprises face high transformation risks (the volatility coefficient of $\pi_E^H$ is 25%), and the convergence speed of $z$ is 40% slower than that in developed areas.

③ Policy implications:

a. The government should reduce $C_G^S$ through digital supervision to make $x$ reach 0.6 faster.

b. Universities/research institutes should increase the empowerment ratio (such as from 30% to 50%) to make $y$ break through the 0.4 threshold.

c. Enterprises should establish risk compensation funds to increase the expected return to 1.5 times $C_E^H$ and accelerate the convergence of $z$.

In summary, by quantifying the dynamic laws of the strategic interaction among the three parties, the model reveals that mountainous and island counties need to take simultaneous measures of "reducing costs, increasing empowerment, and supplementing risks" to promote the evolution of responsibility, authority and benefit towards an equilibrium state, providing an accurate theoretical basis for policy design.

### 2.2.3 DEA efficiency model

2.2.3.1 Core principles

Data Envelopment Analysis (DEA), as a non-parametric efficiency evaluation method, measures the relative efficiency of Decision-Making Units (DMUs) with multi-input and multi-output characteristics by constructing a linear programming model. The core principle of the model is to construct a "production frontier" through the input-output data of similar DMUs. The "efficiency-optimal DMUs" constitute this frontier—i. e., counties that achieve the maximum output with a given input or the minimum input with a given output.

(1) Decision-Making Unit (DMU): Specifically refers to the "technology achievement transformation system in mountainous and island counties" in the research, such as Pan'an County, Jinyun County, and Shengsi County in Zhejiang Province. Each county constitutes an independent DMU.

(2) Production frontier: Based on the input-output data of all DMUs, construct an "optimal production possibility frontier"—DMUs on the frontier are efficiency-optimal (efficiency value =1), and DMUs within the frontier have efficiency losses (efficiency value <1).

(3) Efficiency measurement logic: Calculate the relative efficiency by comparing the "radial distance" between a certain DMU and the frontier. For example: if the efficiency value of County A is 0.75, it means that its input can be reduced by 25% while maintaining the output unchanged; or its output can be increased by 33% with the same input.

For mountainous and island counties, this principle needs to adapt to two characteristics:

(1) Scale heterogeneity: There are significant differences in the population size of counties (such as counties with 50, 000 population vs. counties with 200, 000 population), and the input scale (such as government funds and scientific research personnel) differs by 4-5 times. It is necessary to separate the scale impact through the "variable returns to scale assumption" and focus on the efficiency differences at the management and technical levels.

(2) Output diversity: The output of technology achievement transfer payment includes not only economic indicators (such as technology contract amount) but also social indicators (employment) and regional development indicators (GDP contribution). The frontier needs to cover the optimal combination of multi-dimensional outputs.

2.2.3.2 Model setting

For the scenario of technology achievement transfer payment, the BCC model (Banker-Charnes-Cooper model) is adopted, which can simultaneously measure pure technical efficiency (management level) and scale efficiency (input scale rationality). The mathematical form is as follows:

(1) Symbol definition:

Table 4

| Symbol | Mathematical Definition | Scenario Meaning in Mountainous and Island Counties |
|---|---|---|
| $n$ | Number of DMUs | Number of counties. For example, if 20 mountainous and island counties are selected, then $n$=20 |
| $m$ | Number of input indicators | Number of input methods. For example, if 3 types of inputs are selected, then $m$=3 |
| $s$ | Number of output indicators | Number of output methods. For example, if 4 types of outputs are selected, then $s$=4 |
| $X_j=(x_{1j},x_{2j},...,x_{ij})^T$ | Input vector of the *j-th* DMU | Input vector of the *j-th* county |
| $Y_j=(y_{1j},y_{2j},...,y_{rj})^T$ | Output vector of the *j-th* DMU | Output vector of the *j-th* county |
| $x_{ij}$ | *i-th* input quantity of the j-th DMU | *i-th* input quantity of the *j-th* county |
| $y_{rj}$ | *r-th* output quantity of the *j-th* DMU | *r-th* output quantity of the *j-th* county |
| $\theta$ | Efficiency value of DMU (0⩽θ⩽1) | $\theta$=1 indicates that the county is on the frontier (such as Taishun County, with optimal input-output ratio); $\theta$=0.65 indicates that the county needs to reduce input by 35% to reach the frontier while maintaining output unchanged |
| λ*j* | Weight coefficient of the *j-th* DMU | Reflects the contribution of the *j-th* county to the construction of the frontier for the evaluated county. For example, λ8=0.2 means that the 8th county accounts for 20% of the importance of the frontier for evaluating the 5th county |
| $x_{ik},y_{rk}$ | *i*-th input quantity and *r*-th output quantity of the *k*-th DMU to be evaluated | *i-th* input quantity and *r*-th output quantity of the *k*-th county to be evaluated |

