How Do Local Governments Collaborate Across Levels? An Evolutionary Game Theory Analysis of Policy Demonstrations in China

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Funding information:

National Natural Science Foundation of China, Grant/Award Number:72174155, 72574170.

Social Science Foundation of Chinese Ministry of Education:2025JZDZ046

Abstract

As a central institutional arrangement for promoting local policy innovation in China, policy demonstrations increasingly feature cross-level collaboration by central guidance. This process involves strategic interactions among provincial, municipal, and district governments rather than mere top-down implementation. However, the existing research has insufficiently examined how these cross-level interactions evolve dynamically. To address this literature gap, this study develops an evolutionary game model of provincial, municipal and district governments to analyze their strategic interactions and to identify evolutionarily stable strategy (ESS) under varying incentive and constraint conditions. Numerical simulations illustrate the emergence and evolution of collaborative dynamics. We further validate the model in the case study of City

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 doi: 10.18278/cpj.4.1.3

S and reveal the organizational mechanisms shaping collaborative policy demonstration. The findings suggest that provincial governments provide structural leadership, municipal governments function as coordination hubs, and district governments' cooperation is strongly shaped by grassroots feedback. Effective and sustainable cross-level collaboration hinges on positive incentives and institutionalized resource coordination. This research provides a dynamic theoretical lens for understanding the mechanism of cross-level collaboration in China's policy demonstrations and offers practical insights for the development of sustainable and robust policy innovation in local governments.

Keywords: Cross-Level Government Relations; Policy Demonstrations; Evolutionary Game Theory; Case Analysis

¿Cómo colaboran los gobiernos locales entre niveles? Un análisis de la teoría de juegos evolutiva de las demostraciones de políticas en China

Resumen

Como mecanismo institucional central para promover la innovación en políticas locales en China, la implementación de políticas se caracteriza cada vez más por la colaboración internivel bajo la dirección central. Este proceso implica interacciones estratégicas entre los gobiernos provinciales, municipales y distritales, en lugar de una mera implementación vertical. Sin embargo, la investigación existente no ha examinado suficientemente cómo estas interacciones interniveles evolucionan dinámicamente. Para abordar esta brecha bibliográfica, este estudio desarrolla un modelo de juego evolutivo de los gobiernos provinciales, municipales y distritales para analizar sus interacciones estratégicas e identificar la estrategia evolutivamente estable (ESS) bajo diversas condiciones de incentivos y restricciones. Las simulaciones numéricas ilustran el surgimiento y la evolución de la dinámica colaborativa. Validamos aún más el modelo en el caso de estudio de la Ciudad S y revelamos los mecanismos organizativos que configuran la implementación colaborativa de políticas. Los hallazgos sugieren que los gobiernos provinciales proporcionan liderazgo estructural, los gobiernos municipales funcionan como centros de coordinación y la cooperación de los gobiernos distritales está fuertemente influenciada por

la retroalimentación comunitaria. Una colaboración internivel eficaz y sostenible depende de incentivos positivos y de la coordinación institucionalizada de recursos. Esta investigación proporciona una perspectiva teórica dinámica para comprender el mecanismo de colaboración internivel en las demostraciones de políticas de China y ofrece perspectivas prácticas para el desarrollo de una innovación política sostenible y robusta en los gobiernos locales.

Palabras clave: Relaciones gubernamentales interniveles; Demostraciones de políticas; Teoría de juegos evolutiva; Análisis de casos

地方政府跨层级协作何以实现？——基于中国场景下政策示范创建的演化博弈分析

摘要

作为推动中国地方政策创新的重要制度安排，政策示范呈现出在中央统筹部署下的跨层级协作特征。在这一过程中，省、市、区三级政府之间的互动不再是简单的自上而下过程，而是体现出复杂的策略博弈关系。然而，现有研究尚未系统揭示跨层级政府在政策示范创建过程中的动态互动机制。为弥补这一研究空缺，本研究构建了一个包含省级、市级和区级政府的演化博弈模型，以刻画在不同激励与约束条件下各级政府的策略选择逻辑及其演化稳定策略（ESS），并通过数值仿真进一步揭示跨层级协作关系的生成机制与演化路径。在此基础上，本研究以S市为案例，对模型结论进行验证。研究发现，示范创建过程中，省级政府发挥结构性领导作用，市级政府承担协同枢纽功能，而区级政府的合作意愿则深受基层政策反馈的影响；一个有效且可持续的跨层级协作模式有赖于正向激励机制与制度化的资源协同安排。本研究为理解中国政策示范制度安排及其创建过程中的跨层级政府协作关系提供了动态性的理论分析视角，并为推动地方政府政策创新的可持续发展提供了实践启示。

关键词：跨层级府际关系；政策示范；演化博弈；案例分析

1. Introduction

As China enters a new stage of economic and social development, the pains of economic transformation—such as the scarcity of governance resources and the intensification of institutional pressure—will inevitably impact national politics and local governance. Against this backdrop, there is a growing imperative for governments to rely on policy innovation to address emerging social problems by providing effective policy arrangements and governance models.[3] Moreover, policy innovation serves as a critical means for enhancing the legitimacy and effectiveness of governance and for responding to rising expectations in social governance. Among the diverse strategic tools employed to advance local policy experimentation in China, policy experimentation has long stood as a central instrument of scholarly interest and practical application. It not only embodies China's gradualist approach to policy innovation but also creates institutional space for local governments to explore, adjust, and scale up effective policy solutions.[4] Its core advantage lies in improving the scientific rationality of public policy while mitigating the risks associated with policy failure. At the operational level, pilot-based experimentation allows governments to identify policy issues on a limited scale, make incremental strategy adjustments, and optimize policy design on the basis of trial outcomes—thereby avoiding implementation difficulties that may arise from blanket, one-size-fits-all approaches. In driving local policy innovation through experimentation, intergovernmental relations play a crucial role and constitute a key analytical dimension. The existing research on this issue is relatively rich and can be broadly categorized into three perspectives: strong control by higher-level governments, full autonomy of lower-level governments, and collaborative relationships between superior and subordinate governments. These three relational models not only reflect the central–local power dynamics within China's political system but also directly influence how policy experiments are conducted and how effective they are.

Studies from the perspective of strong control by higher-level governments argue that, during the process of policy experimentation, upper-level authorities—leveraging their organizational authority—often occupy a dominant position, exercising tight supervision and control over local experimenters.[5] In this context, local governments function primarily as implementers, with limited discretion to make only minor adjustments to policy schemes within the boundaries of

3 Teets, J. C., & Hasmath, R. (2020). The evolution of policy experimentation in China. *Journal of Asian Public Policy*, *13*(1), 49-59.

4 Heilmann, S. (2008). Policy experimentation in China's economic rise. *Studies in comparative international development*, *43*(1), 1-26.

5 Callander, S., & Hummel, P. (2014). Preemptive policy experimentation. *Econometrica*, *82*(4), 1509-1528.

existing frameworks.[6] In other words, higher-level governments may set the objectives, content, and scope of experiments through administrative orders or legal regulations while closely monitoring and evaluating the entire process to ensure alignment with national political will. This top-down mode of intergovernmental relations reduces the political risks and uncertainty associated with experimentation, but it also curtails local autonomy, often leading to policy misalignment with local conditions. Conversely, studies emphasizing the full autonomy of lower-level governments suggest that local governments take on a leading role in policy experimentation, enjoying considerable decision-making authority and flexibility.[7] While higher-level governments may provide general policy directions or frameworks, local governments are empowered to independently design and implement policy experiments tailored to local contexts. This model is commonly observed in China's special economic zones and pilot innovation districts. Under this approach, policy innovation is typically driven by external pressures and urgent reform imperatives. A classic example is the household responsibility system reforms initiated in provinces such as Anhui and Sichuan during the early years of China's reform and opening-up.[8] With high levels of local discretion, policy experiments tend to better reflect local realities and are more likely to mobilize social innovation and grassroots creativity, thus increasing the likelihood of success.

