Financial Support for the High-Quality Development of the Real Economy: A Multi-Agent Evolutionary Game and Simulation Analysis

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Abstract. Financial support for the real economy depends not only on the availability of financial resources but also on effective strategic coordination among government regulators, financial institutions, and enterprises. This study develops a multi-agent evolutionary game model to examine how policy guidance, financial allocation, enterprise fund use, and risk governance jointly shape the high-quality development of the real economy. The government chooses between active guidance and limited intervention, financial institutions between supportive financing and conservative allocation, and enterprises between productive operation and opportunistic behavior. Replicator dynamic equations are established to derive the stability conditions of alternative evolutionary equilibria, and numerical simulations are conducted to investigate evolutionary trajectories, path dependence, and parameter sensitivity. The results show that the coordinated equilibrium characterized by active guidance, supportive financing, and productive operation is locally asymptotically stable when the public benefits of intervention exceed policy costs, supportive financing yields sufficient risk-adjusted returns, and productive operation generates higher expected payoffs than opportunistic behavior. Conversely, the system may become locked into a low-support equilibrium when intervention costs, returns from conservative allocation, and opportunistic gains are relatively high. The simulations further reveal pronounced threshold effects and path dependence, with productive enterprise behavior initiating positive feedback and initial strategy distributions shaping the final evolutionary outcome. Within the simulated parameter ranges, credible penalties, lower monitoring costs, and effective risk control exert stronger effects on convergence than increases in subsidies. These findings provide a unified theoretical framework for understanding financial support, risk prevention, and the productive allocation of financial resources.

Keywords: financial support; real economy; high-quality development; multi-agent evolutionary game; financial risk governance; path dependence; numerical simulation

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1 Introduction

The efficient allocation of financial resources to the real economy is essential for sustainable development. By mobilizing savings, screening projects, allocating capital, and managing risk, financial institutions can ease financing constraints, support technological innovation, and promote industrial upgrading (Danladi et al., 2023[1]; Yuan et al., 2024[2]; Hunjra, 2025[3]). However, financial expansion does not necessarily improve real economic performance. When short-term, collateral-intensive, or speculative activities offer higher returns or lower evaluation costs, financial resources may remain within the financial system or flow into asset markets rather than productive sectors (Dafermos et al., 2023[4]).

This problem is particularly important in the transition toward high-quality development, which emphasizes productivity, innovation, structural upgrading, and economic resilience. Innovative firms, small and medium-sized enterprises, green projects, and industries with long investment cycles require stable and appropriately priced financing but often face severe information asymmetry, limited collateral, high screening costs, and uncertain returns. Financial institutions must therefore balance the long-term economic value of productive projects against profitability, liquidity, and default risk (Korneev et al., 2023[5]). At the same time, enterprises decide whether to use external funds for productive investment or divert them toward speculative and opportunistic activities, while governments determine how strongly to intervene through incentives, supervision, and risk-sharing arrangements.

Financial support for the real economy is therefore a strategic coordination problem rather than a one-way process of capital provision. Government incentives and guarantees may reduce financing costs and encourage financial institutions to support strategically important sectors, but excessive intervention can increase fiscal burdens, weaken market discipline, and create moral hazard (Jin et al., 2023[6]). Regulation can restrict speculative behavior and improve credit allocation, yet overly rigid requirements may raise compliance costs and discourage financing for uncertain projects. Enterprises may respond to supportive policies by expanding productive investment, but incomplete monitoring can also encourage risk concealment, fund diversion, and regulatory arbitrage. The final allocation of financial resources consequently depends on the interaction among policy incentives, financial returns, enterprise behavior, risk-sharing mechanisms, and regulatory credibility (Zhuang et al., 2026[7]).

Existing studies have examined financial development and economic growth, financing constraints and corporate investment, financialization and resource misallocation, and financial regulation and systemic stability (Jin & Xie, 2024[8]; Jia et al., 2024[9]; Özmen & Taşdemir, 2026[10]). Nevertheless, three limitations remain. First, governments, financial institutions, and enterprises are often analyzed separately or assumed to have stable preferences, although their strategies evolve in response to policy signals, observed returns, and the behavior of other participants. Second, much of the literature relies on static equilibrium or linear causal analysis and gives limited attention to the dynamic transition from inefficient allocation to coordinated financial support. Third, financial support and risk prevention are frequently treated as separate objectives, despite their close interdependence. Expanding financing without effective risk

governance may increase default risk and moral hazard, whereas excessive risk aversion may result in credit contraction and financial exclusion.

To address these limitations, this study develops a multi-agent evolutionary game involving government regulators, financial institutions, and real-sector enterprises. The government chooses between active guidance and limited intervention, financial institutions between supportive financing and conservative allocation, and enterprises between productive operation and opportunistic behavior. Under bounded rationality, the three groups adjust their strategies through repeated interaction and payoff comparison. The model captures how policy incentives, regulatory costs, financing returns, risk compensation, monitoring costs, default losses, and productive benefits jointly shape the evolution of the financial–real economy system.