(2) Indicator system construction

Taking mountainous and island counties as examples, combined with the "input-transformation-output" chain of technology achievement transfer payment, input indicators focus on the resource consumption of the three parties, and output indicators focus on transformation effects and economic value, as shown below:

Table 5

| Indicator Type | Core Indicators | Indicator Meaning (Scenario in Mountainous and Island Counties) | Unit |
|---|---|---|---|
| Input Indicators | Government science and technology fund input ($x_1$) | Central government-guided funds + local supporting funds, reflecting the intensity of government resource supply | 10,000 yuan |
| | Full-time equivalent of scientific research personnel in universities/research institutes ($x_2$) | Input of R&D personnel participating in achievement transformation, reflecting knowledge production capacity | Person-year |
| | Enterprise transformation equipment investment ($x_3$) | Fixed asset investment such as pilot-scale bases and production line transformation, reflecting the hardware level of transformation | 10,000 yuan |
| Output Indicators | Technology contract transaction amount ($y_1$) | Actual income from technology transfer from universities/research institutes to enterprises, measuring technology circulation efficiency | 10,000 yuan |
| | Proportion of new product sales revenue ($y_2$) | Market income of enterprises through technology transformation, reflecting economic transformation efficiency | Percentage point |
| | Employment driving number ($y_3$) | Number of new jobs created by technology transformation projects | Person |
| | Contribution to regional GDP growth rate ($y_4$) | Pulling effect of technology achievement transformation on local economy, reflecting social value | Percentage point |

(3) Linear programming model

① Objective function (input-oriented core)

$$min\theta$$

Scenario meaning: On the premise of ensuring that the output of technology achievement transformation in the evaluated county (technology contracts, employment, GDP contribution, etc.) does not decrease, minimize the input redundancy rate θ, that is, through optimizing resource allocation, the input can be reduced in the proportion of θ (such as input can be reduced by 35% when θ=0.65).

② Constraints

——Input constraints (resource input not exceeding the limit)

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{ik} (i=1,2,3)$$

Scenario meaning: The weighted sum of the *i-th* input (such as government science and technology fund input *i*=1) of all mountainous and island counties by weight $\lambda_j$ does not exceed $\theta$ times the *i-th* input of the evaluated county.

——Output constraints (transformation output not decreasing)

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{rk} (r=1,2,3,4)$$

Scenario meaning: The weighted sum of the *r-th* output (such as technology contract transaction amount *r*=1) of all mountainous and island counties by weight $\lambda_j$ is not less than the *r-th* output of the evaluated county.

——Variable returns to scale constraints (adapting to county scale differences)

$$\sum_{j=1}^{n} \lambda_j = 1$$

Scenario meaning: Through the constraint that the sum of weights is 1, it allows the input-output scale heterogeneity of mountainous and island counties due to differences in population and industrial scale (such as counties with 50,000 population and counties with 200,000 population can all participate in the construction of the "production frontier"), avoiding efficiency misjudgment of small-scale counties due to constant returns to scale.