However, the absence of political support from higher-level governments can undermine the sustainability of such experiments. More critically, in a unitary political system such as China's, if experiments deviate from the accepted political framework, they can be subject to political manipulation or suppression.[9] A third line of research places greater emphasis on collaborative and interactive relationships between superior and subordinate governments in policy experimentation. It argues that through mechanisms such as negotiation, resource sharing, and benefit distribution, cross-level government actors can jointly promote the implementation of experiments. From this perspective, successful experimentation depends heavily on dialog and coordination.[10] Proponents of this model describe it as one where "the upper level sets the general framework, while the lower level explores concrete pathways," thus ensuring both normative policy guidance and sufficient room

6 Heffer, A. S., & Schubert, G. (2023). Policy experimentation under pressure in contemporary China. *The China Quarterly*, *253*, 35-56.

7 Heilmann, S. (2008). From local experiments to national policy: the origins of China's distinctive policy process. *The China Journal*, (59), 1-30.

8 Lin, J. Y. (1987). The household responsibility system reform in China: a peasant's institutional choice. *American Journal of Agricultural Economics*, *69*(2), 410-415.

9 Zeng, J. (2015). Did policy experimentation in China always seek efficiency? A case study of Wenzhou financial reform in 2012. *Journal of Contemporary China*, *24*(92), 338-356.

10 Mattocks, K. (2025). What is successful policy experimentation? *Policy & Politics*, 1-22.

for local innovation. In this model, the central government provides only principled policy frameworks and essential resource support, while local governments engage in creative exploration within those parameters.[11] However, such intergovernmental collaboration places high demands on the inclusiveness and flexibility of the political system, as well as on the governance capacities and competencies of the participating government actors.

In recent years, within the context of China's policy practices, policy demonstration zones have emerged as a distinct form of experimentation that differs from more locally autonomous pilot programs, reflecting a closer and more coordinated relationship among different levels of government in the policy experimentation process. Chinese scholars have increasingly regarded policy demonstration as a unique policy experimentation tool, distinguishing it from traditional policy pilots.[12] This line of research emphasizes that policy demonstration not only involves localized exploration of specific policies but also highlights the integration of the mobilizing and directive role of higher-level governments with the exploratory and adaptive role of lower-level governments in jointly driving social transformation.[13] Under this mechanism, provincial, municipal, and district governments bear differentiated policy responsibilities, yet they must also jointly engage in problem diagnosis, resource coordination, and experimental implementation. The process is not static. Rather, it involves continuous strategic adjustments in response to administrative incentives, intergovernmental expectations, and feedback from policy performance. Accordingly, this study focuses on the dynamic strategic interactions that emerge within this cross-level governance structure. The central research question of this paper is as follows:

How do provincial, municipal, and district governments adjust their strategies in the process of advancing centrally advocated policy demonstrations, and under what conditions can a stable and sustainable collaborative relationship be established across levels of government?

However, a review of the existing literature reveals several limitations. While current studies contribute to the conceptual understanding of policy demonstration and provide some insights into cross-level collaborative policy experimentation, they have yet to thoroughly explore the intergovernmental coordination mechanisms from the perspective of game theory—especially evolutionary game theory. Moreover, the existing research has focused predominantly on collaboration between central and provincial governments, overlooking the reality that, in

11 Wang, G. (2019). Principle-guided policy experimentation in China: From rural tax and fee reform to hu and wen's abolition of agricultural tax. *The China Quarterly*, *237*, 38-57.

12 Min, Y., & Wan Sheng, Wan. (2013).Explanation：A Key Mechanism of Chinese—Style Policy Implementation. *Journal of Public Management,10*(4),15-25.

13 Min, Y., Chang Jun Chen, & Liang, Z. (2023).Model Construction: A Controlled Mobilization Mechanism in Policy Implementation. *CASS Journal of Political Science* (3),46-59.

local policy experimentation, provincial, municipal, and district-level governments are often the primary actors involved. Additionally, prior studies have not adequately accounted for the influence of participation probabilities or willingness on the strategic choices made by each actor, leaving the understanding of the dynamic evolutionary mechanisms of policy experimentation incomplete.

This study incorporates provincial, municipal, and district governments as key actors in a cross-level collaborative policy experimentation framework and constructs a tripartite evolutionary game model on the basis of their respective participation probabilities. The model is used to derive evolutionarily stable strategies under different conditions. Furthermore, the model's implications are validated through numerical simulation and a case-based analysis.

2. Evolutionary Game Analysis Process

2.1 Model Background

In this study, evolutionary game theory is employed as the analytical framework. In fact, evolutionary game theory offers a particularly suitable and effective framework for analyzing the dynamic relationships among organizational actors. The decision to adopt an evolutionary game-theoretic framework is rooted in the dynamic and adaptive nature of cross-level collaborative policy experimentation in China. Unlike static models that assume fully rational actors making one-off optimization decisions, cross-level collaboration among provincial, municipal, and district governments unfolds as a continuous process of strategic adjustment. Government actors learn from policy feedback, respond to administrative pressures, and modify their strategies over time, reflecting bounded rationality and path-dependent adaptation rather than instantaneous equilibrium optimization. Evolutionary game theory is therefore particularly well suited to this research context. By specifying payoff functions and applying replicator dynamics, the model captures how the willingness of each level of government to participate in collaborative experimentation evolves as relative payoffs change. Furthermore, the identification of equilibrium points and their stability properties, including evolutionarily stable strategies (ESS), allows us to determine which modes of collaboration are likely to be self-sustaining, which are conditionally stable, and which are inherently fragile or prone to breakdown without external intervention. Importantly, this approach complements the case study analysis rather than substituting for it. While the case study provides empirical grounding and contextual specificity, the evolutionary game model offers a mechanism-based theoretical explanation for the observed interaction patterns. In other words, the model does not merely describe how cross-level collaboration occurs but clarifies why certain cooperation arrangements emerge, how they stabilize, and under what conditions they may fail. This integration of formal model-

ing and empirical evidence enhances both the internal validity and the theoretical contribution of the study.

In China, the advancement of policy experimentation relies on the active participation of local governments at multiple levels, primarily provincial governments (hereafter referred to as "provincial governments"), prefecture-level municipal governments (hereafter referred to as "municipal governments"), and district- or district-level governments (hereafter referred to as "district governments"). In the process of using policy experimentation to promote local policy innovation, these governmental tiers fulfill distinct roles in the division of experimental tasks, forming a complex system of collaboration. The provincial government, as the principal initiator of policy experiments, is mainly responsible for overall planning and for ensuring the smooth implementation of experiments through incentive and constraint mechanisms. The municipal government serves as an intermediary coordinator, bridging the upper and lower levels; it is tasked with implementing the guiding principles of the provincial government while adapting policies to local conditions. The district government, as the primary executor, is responsible for the on-the-ground implementation of policy experiments, the outcomes of which are subject to direct evaluation by the local population.

Ideally, intergovernmental cooperation is supported by a "benefit-sharing and cost-sharing" mechanism.[14] Under this arrangement, the gains from policy experimentation are not exclusive to a single level of government but are instead jointly shared among all involved parties. In particular, during the initial stage of experimentation, municipal and district governments often establish an informal contractual relationship around the experimental tasks, supported by a mutual "performance bond," to enhance the credibility and enforcement of the agreement. Additionally, the provincial government is expected to conduct periodic evaluations of policy experimentation performance at lower levels and adjust subsequent funding allocations on the basis of the assessment results.