The analysis identifies the conditions under which the system converges toward a coordinated equilibrium characterized by active guidance, supportive financing, and productive operation. It also examines the possibility of a low-support equilibrium involving limited intervention, conservative allocation, and enterprise opportunism. Numerical simulation is then used as a theoretical experiment to investigate evolutionary trajectories, attraction basins, threshold effects, path dependence, and sensitivity to key policy and risk parameters. The simulation parameters are theoretically assigned benchmark values rather than empirically calibrated observations.

This study makes three contributions. First, it conceptualizes financial support for the real economy as an endogenous coordination process among public authorities, financial intermediaries, and enterprises, thereby incorporating strategic adaptation and behavioral interdependence into financial allocation analysis. Second, it integrates financial support and risk prevention within a unified framework, showing that the effectiveness of finance depends not only on the quantity of funds supplied but also on incentive compatibility, monitoring efficiency, risk sharing, and the productive use of capital. Third, the evolutionary analysis reveals the possibility of multiple equilibria, threshold effects, and path dependence. Moving the system away from an inefficient equilibrium therefore requires a coordinated policy portfolio that aligns public benefits, financial returns, and enterprise incentives.

2 Literature Review and Theoretical Framework

2.1 Financial Support and the High-Quality Development of the Real Economy

Finance supports economic development by mobilizing savings, reducing information and transaction costs, monitoring borrowers, and allocating capital (Mamuti et al., 2025[11]). Its contribution, however, depends less on the scale of financial expansion than on whether funds are directed toward productive activities that improve innovation, efficiency, and industrial upgrading.

High-quality development requires stable, affordable, and appropriately structured financing rather than simple credit expansion (Udeagha & Muchapondwa, 2023[12]). Small, innovative, and technology-oriented firms often face limited collateral, uncertain returns, and high screening costs, which can lead financial institutions to underfund

projects with substantial social value. This reflects a divergence between private financial returns and broader economic benefits such as employment creation, knowledge spillovers, and technological progress.

Government incentives, guarantees, risk-sharing arrangements, and information infrastructure may correct this market failure (Shi et al., 2023[13]). Nevertheless, intervention can also weaken market discipline, distort credit allocation, and encourage fund diversion. The effectiveness of financial support therefore depends on the alignment of government policy, financial institutions' incentives, and enterprises' use of funds.

2.2 Strategic Behavior, Financial Risk, and Institutional Coordination

Financial allocation involves strategic interaction among governments, financial institutions, and enterprises. Governments pursue economic development and financial stability, financial institutions seek risk-adjusted returns, and enterprises decide whether to use financing for productive investment or opportunistic activities. Because these objectives are not fully aligned, coordination failures may arise (Rashid et al., 2024[14]).

Governments can influence financing behavior through subsidies, guarantees, supervision, and risk sharing, but such measures also involve fiscal and administrative costs. Financial institutions must balance the long-term returns of supportive financing against screening costs, liquidity constraints, and default risk (Choudhary & Limodio, 2022[15]). Enterprises may invest in technology, equipment, human capital, and market expansion, or divert funds toward speculative and nonproductive uses.

These strategic choices create feedback effects because the action of one participant changes the expected payoffs and subsequent strategy adjustments of the other two. When enterprises use funds productively, project quality and repayment capacity improve, which lowers financial institutions' perceived default risk and increases the relative attractiveness of supportive financing. Greater supportive financing, in turn, relaxes financing constraints and raises the expected return from productive investment (He et al., 2023[16]). The resulting expansion of productive activity increases the public benefits of government intervention and strengthens the incentive for active guidance. Conversely, opportunistic fund use raises perceived credit risk, encourages conservative allocation, and weakens the government's willingness to maintain costly intervention. Thus, the feedback effects refer to the reciprocal and self-reinforcing adjustments among government guidance, financial allocation, and enterprise behavior.

Financial support and risk prevention are therefore interdependent. Expanding financing without adequate discipline may intensify moral hazard, whereas excessive risk aversion may worsen financing constraints. A stable system requires coordinated risk sharing, effective monitoring, credible disclosure, and productive commitment.

2.3 Evolutionary Game Perspective and Analytical Framework

Traditional game models often assume full rationality, complete information, and instantaneous equilibrium. These assumptions are restrictive because governments, financial institutions, and enterprises operate under uncertainty and adjust their strategies gradually through learning, imitation, and payoff comparison (Wang et al., 2025[17]).

Evolutionary game theory is therefore suitable for analyzing the dynamic formation of financial support mechanisms.

The framework includes three populations. Government regulators choose between active guidance and limited intervention. Financial institutions choose between supportive financing and conservative allocation (Li & Ban, 2026[18]). Real-sector enterprises choose between productive operation and opportunistic behavior.