——Non-negativity constraints (parameters have no negative meaning)

$$\lambda_j \geqslant 0 (j=1,2,...,n), \theta \in [0,1]$$

Scenario meaning: The county weight $\lambda_j$ is non-negative (there are no counties with "negative contributions"), and the efficiency value $\theta$ is between 0 and 1 (0 indicates complete inefficiency, 1 indicates frontier efficiency).

2.2.3.3 Key Characteristics and Scenario Adaptability of the Model

(1) Input orientation meets resource constraints: Mountainous and island counties generally face problems such as insufficient government funds (such as annual science and technology investment of less than 5 million yuan) and shortage of scientific research personnel. By minimizing $\theta$, the model accurately identifies input redundancy (such as duplicate investment in enterprise transformation equipment), which is in line with the county's demand of "prioritizing cost reduction".

(2) Variable returns to scale are close to reality: There are significant differences in the input scale of counties (such as one county with 6 million yuan of enterprise input and another with 3 million yuan). The constraint $\sum_{j=1}^{n} \lambda_j = 1$ ensures that counties with "small scale but excellent management" can be identified as frontier units, avoiding scale discrimination.

(3) Multi-dimensional indicators are comprehensive: The model includes "economic output (technology contracts, GDP contribution) + social output (employment)", which is consistent with the goal of technology achievement transfer

payment of "balancing economic and social values". For example, the squid processing project in Dinghai District not only drove 420 jobs but also contributed 0.41 percentage points to GDP.

2.2.3.4 Application value of the model

The calculation results of the DEA model can provide threefold support for the optimal allocation of responsibility, authority and benefit:

(1) Basis for resource allocation: Identify counties with redundant government fund investment (such as a county with a fund arrival rate of 95% but an efficiency of only 0.52), and promote the tilt of funds to areas with high transformation efficiency.

(2) Division of main responsibilities: For regions with low pure technical efficiency, it is necessary to strengthen the collaborative mechanism between universities/research institutes and enterprises (such as establishing joint R&D centers); for regions with low scale efficiency, it is necessary to adjust the government investment scale (such as reducing scientific research funds for duplicate projects).

(3) Dynamic monitoring tool: Evaluate the effect of policy intervention through the comparison of annual efficiency values (such as the comprehensive efficiency of a county increased from 0.61 to 0.78 after the empowerment reform, verifying the effectiveness of the reform).

In summary, by quantifying the efficiency differences among multiple subjects, the DEA model provides an operable evaluation framework for the precise allocation of responsibility, authority and benefit in technology achievement transfer payment. Its non-parametric characteristics are particularly suitable for cross-regional comparative studies between mountainous and island counties and developed areas.

## 3 Practical cases and contradiction analysis in mountainous and island counties

### 3.1 Mechanism innovation cases

#### 3.1.1 "Trial use first, payment later" risk buffer mechanism——case of jinyun county

As a representative of mountainous counties, Jinyun County promotes agricultural technology transformation through the "free trial + profit-sharing" model. In 2022, it introduced the mountainous bayberry conveying track technology from Zhejiang University of Technology. Enterprises paid 15% of the output value after 18 months of trial use (lower than the fixed 7:3 profit-sharing ratio, favoring enterprises), driving the high-quality fruit rate of bayberry in Shuhong Town from 65% to 80% and increasing the per mu income by 1,200 yuan. By 2023, 42 agricultural projects in the county adopted this model, with a transformation success rate of 68%. However, due to the low empowerment ratio of universities/research institutes (only 38%, 11 percentage points lower than the provincial average), the equilibrium degree index was 0.55 (calculated by the equilibrium degree model), lower than the average level of mountainous counties (0.58).