The above depiction reflects the idealized division of responsibilities and relational dynamics among different levels of government in policy experimentation. In practice, however, the cross-level collaborative relationships among government actors are far more complex. In essence, the provincial government must decide whether to engage in cross-level policy experimentation, while the municipal and district governments must determine whether and how to collaborate during the process. On the basis of this logic, this study draws on the evolutionary game model developed by Wu Jie and colleagues and extends it by constructing a tripartite evolutionary game model involving provincial, municipal, and district governments.[15]

14 Zhu, X., & Wang, Y. (2024). Policy experimentation as communication with the public: Social policy, shared responsibility and regime support in China. *The China Quarterly*, *258*, 400-422.

15 Wu, J., Che XJ, & Sheng YX et al. (2019). Study on Government-industry-university-institute Col-

2.2 Basic Assumptions of the Model

We first need to introduce several basic concepts involved in evolutionary game analyses. In this study, we draw on several core concepts from evolutionary game theory to examine the strategic interactions among provincial, municipal, and district governments in cross-level policy experimentation. The payoff function captures the benefits and costs associated with each actor under different strategy combinations, serving as both the determinant of strategy selection and the foundation for dynamic analysis. On the basis of these payoffs, replicator dynamics describe how strategies evolve over time: strategies yielding above-average payoffs tend to increase in prevalence, whereas less advantageous strategies diminish, enabling a dynamic representation of actors' evolving willingness to participate. An equilibrium point denotes a state in which strategy distributions stabilize, reflecting potential long-term outcomes and providing a basis for evaluating the robustness of cooperative arrangements. To assess the stability of these equilibria, we employ the Jacobian matrix and examine its eigenvalues: negative eigenvalues indicate that small perturbations decay and the system returns to equilibrium, whereas positive eigenvalues signal that deviations amplify, distinguishing stable equilibria, conditionally stable saddle points, and unstable equilibria. An ESS is one that cannot be invaded by a small fraction of deviating actors, representing a robust and sustainable pattern of cooperation. Saddle points are stable along certain dimensions but unstable along others, highlighting cooperation that persists only under specific conditions, while unstable equilibria indicate strategy configurations that cannot be maintained without external intervention or adjustments to payoffs or incentives. Collectively, these concepts provide a rigorous framework for understanding how actors adapt their strategies in response to both individual payoffs and external incentives and identify which cross-level cooperation patterns are likely to be durable, which are conditionally stable, and which require policy support to sustain, offering both theoretical insights and practical guidance for designing effective collaborative policy experiments.

To scientifically construct the game model and clearly articulate the strategies of each actor, the possible equilibrium states, and the logical relationships among various factors, this study proposes the following assumptions on the basis of evolutionary game theory:

(1) Participating Actors: In the game involving tripartite government collaboration in policy experimentation, there are three types of actors: the provincial government (G), the municipal government (S), and the district government (E). The provincial government primarily facilitates effective collaboration between municipal and district governments by offering various incentives and supervising their

laborative Innovation Based on Tripartite Evolutionary Game. *Chinese Journal of Management Science, 27*(01), 162-173.

collaborative experimentation processes. The district government focuses on transforming acquired experimental knowledge and resources into concrete policy innovations, while the municipal government plays a critical intermediary role by providing the necessary policy expertise and resource support. All three actors are assumed to have bounded rationality and adjust their strategies through repeated games to seek optimal outcomes.

(2) Cooperation Strategies: During the collaborative policy experimentation process, the provincial government can choose to either participate (by offering preferential policies and supervising the process) or not participate (leaving municipal and district governments to conduct experiments independently); thus, its strategy set is (participate, not participate). Both the municipal and district governments can choose to cooperate with one another in conducting policy experiments or not cooperate; their strategy sets are (cooperate, not cooperate).

(3) Cooperation Costs: Although the provincial government does not directly engage in the experimentation itself, it incurs a cost G_1 when providing preferential policies and conducting oversight. As the primary actors, the municipal and district governments must invest labor, materials, and financial resources, incurring a total cost C. If the provincial government chooses to participate, the preferential policies it provides reduce the total experimentation cost by an amount denoted as S, making the adjusted cost $C - S$. Let t represent the cost-sharing coefficient between the district and municipal governments. Then, the district government bears a cost of tC or $t\,(C - S)$, and the municipal government bears $(1 - t)C$ or $(1 - t)\,(C - S)$.

(4) Cooperation Benefits: Let R_1 represent the benefit obtained by the provincial government when it chooses to participate. If it chooses not to participate, it still receives partial benefit, denoted as bR_1, where $b \in (0,1)$ represents the proportion of benefit relative to full participation. Let R_2 and R_3 denote the baseline benefits received by the district and municipal governments, respectively, from engaging in collaborative experimentation. When both governments choose to cooperate, an additional benefit R is generated, shared according to the coefficient a: the district government receives aR, and the municipal government receives $(1 - a)R$. If only one side chooses to cooperate, asymmetric outcomes arise. When the municipal government cooperates but the district government does not, the district government independently conducts the experiment and receives a reduced benefit L_1. Conversely, when the district government cooperates but the municipal government does not, the municipal government receives a reduced benefit L_2. Furthermore, the provincial government provides an additional financial incentive G_2 to municipal governments that actively participate in collaboration.

(5) Penalties: To prevent a breach of cooperation under provincial government supervision, a penalty mechanism is established. If the district government chooses to cooperate but

the municipal government does not, the municipal government must compensate the district government with a penalty amount W. Conversely, if the municipal government cooperates but the district government defects, the district government must pay a penalty K to the municipal government.

2.3 Presentation of the Payoff Matrix

In the model, the provincial, municipal, and district governments each choose their strategies on the basis of their respective preferences. Let x denote the probability that the provincial government chooses to participate in the collaborative experiment such that the probability of nonparticipation is $1 - x$; let y denote the probability that the district government chooses to cooperate, with $1 - y$ representing the probability of noncooperation; and let z denote the probability that the municipal government chooses to cooperate, with $1 - z$ representing the probability of noncooperation. Here, x, y, z ∈ (0,1).

On the basis of the five assumptions outlined above, the payoff matrices for the tripartite "province–municipality–district" collaborative experimentation game are presented in Tables 1 and 2. In these matrices, the district government's participation constraint is reflected in the penalty W paid when it breaches cooperation, and its incentive constraint is captured by the benefit-sharing coefficient a when it participates. Similarly, the municipal government's participation constraint is represented by the penalty K paid when it breaches cooperation, while its incentive constraint is reflected in the benefit-sharing coefficient $1 - a$ when it participates in the collaborative experiment.

Table 1. Payoff Matrix of the Intergovernmental Collaborative Experimentation Game with Provincial Government Participation

		Municipal Government	
		Cooperate (z)	Not Cooperate ($1 - z$)
district Government	Cooperate (y)	$R_1 - G_1 - G_2$ $R_2 + aR - t(C - S)$ $R_3 + (1 - a)R - (1 - t)(C - S) + G_2$	$R_1 - G_1$ $R_2 - t(C - S) + W$ $R_3 - W + L_2$
	Not Cooperate ($1 - y$)	$R_1 - G_1 - G_2$ $R_2 + L_1 - K$ $R_3 - (1 - t)(C - S) + K + G_2$	$R_1 - G_1$ R_2 R_3

Table 2. Payoff Matrix of the Intergovernmental Collaborative Experimentation Game without Provincial Government Participation

		Municipal Government	
		Cooperate (z)	Not Cooperate ($1 - z$)
district Government	Cooperate (y)	bR_1 $R_2 + aR - tC$ $R_3 + (1 - a)R - (1 - t)C$	bR_1 $R_2 - tC + W$ $R_3 - W + L_2$
	Not Cooperate ($1 - y$)	bR_1 $R_2 + L_1 - K$ $R_3 - (1 - t)(C - S) + K + G_2$	$R_1 - G_1$ R_2 R_3

2.4 Stability Analysis of Equilibrium Points

The process for deriving the evolutionarily stable strategy (ESS) is provided in Appendix. By performing calculations in MATLAB, the eigenvalues of the Jacobian matrix corresponding to each equilibrium point are obtained, as shown in Table 3.