The desirable equilibrium combines active guidance, supportive financing, and productive operation. In this state, policy support encourages financial participation, productive behavior improves credit quality, and the resulting public benefits sustain government intervention (Wang et al., 2022[19]). The three strategies become mutually reinforcing.

A low-support equilibrium may also emerge when intervention is limited, financial institutions adopt conservative allocation, and enterprises behave opportunistically. Weak policy support reduces financing, restricted financing weakens productive incentives, and opportunism reinforces lenders' risk concerns (Wang & Shi, 2026[20]). The system may therefore remain trapped in an inefficient state.

3 Multi-Agent Evolutionary Game Model

3.1 Model Setting and Payoff Structure

Financial support for the real economy is modeled as a repeated strategic interaction among the government, financial institutions, and real enterprises. The government seeks to promote productive investment, industrial upgrading, and financial stability. Financial institutions aim to maximize risk-adjusted returns, while real enterprises balance long-term productive investment against short-term opportunistic gains. Because the three groups operate under incomplete information and bounded rationality, they cannot identify the optimal strategy instantaneously. Instead, they adjust their strategies gradually through payoff comparison, imitation, and adaptive learning.

The government chooses between active guidance and limited intervention. Active guidance includes fiscal incentives, risk compensation, regulatory supervision, information-sharing mechanisms, and penalties for noncooperative behavior. Let x denote the proportion of governments adopting active guidance.

Financial institutions choose between supportive financing and conservative allocation. Supportive financing directs financial resources toward productive enterprises, particularly innovative firms and enterprises with long investment cycles. Conservative allocation prioritizes liquidity, collateral security, and short-term financial returns. Let y denote the proportion of financial institutions adopting supportive financing.

Real enterprises choose between productive operation and opportunistic behavior. Productive enterprises use financial resources for technological innovation, equipment renewal, human capital development, green transformation, and market expansion. Opportunistic enterprises redirect funds toward speculative investment, excessive financialization, or other nonproductive activities. Let z denote the proportion of enterprises adopting productive operation. The strategy proportions satisfy

$$0 \le x \le 1, 0 \le y \le 1, 0 \le z \le 1, \quad (1)$$

The strategy variables and model parameters are defined in Table 1.

Table 1. Definitions of model parameters

Parameter	Definition
x	Proportion of government regulators adopting active guidance
y	Proportion of financial institutions adopting supportive financing
z	Proportion of real-sector enterprises adopting productive operation
B_g	Public benefit under active guidance, supportive financing, and productive operation
b_g	Public benefit under limited intervention, supportive financing, and productive operation
C_g	Fiscal and administrative cost of active government guidance
S_f	Subsidy or risk compensation provided to supportive financial institutions
S_e	Incentive provided to enterprises adopting productive operation
F_f	Penalty imposed on financial institutions adopting conservative allocation
F_e	Penalty imposed on enterprises engaging in opportunistic behavior
L_g	Public loss caused by opportunistic financing under active guidance
l_g	Public loss caused by opportunistic financing under limited intervention
π_f	Direct return from financing productive enterprises
q_f	Reputational and relationship benefit generated by supportive financing
C_f	Screening and monitoring cost of supportive financing
π_o	Short-term return from financing opportunistic enterprises
D_f	Expected default loss borne by financial institutions
π_c	Return from conservative financial allocation
R_p	Operating return from productive enterprise activity
C_p	Cost of productive investment
V_p	Additional productive benefit generated by supportive financing
R_o	Baseline private return from opportunistic behavior
V_o	Private benefit obtained through the diversion of financial resources
D_e	Expected reputational, repayment, and market loss from opportunistic behavior

Active government guidance is assumed to improve institutional coordination and reduce the public losses associated with financial misconduct. Therefore,

$$B_g > b_g, l_g > L_g \quad (2)$$

Based on these assumptions, the payoff matrix is presented in Table 2.

Table 2. Payoff matrix of the tripartite evolutionary game

Government strategy	Financial institution strategy	Enterprise strategy	Government payoff	Financial institution payoff	Enterprise payoff
Active guidance	Supportive financing	Productive operation	$B_g - C_g - S_f - S_e$	$\pi_f + q_f - C_f + S_f$	$R_p - C_p + S_e + V_p$
Active guidance	Supportive financing	Opportunistic behavior	$-C_g - S_f + F_e - L_g$	$\pi_o - C_f - D_f + S_f$	$R_o + V_o - F_e - D_e$
Active guidance	Conservative allocation	Productive operation	$-C_g - S_e + F_f$	$\pi_c - F_f$	$R_p - C_p + S_e$
Active guidance	Conservative allocation	Opportunistic behavior	$-C_g + F_f + F_e$	$\pi_c - F_f$	$R_o - F_e$
Limited intervention	Supportive financing	Productive operation	b_g	$\pi_f + q_f - C_f$	$R_p - C_p + V_p$