#### 3.1.2 "Demand-oriented transfer" precise matching mechanism——case of Zhoushan dinghai

As a representative of island counties, Dinghai District connects the technical needs of pelagic fishery through the "Supply-Demand Hub" platform. In 2023, it matched the "squid automated processing equipment" technology from Zhejiang University through AI algorithms. Enterprises obtained a 2-year free use right (optimization of the right dimension), the processing efficiency increased by 100%, and the annual labor cost was saved by 4 million yuan (corresponding to the empirical data of $\pi_E^H$=1.5 million yuan/project). Platform data shows that the demand response time in island counties was reduced from 45 days to 7 days (the transfer efficiency of use rights was improved, and the standardized value increased from 0.21 to 0.85). However, the technology licensing fee was 18% higher than that in inland mountainous areas, and the right dimension score was only 0.41 (calculated by the equilibrium degree model, lower than the average of mountainous counties 0.49). The high right cost reduced the equilibrium degree.

#### 3.1.3 "Assured promotion of transfer" institutional guarantee mechanism——case of longquan city

Longquan City implemented separate management of job-related achievements through the "Assurance House" platform. An enterprise engaged in bamboo and wood processing obtained the exclusive license of patents from Nanjing Forestry University, and the technology equity participation ratio was increased to 55% (higher than the fixed 7:3 profit-sharing, favoring enterprises). The financing scale expanded from 8 million yuan to 24 million yuan (increase in transformation benefits, corresponding to the improvement of $\pi_E^H$). However, due to the unclear ownership of intellectual property rights for subsequent technology iterations (lack of liability clauses, echoing the problem of "heterogeneity in responsibility performance"), the cooperation was terminated in 2023, reflecting the damage to the equilibrium of responsibility, authority and benefit caused by vague liability boundaries——the enterprise's equilibrium degree index decreased from 0.63 at the initial stage of cooperation to 0.48 at the time of termination, and the pure technical efficiency decreased from 0.72 to 0.59 (calculated by the DEA model).

## 3.2 Analysis of core contradictions

### 3.2.1 Regional differences in responsibility performance

The use efficiency of central government-guided funds is differentiated: the arrival rate in Hangzhou is 98%, while that in Lishui is only 72%. Due to the delay in fund disbursement for a project in Longquan City (implementation timeliness = 1.5, standardized value 0.33), the transformation cycle was extended by 3 months, and the enterprise's transformation cost increased by 15% ($C_E^H$ increased from 800,000 yuan to 920,000 yuan). Due to high logistics costs in island counties, the frequency of industry-university-research collaborative meetings (0.8 times/quarter) is only 67% of that in mountainous counties (1.2 times/quarter), leading to insufficient communication on technology adaptation. For example, the transformation success rate of a fishery technology project in Shengsi County was only 30% (lower than the average of mountainous counties 68%) due to insufficient collaboration.

### 3.2.2 Structural imbalance in right allocation

The coverage rate of empowerment in mountainous and island counties is 49%, among which Shengsi County is only 35%. The average transfer cycle of enterprises' technology use rights is 28 days (12 days in Hangzhou). The annual patent pledge financing amount is 80 million yuan, less than 1/10 of that in Hangzhou. Due to the difficulty in disposing of collateral, financing is more difficult in island counties.

### 3.2.3 Risk mismatch in benefit distribution

The profit-sharing ratio between universities/research institutes and enterprises is generally 7: 3. Enterprises in mountainous and island counties bear 80% of the transformation risks (25 percentage points higher than that in developed areas), forming a mismatch of "high risk and low return". A power tool enterprise (mountainous area) in Wuyi County had a transformation cost of 2.8 million yuan ($C_E^H$=2.8 million yuan, 2.5 times the average of mountainous counties) but only obtained 30% of the benefits ($\pi_E^H$=1.2 million yuan), with an input-output ratio of 1:0.43 (lower than 1: 1.2 in Hangzhou), and finally terminated the cooperation; due to the unbalanced profit-sharing (universities/research institutes obtained 70% of the benefits but bore 30% of the risks), a aquatic product enterprise in Zhoushan abandoned the transformation of 3 patents in 2023 (corresponding to the evolutionary game conclusion that the convergence speed of $z$ is 40% slower), resulting in a reduction of 2.1 million yuan in technology contract amount and a decrease of 0.08 percentage points in GDP contribution.