Table 3. Eigenvalues of the Jacobian Matrix

Equilibrium Points	Eigenvalue α_1	Eigenvalue α_2	Eigenvalue α_3
$E_1(0,0,0)$	$1-b(R_1-G_1)$	$-tC-W$	$-(1-t)C+K$
$E_2(0,0,1)$	$(1-b)R_1-G_1-G_2$	$aR+K-L_1-tC$	$-[-(1-t)C+K]$
$E_3(0,1,0)$	$(1-b)R_1-G_1$	$-(-tC+W)$	$(1-a)R+W-L_2-(1-t)C$
$E_4(0,1,1)$	$(1-b)R_1-G_1-G_2$	$-(aR+K-L_1-tC)$	$-[(1-a)R+W-L_2-(1-t)C]$
$E_5(1,0,0)$	$-[(1-b)R_1-G_1]$	$-t(C-S)+W$	$G_2-(1-t)(C-S)+K$
$E_6(1,0,1)$	$-[(1-b)R_1-G_1-G_2]$	$aR+K-L_1-t(C-S)$	$-[G_2-(1-t)(C-S)+K]$
$E_7(1,1,0)$	$-[(1-b)R_1-G_1]$	$-[W-t(C-S)]$	$(1-a)R+W-L_2+G_2-(1-t)(C-S)$
$E_8(1,1,1)$	$-[(1-b)R_1-G_1-G_2$	$-[aR+K-L_1-t(C-S)]$	$-[(1-a)R+W-L_2+G_2-(1-t)(C-S)]$

To simplify the analysis of the signs of the eigenvalues and ensure consistency with realistic policy contexts, the following assumptions are made:

$$(1-b)R_1-G_1-G_2>0\ ;\quad aR+K-L_1-tC>0\ ;\quad (1-a)R+W-L_2-(1-t)C>0$$

These conditions imply that the net benefit of engaging in collaborative policy experimentation by the provincial, municipal, and district governments is greater than the net benefit of pursuing experimentation independently. The analysis proceeds by considering the following scenarios:

Case 1: When

$G_2+K-(1-t)(C-S)<0; W-t(C-S)<0,$

this indicates that the sum of the penalty paid by the district government to the municipal government and the benefit provided by the provincial government to the municipal government is less than the municipal government's cost of participating in the collaborative experiment when the provincial government is involved; simultaneously, the penalty paid by the district government when acting unilaterally is less than the cost incurred by the municipal government when it is collaborating under provincial supervision. Under these conditions, as shown in Table 4, the eigenvalues of the Jacobian matrices corresponding to equilibrium points $E_5(1,0,0)$ and $E_8(1,1,1)$ are nonpositive, indicating that both are stable equilibrium points. The corresponding evolutionary strategies are (participate, not cooperate, not cooperate) and (participate, cooperate, cooperate).

Case 2: When

$K-(1-t)C>0$ or $(W-tC)>0$,

the penalty paid by the district government when it acts unilaterally is greater than the municipal government's cost of cooperation when the provincial government is not involved; otherwise, the penalty paid by the municipal government is greater than the district government's cost of cooperation under the same conditions. In this case, as shown in Table 4, the eigenvalues of the Jacobian matrix at $E_8(1,1,1)$ are nonnegative, implying that the system has a unique stable equilibrium point at E_8, with the corresponding strategy being (participate, cooperate, cooperate).

Case 3: When

$G_2+K-(1-t)(C-S)>0$and $K(1-t)C<0$ *or* $W-t(C-S)>0$, or when $W-t(C-S)>0$ and $W-tC<0$,

this reflects a situation in which the combined penalty and benefit received by the municipal government exceeds its cost of cooperation when the provincial government is involved and the penalty for noncooperation is less than the cost under nonparticipation; otherwise, the penalty paid by the municipal government is greater than the cost borne by the district government under provincial participation but still less than the cost under nonparticipation. In this case, as shown in Table 4, the eigenvalues of the Jacobian matrix at equilibrium point $E_8(1,1,1)$ are nonpositive, suggesting that E_8 is a stable equilibrium point. The corresponding evolutionary strategy is as follows: (participate, cooperate, cooperate).

Table 4. Properties of the Eigenvalues at Equilibrium Points under Different Conditions

Equilibrium Points	Case 1				Case 2				Case 3			
	α_1	α_2	α_3	Stability	α_1	α_2	α_3	Stability	α_1	α_2	α_3	Stability
$E_1(0,0,0)$	+	−	+, −	Unstable equilibrium point	+	+	+	Saddle point	+			Unstable equilibrium point
$E_2(0,0,1)$	+	+	+, −	Saddle point	+	+	−	Unstable equilibrium point	+	+	+	Saddle point
$E_3(0,1,0)$	+	+	+	Saddle point	+	−	+	Unstable equilibrium point	+	+	+	Saddle point
$E_4(0,1,1)$	+	−	−	Unstable equilibrium point	+	−	−	Unstable equilibrium point	+	−	−	Unstable equilibrium point
$E_5(1,0,0)$	−	−	−	ESS	−	+	+	Unstable equilibrium point	−	+	+	Unstable equilibrium point

(Cont'd.)

Equilibrium Points	Case 1				Case 2				Case 3			
	α_1	α_2	α_3	Stability	α_1	α_2	α_3	Stability	α_1	α_2	α_3	Stability
$E_6(1,0,1)$	−	+	+	Unstable equilibrium point	−	+	−	Unstable equilibrium point	−	+	−	Unstable equilibrium point
$E_7(1,1,0)$	−	+	+	Unstable equilibrium point	−	−	+	Unstable equilibrium point	−	−	+	Unstable equilibrium point
$E_8(1,1,1)$	−	−	−	ESS	−	−	−	ESS	−	−	−	ESS

3. Case Observation

After the stability analysis of the equilibrium points is complete, it is generally necessary to conduct numerical simulations for two primary purposes. First, simulations serve to validate the correctness of the theoretical analysis. Stability analysis typically relies on mathematical derivations, which often fail to capture the global dynamic properties of the system. Through simulation, one can visually assess the convergence and volatility of equilibrium points, thereby confirming the reliability of the theoretical deductions. Second, while theoretical analysis usually yields conclusions about stability, it does not demonstrate how the system evolves toward equilibrium. Simulations help illustrate the long-term evolutionary trajectories of the system.

3.1 Simulation Analysis

In this section, we conduct simulations on the basis of empirical insights drawn from one of the authors' field investigations in Province H, which is located in central China. These simulations are grounded in real-world policy experimentation and aim to further explore questions not fully addressed in the theoretical analysis.