Limited intervention	Supportive financing	Opportunistic behavior	$-l_g$	$\pi_o - C_f - D_f$	$R_o + V_o - D_e$
Limited intervention	Conservative allocation	Productive operation	0	π_c	$R_p - C_p$
Limited intervention	Conservative allocation	Opportunistic behavior	0	π_c	R_o

The payoff structure reflects the strategic complementarity identified in Section 2. Government incentives and penalties change the relative returns of financial institutions and enterprises. Supportive financing increases the expected return from productive operation, while productive enterprise behavior improves credit quality and reduces expected default losses. However, financial support may also create opportunities for fund diversion when monitoring and penalties are insufficient.

3.2 Replicator Dynamic System

The expected payoffs of the government under active guidance and limited intervention are respectively given by

$$U_G^A = yz(B_g - C_g - S_f - S_e) + y(1-z)(-C_g - S_f + F_e - L_g) + (1-y)z(-C_g - S_e + F_f) + (1-y)(1-z)(-C_g + F_f + F_e),$$
$$U_G^L = yzb_g - y(1-z)l_g. \tag{3}$$

The government adjusts its strategy according to the payoff difference between active guidance and limited intervention. Its replicator dynamic equation is

$$\dot{x} = x(1-x)[-C_g - yS_f - zS_e + (1-y)F_f + (1-z)F_e + yz(B_g - b_g) + y(1-z)(l_g - L_g)]. \tag{4}$$

Equation (4) shows that the probability of active guidance increases when the incremental public benefit $B_g - b_g$, the risk-reduction effect $l_g - L_g$, and regulatory penalties are sufficiently large. Conversely, high intervention costs and excessive fiscal incentives reduce the government's willingness to maintain active guidance.

The expected payoffs of financial institutions adopting supportive financing and conservative allocation are

$$U_F^S = xS_f - C_f + z(\pi_f + q_f) + (1-z)(\pi_o - D_f),$$
$$U_F^C = \pi_c - xF_f. \tag{5}$$

The replicator dynamic equation of financial institutions is

$$\dot{y} = y(1-y)[x(S_f + F_f) - C_f - \pi_c + z(\pi_f + qf) + (1-z)(\pi_o - D_f)]. \tag{6}$$

Supportive financing becomes more attractive when government subsidies, penalties for conservative allocation, productive financing returns, and reputational benefits increase. Higher monitoring costs, default losses, and returns from conservative allocation have the opposite effect.

The expected payoffs of enterprises adopting productive operation and opportunistic behavior are

$$U_E^P = R_p - C_p + xS_e + yV_p,$$
$$U_E^O = R_o + y(V_o - D_e) - xF_e. \tag{7}$$

The replicator dynamic equation of real enterprises is

$$\dot{z} = z(1-z)[R_p - C_p - R_o + x(S_e + F_e) + y(V_p - V_o + D_e)] \tag{8}$$

Equation (8) indicates that productive operation becomes more attractive when productive returns, government incentives, penalties for opportunistic behavior, financing benefits, and expected losses from fund misuse increase. A higher cost of productive investment or a higher private return from opportunistic behavior reduces the probability of productive operation.

The interaction between financial institutions and enterprises can be further interpreted through two strategy thresholds. If the net return from financing productive enterprises exceeds that from financing opportunistic enterprises, the critical proportion of productive enterprises required to induce supportive financing is

$$z_F^* = \frac{C_f + \pi_c - \pi_o + D_f - x(S_f + F_f)}{\pi_f + q_f - \pi_o + D_f}. \tag{9}$$

When $z > z_F^*$, supportive financing generates a higher expected payoff than conservative allocation. Equation (9) indicates that government subsidies and regulatory penalties reduce the threshold for supportive financing, whereas screening costs, default losses, and alternative financial returns increase it.

Similarly, the critical proportion of supportive financial institutions required to induce productive enterprise operation is

$$y_E^* = \frac{C_p + R_o - R_p - x(S_e + F_e)}{V_p - V_o + D_e}. \tag{10}$$

When $y > y_E^*$, productive operation generates a higher expected payoff than opportunistic behavior. Government incentives, penalties, financing benefits, and expected losses from fund misuse reduce the threshold for productive operation.

Equations (9) and (10) reveal a reciprocal reinforcement mechanism. A higher proportion of productive enterprises reduces expected credit risk and encourages supportive financing. Greater access to supportive financing, in turn, increases the relative return from productive investment. This interaction may generate either a virtuous cycle of financial–real economy coordination or a self-reinforcing low-support equilibrium.