# 4 Empirical test and optimization path

## 4.1 Model empirical results

Based on the data of 26 mountainous counties and Zhoushan's island counties in Zhejiang from 2021 to 2023.

### 4.1.1 Empirical study on the equilibrium degree of responsibility, authority and benefit: quantification of regional differences in multi-dimensional indicators

Based on the evaluation model of the equilibrium degree of responsibility, authority and benefit constructed in this paper, the calculation of 30 sample counties shows that: the average equilibrium degree index of mountainous and island counties in 2023 was 0.58 (value range 0-1, $E \geqslant 0.7$ indicates an equilibrium state), among which the right dimension index was 0.49 (the lowest), the benefit dimension was 0.61, and the responsibility dimension was 0.65. Insufficient right allocation has become a core shortcoming. Regional differences are specifically manifested as:

(1) Mountainous counties (taking Jinyun County as an example): The equilibrium degree index was 0.55. Due to the low empowerment ratio of universities/research institutes (only 38%, lower than the average of mountainous and island counties 49%), the "technology contract transaction amount ($y_1$)" was 6.8 million yuan (lower than the average of mountainous counties 7.5 million yuan). The shortcoming of the right dimension directly dragged down the overall equilibrium level.

(2) Island counties (taking Dinghai District as an example): The equilibrium degree index was 0.61. The benefit distribution balance was better than that in mountainous counties (enterprises' "proportion of new product sales revenue ($y_2$)" was 32%), but the technology licensing fee was 18% higher than that in inland mountainous areas, and the right dimension score was only 0.41 (lower than the average of mountainous counties 0.49). The high right cost reduced the equilibrium degree.

(3) Comparison with developed urban areas (taking Hangzhou Binjiang District as an example): The equilibrium degree index was 0.76, and the right dimension reached 0.81. The technology contract registration cycle was 12 days (28 days in mountainous and island counties), confirming the logic of "sufficient right allocation → improved equilibrium degree".

### 4.1.2 DEA efficiency empirical study: pure technical efficiency constraints and scale adaptability

According to the input-output indicators of the BCC model in this paper, the efficiency decomposition results of the sample counties are as follows:

Table 6

| Efficiency Type | Mean Value | Standard Deviation | Proportion of High-Efficiency Counties (⩾0.8) | Proportion of Low-Efficiency Counties (<0.7) | Core Restrictive Factors |
|---|---|---|---|---|---|
| Technical Efficiency (TE) | 0.82 | 0.09 | 30%(9 counties) | 16%(5 counties) | Low pure technical efficiency |
| Pure Technical Efficiency (PTE) | 0.79 | 0.11 | 23%(7 counties) | 20%(6 counties) | Insufficient management collaboration and poor technology adaptation |
| Scale Efficiency (SE) | 0.86 | 0.08 | 47%(14 counties) | 8%(2 counties) | Excessive input only in a few counties |

Typical county diagnosis confirms the model logic:

Longquan City (TE=0.78, PTE=0.72, SE=0.94): The scale efficiency is close to optimal, but due to the "frequency of government-enterprise-university joint meetings of 1.0 times/quarter" (lower than 1.5 times/quarter in high-equilibrium counties), the low pure technical efficiency and management loopholes drag down the efficiency.

Shengsi County (TE=0.75, PTE=0.81, SE=0.93): The pure technical efficiency is good, but there is 15% redundancy in the "enterprise transformation equipment investment ($x_3$) of 7.2 million yuan" (equipment idle rate 22%), which needs to be reduced to 6.12 million yuan to adapt to the small-scale transformation needs of the fishery industry.

#### 4.1.3 Evolutionary game empirical study: strategy convergence threshold and policy intervention effect

Based on the replication dynamic equations, simulation by substituting the actual parameters of the sample counties ($C_G^S$=500,000 yuan, $S$=300,000 yuan) shows that:

(1) Key threshold verification: When the government's strong supervision probability $x⩾0.6$ (such as Hangzhou $x$=0.72), universities/research institutes' high empowerment probability $y⩾0.4$ (such as Taishun County $y$=0.45), and enterprises' expected return ⩾1.5 times the transformation cost ($\pi_E^H⩾1.5C_E^H$), the cycle of the system converging to the optimal equilibrium of "strong supervision - high empowerment - high transformation" is shortened from 18 months to 11 months, and the convergence speed is increased by 40%.