In December 2013, six ministries of the Chinese central government—including the National Development and Reform Commission, Ministry of Finance, Ministry of Land and Resources, Ministry of Water Resources, Ministry of Agriculture and Rural Affairs, and the National Forestry and Grassland Administration—jointly issued the *Notice on the Pilot Implementation of National Ecological Civilization Demonstration Zones*, officially launching the construction of such zones. This initiative was a key step in implementing the *State Council's Opinion on Accelerating the Development of Energy Conservation and Environmental Protection Industries*, which called for the selection of 100 representative regions across the country to undertake ecological demonstration zone pilots.

City S of Province H was successfully included in the first batch of 100 National Ecological Civilization Demonstration Zones. Through this selection, the city launched a policy experimentation process centered on ecological governance. In the course of implementation, close cooperation was required among the provincial government (Province H), the municipal government (City S), and the district government under City S (District T).

Specifically, Province H was expected to prioritize this policy experiment in its governance agenda and support City S by providing preferential policies and special funding allocations, thereby reducing intergovernmental transaction costs and facilitating collaborative policy experimentation. As of now, City S has achieved notable progress and received multiple honors for its demonstration efforts. For instance, in 2019—the year of mid-term central evaluation—City S was named a member of the third batch of *National Ecological Civilization Demonstration Cities* by the Ministry of Ecology and Environment.

During the joint experimentation between City S and District T, the two parties formed an informal contractual relationship, under which failure by either party to fulfill its commitments would result in the payment of a breach penalty to the other.

On the basis of the actual case of City S, the initial parameter settings for the simulation are assumed as follows:

- Province H's payoff from participating: $R_1 = 40$
- Cost of formulating preferential policies and supervision by Province H: $G_1 = 5$
- Cost reduction from Province H's participation: $S = 8$
- Financial support from Province H to City S: $G_2 = 8$
- Benefit ratio when Province H does not participate: $b = 0.5$
- Total cooperation cost between City S and District T: $C = 45$, cost-sharing ratio $t = 0.5$
- Additional benefit from cooperation: $R = 100$, benefit-sharing ratio $a = 0.5$
- Independent experimentation payoffs: $L_1 = 25$ (District T), $L_2 = 30$ (City S)
- Penalties for breach: $K = 5$, $W = 5$
- Initial cooperation probabilities: 0.5 for Province H, City S, and District T

On the basis of these parameter values, this section uses MATLAB to simulate the dynamic evolutionary paths of strategy selection among Province H, City S, and District T under different initial conditions. The simulation further explores how variations in actors' initial willingness to participate, the preferential policies provided by the provincial government, the severity of penalties, and the benefit distribution coefficients affect system outcomes.

Figure 1 shows the simulation of how the initial probabilities of participation in the collaborative experiment by Province H, City S, and District T affect the strategy choices of each actor in the collaborative policy experiment under three different initial values: $x = 0.5$, $y = 0.5$, $z = 0.5$; $x = 0.4$, $y = 0.4$, $z = 0.4$; and $x = 0.6$, $y = 0.6$, $z = 0.6$, while all the other parameters remain unchanged.

The three-dimensional simulation graphs are generated using the plot3 function in MATLAB.

- The red dashed line represents the first set of initial conditions;
- The blue circular line represents the second set;
- The magenta cross-marked line represents the third set.

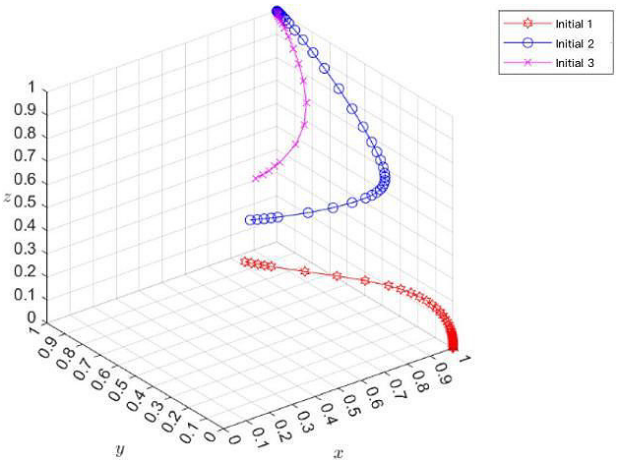

Figure 1. 3D Simulation Plot.

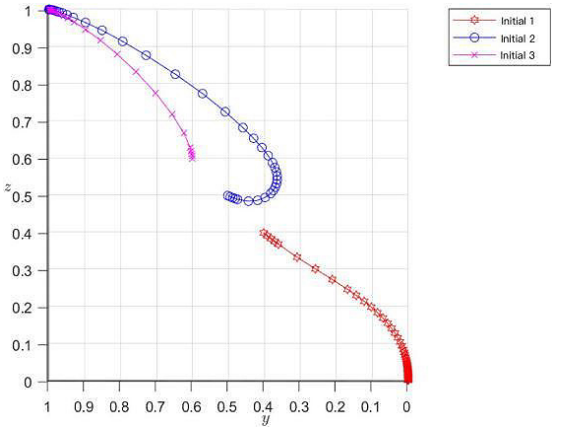

Figure 2. Simulation Plot on the y – z Relationship Plane.

Figures 2, 3, and 4 illustrate the two-dimensional projection planes showing interactions between each pair of actors.

Assuming that Province H, City S, and District T share the same initial participation probability, Figure 1 shows that the system's initial values range between 0.4 and 0.6. When the initial participation probability falls below a critical threshold, the system converges to the equilibrium point (1, 0, 0).

By switching to the y–z plane projection (Figure 2), it becomes evident that District T converges to the equilibrium point faster than City S does, indicating a more rapid shift in strategic behavior at the district level.

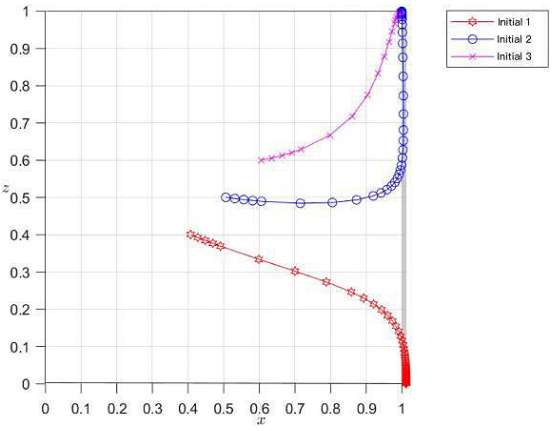

Figure 3. Simulation Plot on the x–z Relationship Plane.

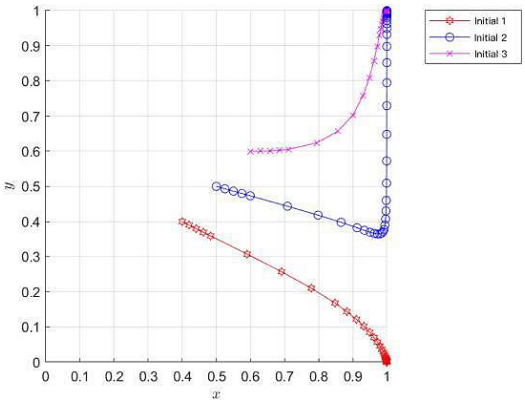

Figure 4. Simulation Plot on the x–y Relationship Plane.

When the initial participation probability exceeds the critical threshold, the system converges to the equilibrium point (1, 1, 1). When the initial participation probabilities of all three actors fall within a moderate range, the participation probability of Province H tends to increase significantly, while City S's participation increases at a relatively slower pace, and District T's willingness to participate initially declines. However, as the participation probabilities of the province and municipality increase, District T's participation also gradually increases.

Notably, when Province H fully commits to participating in the policy experiment, the willingness of both City S and District T to engage sharply increases. When all three actors demonstrate high initial participation probabilities, the system consistently converges to the collaborative equilibrium (1, 1, 1).