3.3 Equilibrium and Stability Analysis

Combining Equations (4), (6), and (8), the complete tripartite evolutionary system is

$$\begin{cases} \dot{x} = x(1-x)[-C_g - yS_f - zS_e + (1-y)F_f + (1-z)F_e + yz(B_g - b_g) + y(1-z)(l_g - L_g)], \\ \dot{y} = y(1-y)[x(S_f + F_f) - C_f - \pi_c + z(\pi_f + qf) + (1-z)(\pi_o - D_f)], \\ \dot{z} = z(1-z)[R_p - C_p - R_o + x(S_e + F_e) + y(V_p - V_o + D_e)]. \end{cases} \tag{11}$$

Setting the three replicator dynamic equations equal to zero yields eight pure-strategy equilibrium points:

$$E_1 = (0,0,0),\ E_2 = (0,0,1),\ E_3 = (0,1,0), E_4 = (0,1,1), E_5 = (1,0,0),\ E_6 = (1,0,1), E_7 = (1,1,0),\ E_8 = (1,1,1). \tag{12}$$

Let the right-hand sides of the three dynamic equations be denoted by F_G, F_F, and F_E, respectively. The Jacobian matrix is

$$J = \begin{bmatrix} \frac{\partial F_G}{\partial x} & \frac{\partial F_G}{\partial y} & \frac{\partial F_G}{\partial z} \\ \frac{\partial F_F}{\partial x} & \frac{\partial F_F}{\partial y} & \frac{\partial F_F}{\partial z} \\ \frac{\partial F_E}{\partial x} & \frac{\partial F_E}{\partial y} & \frac{\partial F_E}{\partial z} \end{bmatrix}. \tag{13}$$

At a pure-strategy equilibrium, the off-diagonal elements associated with $x(1-x)$, $y(1-y)$, and $z(1-z)$ become zero. Local asymptotic stability can therefore be determined from the signs of the three diagonal eigenvalues.

The desirable coordinated equilibrium is

$$E_8 = (1,1,1) \tag{14}$$

which represents active government guidance, supportive financing, and productive enterprise operation. At this equilibrium, the corresponding eigenvalues are

$$\begin{aligned} \lambda_1 &= -[B_g - b_g - C_g - S_f - S_e], \\ \lambda_2 &= -[S_f + F_f + \pi_f + q_f - C_f - \pi_c], \\ \lambda_3 &= -[R_P - C_p - R_o + S_e + F_e + V_p - V_o + D_e]. \end{aligned} \tag{15}$$

For the coordinated equilibrium to be locally asymptotically stable, all three eigenvalues must be negative. Therefore,

$$\begin{cases} B_g - b_g > C_g + S_f + S_e, \\ S_f + F_f + \pi_f + q_f > C_f + \pi_c, \\ R_P + S_e + F_e + V_p + D_e > C_p + \mathrm{R}_o + \mathrm{V}_o. \end{cases} \tag{16}$$

The first condition requires the incremental public benefit generated by active coordination to exceed the government's fiscal and administrative costs. The second requires supportive financing to produce a higher risk-adjusted payoff than conservative allocation. The third requires productive operation to generate a higher expected payoff than opportunistic behavior.

Proposition 1. The coordinated equilibrium $E_8 = (1,1,1)$ is locally asymptotically stable under the replicator dynamics when active guidance, supportive financing, and productive operation are simultaneously incentive-compatible.

This result indicates that government intervention alone cannot sustain financial support for the real economy. The government must obtain sufficient public returns, financial institutions must receive adequate risk-adjusted returns, and enterprises must gain more from productive use of funds than from opportunistic activities.

The opposite equilibrium is

$$E_1 = (0,0,0), \tag{17}$$

which represents limited government intervention, conservative financial allocation, and enterprise opportunism. The eigenvalues at this equilibrium are

$$\begin{aligned} \lambda_1 &= -C_g + F_f + F_e, \\ \lambda_2 &= \pi_o - D_f - C_f - \pi_c, \\ \lambda_3 &= R_P - C_p - R_o. \end{aligned} \tag{18}$$

The low-support equilibrium is locally asymptotically stable when

$$\begin{cases} C_g > F_f + F_e, \\ \pi_c > \pi_o - D_f - C_f, \\ R_o > \mathrm{R}_p - C_p. \end{cases} \tag{19}$$

Under these conditions, the government lacks sufficient incentives to intervene, financial institutions prefer conservative allocation, and enterprises receive a higher return from opportunistic behavior. Individually rational strategy choices therefore produce a collectively inefficient outcome.

Proposition 2. When government intervention costs, conservative financial returns, and opportunistic private gains are sufficiently high, the system may become locked into a low-support equilibrium even when coordinated financial support may generate higher aggregate payoffs.

The system may also contain an interior equilibrium:

$$E^* = (x^*, y^*, z^*), 0 < x^*, y^*, z^* < 1. \tag{20}$$

The interior equilibrium satisfies

$$\Delta_G(y^*, z^*) = \Delta_F(x^*, z^*) = \Delta_E(x^*, y^*) = 0. \tag{21}$$

The interior equilibrium generally represents a critical boundary separating the attraction regions of the coordinated and low-support equilibria. Its position depends on the model parameters and the initial strategy proportions. Consequently, systems with identical structural parameters may converge toward different outcomes when their initial conditions differ.