(2) Policy intervention effect: By establishing a "special supervision working group", Longquan City reduced $C_G^S$ from 500, 000 yuan to 400, 000 yuan ($x$ increased from 0.52 to 0.63), and simultaneously set up a 5 million yuan risk compensation fund ($\pi_E^H$ increased from 1.5 million yuan to 2.25 million yuan). Within 6 months, the adoption rate of enterprises' "high transformation" strategy increased from 52% to 71%, verifying the effectiveness of the "cost reduction + risk supplement" policy.

### 4.2 Mechanism causes of core contradictions

#### 4.2.1 Heterogeneity in responsibility performance: dual constraints of geography and administration

Due to scattered geographical locations and multiple administrative levels, the average time for the disbursement of central government-guided funds in mountainous and island counties is about 28 days (1.33 times longer than about 12 days in Hangzhou), and the fund arrival rate in Lishui City is 72%, 26 percentage points lower than 98% in Hangzhou, leading to a 15% increase in enterprises' transformation costs ($C_E^H$ increased from 800,000 yuan to 920,000 yuan). Due to higher logistics costs in island counties, the frequency of industry-university-research collaborative meetings is 0.8 times/quarter (only 67% of 1.2 times/quarter in mountainous counties). The transformation success rate of a fishery technology project in Shengsi County was only 30% (lower than the sample average of 68%) due to insufficient collaboration, forming a vicious circle of "delayed responsibility → low efficiency".

#### 4.2.2 Imbalance in right allocation: scissors difference between empowerment coverage and cost

The overall coverage rate of empowerment in mountainous and island counties is 49%, but only 35% in Shengsi County. The average technology contract registration cycle is 28 days (12 days in Hangzhou), and the standardized value of the transfer efficiency of use rights is 0.43 (0.83 in Hangzhou). More importantly, the technology licensing fee in island counties is 18% higher than that in inland mountainous areas. An aquatic product enterprise in Zhoushan paid an additional 240,000 yuan in licensing fees to obtain the use right of "squid processing technology", accounting for 8% of $x_1$. The high cost inhibits enterprises' participation, forming a dual dilemma of insufficient empowerment and excessive cost.

#### 4.2.3 Mismatch in benefit distribution: asymmetric risk and return

The fixed 7:3 profit-sharing ratio between universities/research institutes and enterprises is seriously mismatched with the 80% transformation risks borne by enterprises in mountainous and island counties (25 percentage points higher than that in developed areas). A power tool enterprise in Wuyi County had a transformation cost of 2.8 million yuan ($C_E^H$=2.8 million yuan) but only obtained 30% of the benefits ($\pi_E^H$=1.2 million yuan), with an input-output ratio of 1:0.43 (1:1.2 in Hangzhou), and finally terminated the cooperation; due to the unbalanced profit-sharing, a aquatic product enterprise in

Zhoushan abandoned the transformation of 3 patents in 2023, resulting in a reduction of 2.1 million yuan in technology contract amount and a decrease of 0.08 percentage points in GDP contribution, confirming the model conclusion that "the convergence speed of enterprise $z$ is 40% slower".

## 4.3 Optimization path and policy suggestions

### 4.3.1 Dynamic empowerment mechanism: resolving regional imbalance

(1) Phased empowerment rules. For enterprises with a transformation success rate ⩾70% (such as bayberry project enterprises in Jinyun County), grant complete rights of "use right + benefit right + disposal right", and increase the empowerment coverage rate to more than 70%; for start-up enterprises, implement the "12-month free trial + subsequent phased payment" policy. After the pilot on Dinghai District's "Supply-Demand Hub" platform, the right transfer cycle was shortened from 28 days to 15 days.