The simulation results indicate that as the overall participation probabilities increase:

- The convergence of x toward 1 slows down,

- The convergence of y and z toward 1 accelerates.

Ultimately, all three actors tend to adopt highly collaborative strategies when they participate in the policy experiment.

This pattern suggests that, in collaborative intergovernmental policy experimentation, when the municipal and district governments initially exhibit low willingness to participate, Province H tends to step in more assertively, assuming a leadership role and actively guiding and facilitating coordination among all parties to ensure effective implementation of the experiment.

Figures 5, 6, and 7 illustrate how changes in the initial participation probability of one actor affect the strategy evolution of the other two under different starting conditions.

When x (Province H) is below the intermediate threshold, both y (District T) and z (City S) eventually converge to 0. In this case, increases in x slow the rate at which y and z converge to 0, with z converging more slowly than y does. Conversely, when x exceeds the critical value, both y and z converge to 1, and higher values of x accelerate their convergence. In this case, z converges faster than y does. The simulation results indicate that increasing Province H's initial participation can effectively stimulate the willingness of City S and District T to cooperate, with City S being more responsive than District T is.

This suggests that in China's top-down administrative hierarchy, provincial governments typically do not directly allocate resources such as funding to district-level governments; instead, these resources are distributed via municipal governments. This governance arrangement makes the municipal government's willingness to cooperate highly dependent on the provincial government's position. In contrast, district governments—which are more directly connected to grassroots constituents—are more likely to be influenced by the needs and expectations of policy recipients. Therefore, in the absence of strong support from higher-level governments, District T's willingness to cooperate will also decline if both Province H and City S are hesitant to engage in cross-level collaboration.

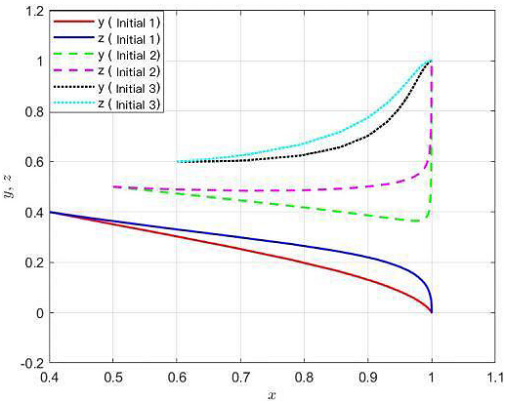

Figure 5. Simulation of the Effects of Province H's Initial Participation Probability.

Figure 6 presents the simulation of how changes in y affect x and z. When y is below the intermediate value—especially as it approaches 0—x gradually increases toward 1, while z decreases toward 0. When y exceeds the threshold, all three variables—x, y, and z—converge to 1. Moreover, increases in y significantly accelerate z's convergence, and z converges faster than x does.

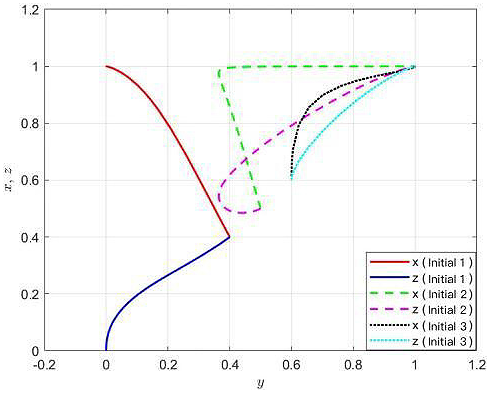

Figure 6. Simulation of the Effects of District T's Participation.

Figure 7 shows the influence of changes in z on x and y When z is low—especially near 0—x tends to increase toward 1, whereas y decreases toward 0. As z increases beyond the intermediate level, both x and y increase as well, and y converges faster than x does. This suggests that as City S's initial willingness to cooperate increases, District T's cooperation tends to strengthen, whereas Province H's cooperation increases more slowly. Ultimately, however, all three actors converge toward collaboration.

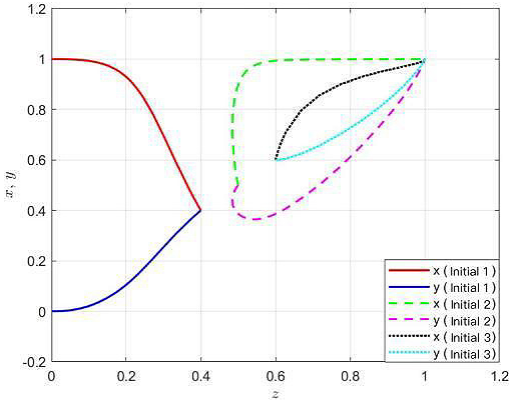

Figure 7. Simulation of the Effects of City S's Participation.

The simulation results demonstrate that increases in either District T's or City S's initial willingness to cooperate positively affect the other's propensity to participate, ultimately leading all the parties to adopt collaborative

strategies in policy experimentation.

This is consistent with empirical observations from the policy experimentation process in City S, one of China's designated National Ecological Civilization Demonstration Zones. As the central hub of governance resources, City S bears the primary responsibility for local policy experimentation. When District T displays a strong willingness to collaborate, City S also becomes more inclined to engage in collaboration to more efficiently allocate and apply the resources it controls.

On the basis of the replicator dynamics and stability analysis of the equilibrium points, this study yields several core findings regarding the mechanisms of cross-level collaborative policy experimentation:

First, *the participation behaviors of the three governmental actors exhibit path dependence and sensitivity to initial conditions*: When all the actors begin with low initial participation probabilities, the system converges to the equilibrium (1, 0, 0), in which only the provincial government remains engaged while the municipal and district governments choose not to cooperate. When the initial probabilities are high, the system converges to the full-cooperation equilibrium (1, 1, 1). When initial probabilities are moderate, the provincial participation tendency increases first, the municipal government follows more gradually, and the district government demonstrates a delayed and initially declining cooperative response. These findings indicate that differences in perceived benefits, policy pressure, and behavioral adjustment speed across levels produce stage-based evolutionary patterns in collaborative governance.

Second, *the provincial government plays a structurally dominant leadership role*: Higher levels of provincial participation reshape the payoff functions of the municipal and district governments through policy incentives and resource coordination, accelerating convergence toward the cooperative equilibrium (1, 1, 1). Thus, the province functions not only as the initiator of the policy experiment but also as the source of incentives and stabilizer of cross-level collaboration, directly influencing whether cooperation becomes sustained and institutionalized.

Third, *the municipal government serves as a critical transmission and amplification node in the collaborative structure*: The municipal government is more responsive to the strategic signals of the provincial government and exerts a stronger influence on the district government than vice versa. Changes in the district government's strategy exert relatively limited feedback effects on the municipality, whereas increases in the level of municipal cooperation significantly increase the district government's willingness to cooperate. This dynamic reflects a top-down diffusion mechanism in which experimental momentum flows from the provincial to the municipal to district levels.

Fourth, *positive incentives outperform punitive measures*: Incentive policies at the provincial level effectively increase participation probabilities among both municipal and district gov-

ernments, whereas punishment-based constraints between municipal and district governments promote cooperation only temporarily and with weaker effects. This suggests that compared with reliance on horizontal sanction-based mechanisms, vertical, incentive-based coordination is more conducive to stable collaborative experimentation.

3.2 Case Verification

To play a pivotal role in China's national ecological civilization construction, City S in Province H was included in the first batch of National Ecological Civilization Demonstration Zones. During this policy experimentation process, close cooperation among the provincial, municipal, and district governments was required to reduce the cost of policy innovation and improve coordination efficiency. This case study analyzes City S's policy experimentation to assess the real-world applicability of the simulation model and explore issues not fully addressed by the simulation analysis.