Proposition 3. The evolutionary process exhibits threshold effects and path dependence. Policy incentives, risk-sharing arrangements, financing costs, and opportunistic returns influence both the directly targeted actor and the strategic expectations of the other participants.

The model suggests that no single policy instrument can independently generate the coordinated equilibrium. Subsidies may encourage financial participation but increase fiscal expenditure. Penalties may discourage opportunistic behavior but cannot offset persistently low productive returns. Risk-sharing arrangements may reduce default exposure but require credible screening and monitoring. A sustainable financial–real economy relationship therefore depends on a coordinated policy portfolio that simultaneously improves public returns, financial incentives, and enterprise discipline.

4 Numerical Simulation and Dynamic Analysis

4.1 Simulation Design and Baseline Evolution

The analytical results in Section 3 identify the conditions under which the tripartite system may converge toward coordinated financial support or remain trapped in a low-support equilibrium. Numerical simulation is employed to illustrate these evolutionary mechanisms, evaluate the effects of initial strategy distributions, and examine how policy and risk parameters alter the speed and direction of convergence. The simulation is a theoretical experiment rather than a data-based empirical analysis. Accordingly, the parameters are specified as dimensionless benchmark values to preserve their relative economic meanings rather than being calibrated to a particular empirical setting. A fixed-step fourth-order Runge–Kutta method is used for the trajectory, basin, and sensitivity simulations, while a vectorized Euler scheme is used for the dense two-dimensional parameter grid.

The baseline parameters are reported in Table 3. They satisfy the three stability conditions in Equation (16). In particular, the incremental public benefit from active guidance exceeds its policy cost, supportive financing generates a higher long-term risk-adjusted return than conservative allocation, and productive operation provides enterprises with a higher expected payoff than opportunistic behavior.

Table 3. Baseline parameter setting

Parameter group	Parameter	Value	Parameter	Value	Parameter	Value
Government	B_g	10	b_g	3	C_g	2
Government	S_f	1	S_e	1	F_f	1.5
Government	F_e	1.5	L_g	1	l_g	3
Financial institution	π_f	4	q_f	1	C_f	1.5
Financial institution	π_o	2.5	D_f	2	π_c	2.5
Enterprise	R_p	4	C_p	1.5	V_p	2
Enterprise	R_o	2.5	V_o	1.5	D_e	1.5

Figure 1 presents the baseline evolutionary process. Panel (a) shows the temporal trajectories of active government guidance, supportive financing, and productive operation. Productive operation increases first, supportive financing initially declines and subsequently reverses, and active guidance converges after a short transitional adjustment. The dashed horizontal line denotes the 0.95 convergence threshold. Panel (b) presents the corresponding joint trajectory in the three-dimensional strategy space, showing the movement from the initial state (0.3, 0.3, 0.3) toward the coordinated equilibrium $E_8 = (1, 1, 1)$.

The trajectory of financial institutions exhibits a more complex adjustment pattern. The proportion adopting supportive financing initially declines from 0.30 to approximately 0.19. This decline does not indicate a negative strategy probability; rather, it reflects a temporarily negative growth rate of y. During the early stage, the proportion of enterprises engaging in productive operation is insufficient to offset the screening, monitoring, and expected default costs associated with supportive financing. Consequently, conservative allocation initially provides financial institutions with a higher

expected payoff. As productive operation becomes more prevalent and the expected quality of financed projects improves, the relative payoff of supportive financing turns positive. The trajectory of y therefore reverses, remains within the interval [0,1] throughout the simulation, and exceeds the convergence threshold of 0.95 at approximately $t = 3.8$.

The government strategy displays a similar but weaker transitional adjustment. Active guidance rises initially because penalties and risk reduction partially offset intervention costs, but subsequently experiences a shallow decline while subsidies and administrative expenditure remain relatively high. Once supportive financing and productive operation become dominant, the incremental public return increases substantially, causing x to rise rapidly and exceed 0.95 at approximately $t = 4.2$.

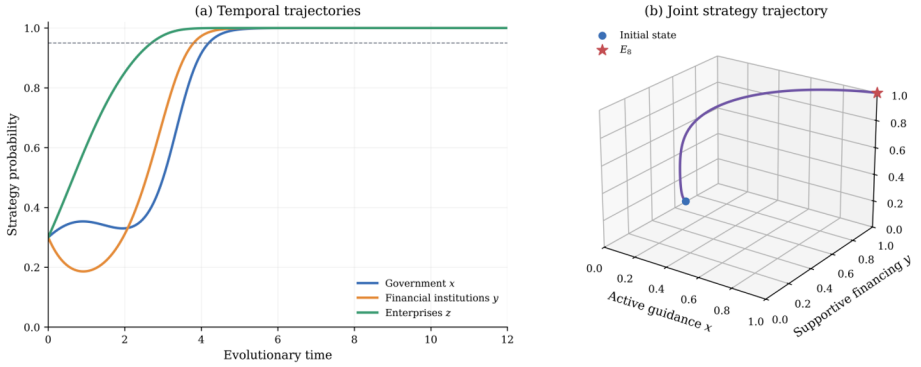


Fig. 1. Baseline evolutionary trajectories of the tripartite system.