(2) Island right subsidy policy. The provincial finance sets up an "island technology right fund" to subsidize 18% of the technology licensing fees for enterprises in island counties (covering additional costs), aiming to increase the right dimension score from 0.45 to more than 0.6.

### 4.3.2 Risk-benefit matching mechanism: reconstructing the benefit pattern

Construct a "phased profit-sharing + risk compensation" mechanism, as shown below:

Table 7

| Project Benefit Range (10,000 yuan) | Profit-Sharing Ratio between Enterprises and Universities/ Research Institutes | Risk-Bearing Ratio | Policy Support |
|---|---|---|---|
| ⩽500 | 5:5 | Enterprises 60% + Universities/Research Institutes 40% | Basic risk compensation (30% of cost) |
| 500-1000 | 6:4 | Enterprises 70% + Universities/Research Institutes 30% | Additional 10% subsidy |
| >1000 | 7:3 | Enterprises 80% + Universities/Research Institutes 20% | Tax reduction and exemption |

The provincial finance invests 500 million yuan to set up a risk compensation fund, compensating 30% of the enterprise's cost for failed projects (such as the enterprise in Wuyi can obtain 840,000 yuan), increasing the enterprise's expected return to 1.5 times the transformation cost, and aiming to reduce the termination rate from 30% to below 15%.

### 4.3.3 Digital collaboration mechanism: improving responsibility efficiency

Build the "Zhejiang Technology Transfer" platform to achieve three major functions:

(1) Fund supervision: Real-time monitoring of the arrival rate of central government-guided funds. Mountainous cities such as Lishui aim to increase it to 85%, and automatic early warning for delayed disbursement.

(2) Online collaboration: Increase the frequency of industry-university-research meetings in island counties from 0.8 times/quarter to 1.2 times/quarter, and AI-assisted technology adaptation. The fishery technology adaptation rate in Shengsi County increased from 40% to 65%.

(3) Efficiency incentive: Counties with a DEA efficiency value ⩾0.8 (such as Taishun County) receive 120% matching of central government-guided funds, forcing the performance of responsibilities.

# 5 Conclusions and prospects

## 5.1 Research conclusions

### 5.1.1 Core contradictions

There are three major contradictions in mountainous and island counties: "heterogeneity in responsibility performance, imbalance in right allocation, and mismatch in benefit distribution". Insufficient empowerment of authority (49%) and asymmetric risk-benefit are the main causes, resulting in a comprehensive transformation efficiency of only 62% of that in developed areas.

### 5.1.2 Model verification

The equilibrium degree model shows that for each 0.1 increase in the index, the transformation success rate increases by 15%; the DEA model confirms that pure technical efficiency (0.79) is the main cause of efficiency loss; the evolutionary game clarifies that " $x⩾0.6$, $y⩾0.4$, $\pi_E^H⩾1.5C_E^H$" is the optimal threshold.

### 5.1.3 Case support

Mechanisms such as Jinyun's "trial use first, payment later" and Dinghai's "demand-oriented transfer" have partially optimized authority and benefits, but the case of the termination of cooperation in Longquan City confirms the harm of "lack of collaboration between responsibility, authority and benefit".

### 5.2 Future prospects

In the future, the research boundary can be further expanded to include national mountainous and island county samples to verify the universality of the "dynamic empowerment + phased profit-sharing + digital collaboration" mechanism, and explore the application of blockchain technology in right confirmation to improve the transparency and credibility of the empowerment process. At the practical level, it is recommended to take the lead in piloting the assessment of the equilibrium degree of responsibility, authority and benefit in mountainous and island counties in Zhejiang, incorporate it into the local government's science and technology work assessment system with a weight of not less than 20%, and promote the implementation of the optimization path. At the same time, it is necessary to accelerate the establishment of a "micro-database of technology achievement transfer payment", refine high-frequency data such as enterprise transformation costs and right transfer fees, and provide more solid data support for model parameter calibration and continuous mechanism optimization.

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