Ambiguity in vertical intergovernmental relations is likely to give rise to conflict.[16] At the initial stage of the demonstration zone initiative, Province H, City S, and District T had differing levels of willingness to participate and adopted different collaboration strategies. While Province H officially supported the policy experiment, its commitment was limited. Local governments had long prioritized GDP growth, and extensive development models still dominated. The pressure of economic restructuring further constrained governance resources, leading the provincial government to adopt a wait-and-see attitude toward the policy demonstration.

City S, as the designated demonstration zone, was motivated to pursue the policy initiative but faced resource constraints and sought stronger support at the provincial level to offset the risks and costs associated with policy innovation. District T, influenced by fiscal pressure and industrial transition, was uncertain about the potential benefits of participating in the demonstration project and thus demonstrated low initial willingness to cooperate. These divergences led to significant obstacles in intergovernmental coordination.

To accelerate the progress of the demonstration initiative, Province H introduced a series of supportive policies. First, it established systematic standards for watershed and regional governance based on the ecological status of key areas, providing a policy framework for localities such as City S. In addition, City S received preferential policy treatment in land-use planning and industrial restructuring and was granted a strategic role in the *Provincial Plan for the J River Ecological Economic Belt (2014–2025)*, supporting its development as a modern, eco-friendly regional center. Province H also encouraged City S to transcend administrative boundaries by promoting the establishment of ecological economic develop-

16 Yasuda, J. (2021). Regulatory Scaffolding: Food Safety Politics in Federal, Unitary, and Multilevel Systems 1. *China Policy Journal*, 2(1).

ment pilot zones and actively facilitated international cooperation, such as the UK–China Eco-City pilot project in City S.

Support for these policies effectively reduced intergovernmental coordination costs, strengthened City S's motivation to engage in experimentation, and encouraged cooperation with District T. However, in the early stages, City S did not provide sufficient incentives to District T, resulting in continued low cooperation willingness and resistance to the demonstration effort.

To enhance implementation capacity, Province H adopted a dual approach of incentives and sanctions. In line with the *National Demonstration Zone Construction Plan*, which emphasized lifetime accountability for ecological governance, Province H established stricter reward-and-punishment mechanisms, upgraded its performance evaluation system, and incorporated demonstration results into annual government performance appraisals, thereby increasing political pressure on lagging local governments.

Against this backdrop, City S increased its support for District T by establishing dedicated funds, offering preferential market policies, and proactively attracting private investment to participate in the demonstration trial. These measures enhanced District T's motivation to participate, eventually leading to full cooperation and the formation of a cross-level collaborative policy experimentation mechanism involving the Province H, City S, and District T.

After several years of experimentation and innovation, City S achieved significant results and, in 2019, was awarded the title of *National Ecological Civilization Demonstration City* by the Ministry of Ecology and Environment—marking a milestone in the success of this policy experiment.

This case demonstrates the real-world relevance of the theoretical and simulation-based conclusions presented earlier. The policy incentives, performance assessments, and fiscal transfers provided by provincial governments play a critical role in cross-level intergovernmental collaboration. The motivation of local governments to participate in policy experiments depends not only on their internal resource capacities but also on external policy signals from higher levels. As an intermediary actor, the municipal government is responsible for aggregating governance resources from the upper level and redistributing them downstream.

The informal contractual relationship between City S and District T, especially the embedded penalty mechanisms, significantly shapes their willingness to collaborate. Moreover, for District T, whose policy innovations must ultimately be implemented and evaluated in local practice, the perceptions and responses of policy recipients within the jurisdiction become crucial variables in shaping intergovernmental collaboration dynamics.

To align the model findings with the case analysis, we created a Table 5 that systematically organizes the key elements.

Table 5. Correspondence between the Game Model Findings and Case Evidence

Core Finding from Evolutionary Game Analysis	Case Context	Policy Actions	Impact on Cross-Level Collaboration
Path dependence and sensitivity to initial participation	Initial differences in willingness of Province H, City S, and District T	City S had limited resources; District T was hesitant; Province H adopted a cautious stance	Low initial cooperation, slowing policy implementation
Dominant leadership role of the provincial government	Province H introduced systematic governance standards, provided fiscal and policy support, and promoted international pilot projects	Reward mechanisms, policy preferences, ecological-economic development initiatives	Increased participation willingness of City S and District T, accelerating convergence toward full cooperation equilibrium
Intermediary role of the municipal government	City S coordinated resources and supported District T	Dedicated funds, market incentives, attracting private investment	Municipal government's actions strongly influenced district-level cooperation, creating a top-down diffusion mechanism
Positive incentives outperform punitive measures	District T initially did not cooperate; Province H and City S provided policy and financial incentives	Reward policies, performance evaluations incorporated into annual assessments	Promoted sustained cooperation; punitive measures had limited and short-term effects, while positive incentives were more effective

4. Conclusion and Discussion

On the basis of the assumption of bounded rationality, this study employs evolutionary game theory to construct a collaborative policy experimentation payoff matrix involving a provincial government as the initiator, a municipal government as the coordinator, and a district government as the executor. This research systematically analyzes the strategic evolution process among these three levels of government in the context of cross-level collaboration. By integrating numerical simulations and case study analysis, the study explores the behavioral strategies of each actor and their influencing factors.

4.1 Conclusion

First, the influence of each actor's participation probability on the others is asymmetrical. On the one hand, the district government is less affected by the participation of provincial and municipal governments and is more influenced by the policy recipients within its jurisdiction. In contrast, the municipal government is more sensitive to the provincial government's participation. In the case study, City S's willingness to collaborate was more effectively activated than that of District T. On the other hand, the mutual influence between municipal and district governments is not symmetrical—District T is more responsive to changes in City S's participation probability. As demonstrated in the case, when City S's willingness to collaborate increased, coupled with the concentration of governance resources at the municipal level, District T's collaboration probability also rose accordingly.

Second, as the dominant force in local policy experimentation, the provincial government plays a critical role in structuring and sustaining cross-level collaborative relationships because of its organizational authority and resource coordination capacity. Different interorganizational relationships lead to different governance structures, which in turn affect organizational performance.[17] Unlike highly decentralized countries, where local policy experimentation is often driven from the bottom up, China's local policy experiments are largely guided by the top-down policy leadership of higher-level governments. This implies that provincial governments not only bear responsibility for policy design and resource allocation but also need to influence lower-level governments through administrative evaluations, fiscal transfers, and strategic incentives, ensuring smooth implementation and alignment with overarching policy objectives.

Third, the district government, as the implementing actor, must ensure that the policy innovations driven by experimentation are grounded in local realities and subject to public scrutiny. This means that district-level participation must be aligned not only with upper-level policy directives but also with the economic conditions, industrial structure, and social needs of the jurisdiction. Furthermore, policy experimentation should not be viewed as a government-alone endeavor; rather, it requires the activation of societal creativity and vitality. Successfully embedding social actors into the government-led policy innovation process is essential to achieving feasible and sustainable outcomes.