The baseline result supports Proposition 1. The coordinated equilibrium does not arise because all participants immediately select cooperative strategies. Instead, productive enterprise behavior initially acts as the principal driver. Its improvement changes financial institutions' expectations, after which supportive financing becomes profitable. The joint increase in y and z then raises the public return from policy intervention and stabilizes active government guidance. Financial support for the real economy therefore emerges through sequential reinforcement rather than simultaneous adjustment.

4.2 Initial Conditions and Path Dependence

To examine path dependence, a near-threshold parameter scenario is constructed. Compared with the baseline setting, the government intervention cost is increased to $C_g = 4$, the two penalty parameters are reduced to $F_f = F_e = 1$, the return from conservative allocation is increased to $\pi_c = 3$, and the productive operating return is reduced to $R_p = 3$. The public benefit under coordinated action is increased to $B_g = 12$, ensuring that the coordinated equilibrium remains locally stable once it is reached. All other parameters retain their baseline values.

Under this setting, both $E_1 = (0, 0, 0)$ and $E_8 = (1, 1, 1)$ can be locally stable. The final outcome therefore depends on whether the initial strategy proportions exceed the critical boundary separating the two attraction basins. Table 4 reports the results for symmetric initial conditions. For trajectories converging toward E_8, convergence time is defined as the first time at which $x, y, z \geq 0.95$. For trajectories converging toward E_1, it is defined as the first time at which $x, y, z \leq 0.05$.

Table 4. Initial conditions and evolutionary outcomes under the near-threshold scenario

Initial condition (x_0, y_0, z_0)	Final evolutionary state	Equilibrium reached	Approximate convergence time	Interpretation
(0.2, 0.2, 0.2)	(0, 0, 0)	Low-support equilibrium	1.9	Weak initial coordination rapidly reinforces noncooperation
(0.4, 0.4, 0.4)	(0, 0, 0)	Low-support equilibrium	3.6	Moderate participation remains below the critical threshold
(0.5, 0.5, 0.5)	(0, 0, 0)	Low-support equilibrium	5.3	The system approaches the separatrix but eventually declines
(0.55, 0.55, 0.55)	(1, 1, 1)	Coordinated equilibrium	5.6	A small increase in initial participation changes the final outcome
(0.6, 0.6, 0.6)	(1, 1, 1)	Coordinated equilibrium	2.5	Stronger initial expectations accelerate positive reinforcement
(0.8, 0.8, 0.8)	(1, 1, 1)	Coordinated equilibrium	0.9	High initial coordination produces rapid convergence

The sharp difference between the initial conditions of 0.50 and 0.55 is particularly important. A five-percentage-point increase in the initial participation of each actor changes the final equilibrium from complete noncooperation to full coordination. This result illustrates that the effect of financial policy is not necessarily continuous. When the system is located below the critical threshold, incremental support may produce only temporary changes. Once the threshold is crossed, however, strategic complementarity creates a self-reinforcing transition toward the coordinated equilibrium.

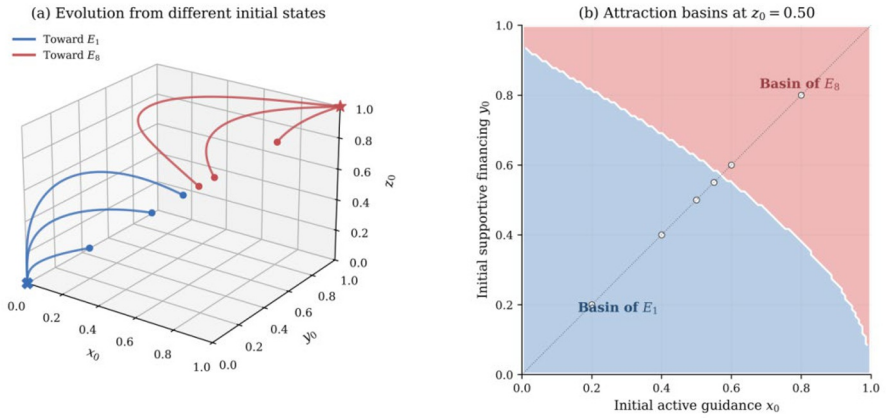


Fig. 2. Path dependence and attraction basins of the evolutionary system.