4.2 Discussion

The main theoretical contribution of this study lies in its contextualization within China's governance setting, revealing the operational logic of a centrally advocated policy experimentation mechanism—policy demonstration—which differs from that of conventional locally

17 Wang, W. J. (2024). Power Balance, Institutionalization, and the Governance of Serendipitous Networks. *China Policy Journa*l, 3(1), 49-75.

initiated pilot programs. Simultaneously, it analyzes how provincial, municipal, and district governments engage in collaborative policy experimentation during the implementation of policy demonstrations, as well as the underlying logic governing such cross-level cooperation. Building on this, collaborative policy experimentation refers to a mode of policy experimentation that arises under a centrally advocated, top-down policy experimentation mechanism—specifically, the advancement of policy demonstrations—where provincial, municipal, and district governments engage in tight coordination on the basis of specific organizational structures and incentive mechanisms. Within this mode, each level of government not only assumes its differentiated policy responsibilities but also dynamically adjusts its strategies in response to the actions and feedback of other levels, facilitating information sharing, optimized resource allocation, and mutual incentives or constraints. This process promotes the coordinated implementation and institutionalization of policy innovations. This definition emphasizes not only the tight and institutionalized nature of cross-level collaboration but also the dynamic and mechanism-driven characteristics of collaborative experimentation, thereby providing a theoretical framework for understanding how policy demonstrations operate effectively in practice. Moreover, most previous studies have focused on policy experimentation at the central and local levels and lack a systematic analysis of cross-level collaboration among local governments. By introducing a cross-level interaction perspective, this study expands the understanding of policy experimentation mechanisms and specifically reveals the strategic interactions and collaborative dynamics among multiple levels of government.

This study has several limitations. First, the findings are based on a small set of typical cases, which may not fully capture the diversity of policy demonstration practices across different provinces, cities, and districts in China. As a result, the generalizability of the conclusions to other regions may be limited, and future research could expand the sample size or conduct large-scale comparative analyses. Second, the evolutionary game model relies on simplifying assumptions regarding payoff functions, strategy sets, and incentive mechanisms. While the model provides a useful framework for understanding dynamic interactions among provincial, municipal, and district governments, it cannot fully account for the complexity of real-world policy progress, where nonrational behavior, political bargaining, and unexpected events may influence decisions. Future studies on policy demonstrations will rely on continued exploration and expansion by the academic community.

Appendix: ESS solution

Construction of the Expected Payoff Function

From Tables 1 and 2, we can derive the expected payoff functions and average expected payoffs for the provincial, municipal, and district governments when choosing strategies during the game. Specifically, the expected payoff functions for the provincial government when it chooses to participate U_{g1} or not participate U_{g2}, as well as its average expected payoff U_g^m, are as follows:

$$\begin{cases} U_{g1} = yz(R_1 - G_1 - G_2) + y(1-z)(R_1 - G_1) + (1-y)z(R_1 - G_1 - G_2) + (1-y)(1-z)(R_1 - G_1) \\ U_{g2} = yzbR_1 + y(1-z)bR_1 + (1-y)zbR_1 + (1-y)(1-z)bR_1 \\ U_g^m = xU_{g1} + (1-x)U_{g2} \end{cases}$$

The expected payoffs for the district government when it chooses to cooperate $\boldsymbol{U_{e1}}$ and not cooperate $\boldsymbol{U_{e2}}$, as well as its average expected payoff U_e^m, are defined as follows:

$$\begin{cases} U_{e1} = zx[R_2 + aR - t(C-S)] + (1-z)x[R_2 - t(C-S) + W] + (1-x)z(R_2 + aR - tC) + (1-y)(1-x)(R_2 - tC + W) \\ U_{e2} = zx(R_2 + L_1 - K) + (1-z)xR_2 + z(1-x)(R_2 - K - L_1) + (1-z)(1-x)R_2 \\ U_e^m = yU_{e1} + (1-y)U_{e2} \end{cases}$$

The expected payoffs for the municipal government when it chooses to cooperate U_{s1} and not cooperate U_{s2}, as well as its average expected payoff U_S^m, are defined as follows:

$$\begin{cases} U_{s1} = xy[R_3 + (1-a)R - (1-t)(C-S) + G_2] + (1-y)x[R_3 - (1-t)(C-S) \\ +K + G_2 + (1-x)y[R_3 + (1-a)R - (1-t)C] + (1-x)(1-y)[R_3 - (1-t)C + K] \\ U_{e2} = xy(R_3 + L_2 - W) + (1-y)xR_3 + y(1-x)(R_3 + L_2 - W) + (1-y)(1-x)R_3 \\ U_s^m = zU_{s1} + (1-z)U_{s2} \end{cases}$$

Solving Evolutionarily Stable Strategies Using Replicator Dynamic Equations

On the basis of the preceding analysis, the replicator dynamic equations for the provincial government, district government, and municipal government are derived as follows:

$$\begin{aligned} F(x) = \frac{dx}{dt} &= x\left(U_{g1} - U_g^m\right) \\ &= x(1-x)[yz\Big((1-b)R_1 - G_1 - G_2 + y(1-z)\big((1-b)R_1 - G_1\big) \\ &\quad + (1-y)z(1-b)R_1 - G_1 - G_2\Big) + (1-y)(1-z)(1-b)R_1 - G_1)] \\ &= x(1-x)[(1-b)R_1 - G_1 - zG_2 \end{aligned}$$

$$\begin{aligned} F(y) = \frac{dy}{dt} &= y(U_{e1} - U_e^m) \\ &= y(y-1)\{xz[aR - t(C-S) - L_1 + K] \\ &\quad + x(1-z)[W - t(C-S) + (1-x)z(aR - tC + K - L_1) \\ &\quad + (1-x)(1-z)(W - tC)\} \\ &= y(1-y)[xtS - tC + z(aR + K - L_1 - W) + W] \end{aligned}$$

$$F(z) = \frac{dz}{dt} = z(U_{s1} - U_s^m)$$
$$= z(1-z)\{xy[(1-a)R - (1-t)(C-S) + G_2 - L_2 + W]$$
$$+ x(1-y)\big(K + G_2 - (1-t)(C-S)\big) + (1-x)(1-y)[K - (1-t)C]\}$$
$$= z(1-z)\{x[(1-t)S + G_2] + y[(1-a)R + W - L_2 - K] + K - (1-t)C\}$$

By combining the three replicator dynamic equations, we obtain the replicator dynamic system that characterizes the evolutionary interactions among the three levels of government:

$$\begin{cases} F(x) = x(1-x)[(1-b)R_1 - G_1 - zG_2 \\ F(y) = y(1-y)[xtS - tC + z(aR + K - L_1 - W) + W] \\ F(z) = z(1-z)\{x[(1-t)S + G_2] + y[(1-a)R + W - L_2 - K] + K - (1-t)C\} \end{cases}$$

On the basis of the replicator dynamic system, the Jacobian matrix of the tripartite evolutionary game system can be derived as follows:

$$j = \begin{matrix} (1-2x)[(1-b)R_1 - G_1 - zG_2] & y(1-y)tS & -x(1-x)G_2 \\ y(1-y)tS & (1-2y)[xtS - tC + z(aR + K - L_1 - W) + W] & y(1-y)(aR + K - L_1 - W) \\ z(1-z)[(1-t)S + G_2] & z(1-z)[(1-a)R + W - L_2 - K] & (1-2z)\{x[(1-t)S + G_2] + y[(1-a)R + W - L_2 - K] + K - (1-t)C\} \end{matrix}$$

In this system, by setting the three replicator dynamic equations equal to zero, we obtain the local equilibrium points as follows:

$E_1(0,0,0)$, $E_2(0,0,1)$, $E_3(0,1,0)$, $E_4(0,1,1)$, $E_5(1,0,0)$, $E_6(1,0,1)$, $E_7(1,1,0)$, and $E_8(1,1,1)$.

According to Lyapunov's first method, if all the eigenvalues of the Jacobian matrix at a given equilibrium point have negative real parts, the equilibrium point is asymptomatically stable.