Figure 2 illustrates path dependence under the near-threshold parameter scenario. Panel (a) presents trajectories from six symmetric initial states. Blue trajectories converge toward the low-support equilibrium E_1, whereas red trajectories converge toward the coordinated equilibrium E_8. Panel (b) reports the numerically estimated attraction basins when $z_0 = 0.5$. The white curve separates the two basins, while the dotted diagonal represents symmetric initial conditions with $x_0 = y_0$.

The path-dependent result supports Proposition 2 and Proposition 3. A financial system characterized by low confidence, conservative lending, and opportunistic enterprise behavior may remain trapped even when the coordinated equilibrium may generate higher aggregate payoffs. Temporary policy interventions may be ineffective when they fail to move the system across the attraction boundary. Effective governance must therefore change not only current payoffs but also expectations about the future behavior of other participants.

4.3 Parameter Sensitivity and Governance Effects

The effects of policy instruments and financial risk parameters are examined by varying one parameter at a time while maintaining the baseline values of the remaining parameters. Convergence time is defined as the first point at which all three strategy probabilities exceed 0.95. Each parameter is evaluated under low, baseline, and high settings, and a separate convergence time is reported for each setting. The sensitivity results are summarized in Table 5.

Table 5. Sensitivity of convergence time to key parameters

Parameter	Low value	Convergence time	Baseline value	Convergence time	High value	Convergence time	Main effect
Financial subsidy S_f	0.4	4.24	1	4.2	1.6	4.46	Moderate subsidy is more effective than excessive subsidy
Enterprise incentive S_e	0.4	3.4	1	4.2	1.6	5.94	Higher incentives raise fiscal costs and may slow system-wide convergence
Penalty on conservative allocation F_f	0.5	40.02	1.5	4.2	2.5	2.41	Strong penalties substantially accelerate supportive financing
Penalty on opportunism F_e	0.5	20.66	1.5	4.2	2.5	3.02	Credible penalties rapidly strengthen productive behavior
Monitoring cost C_f	0.8	2.95	1.5	4.2	2.2	34.13	High monitoring costs severely delay supportive financing
Expected default loss D_f	0.8	3.15	2	4.2	3.2	7.35	Greater default exposure weakens financial participation
Opportunistic benefit V_o	0.5	3.86	1.5	4.2	2.5	4.67	Higher private gains slow productive strategy adoption

The first important result is that subsidies do not have a uniformly positive effect. A moderate financial subsidy marginally accelerates the transition toward the coordinated equilibrium, but a further increase raises the government's intervention cost and may slow the adjustment of x. The enterprise incentive S_e produces an even clearer tradeoff. Although it directly raises the return from productive operation, it simultaneously

reduces the government's net payoff from active guidance. The overall effect therefore depends on whether the behavioral response of enterprises is sufficient to compensate for the additional fiscal burden.

Penalties generate a stronger and more monotonic effect. Increasing F_f from 0.5 to 2.5 reduces convergence time from approximately 40.0 to 2.4. A higher F_f affects financial institutions directly by increasing the cost of conservative allocation and affects the government indirectly by improving the effectiveness of intervention. Similarly, a stronger penalty on enterprise opportunism reduces the convergence time from approximately 20.7 to 3.0. The result does not imply that penalties should be unlimited; rather, credible enforcement can be more effective than relying exclusively on recurrent subsidies.

Figure 3 compares the effects of penalty-based and incentive-based policy instruments. Panel (a) shows that increasing F_f or F_e substantially reduces the time required to reach the coordinated equilibrium. Panel (b) shows that incentive-based instruments have weaker and differentiated effects. The effect of S_f is mildly non-monotonic, whereas an increase in S_e lengthens joint convergence time over the simulated range because the additional enterprise incentive simultaneously raises the government's fiscal burden.

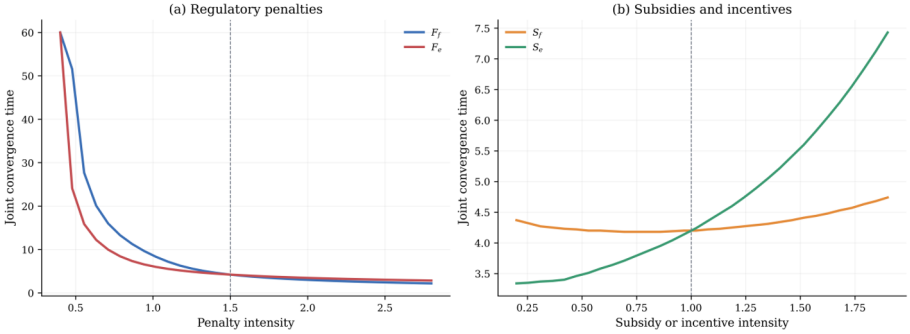


Fig. 3. Comparative effects of regulatory penalties and subsidies.

Financial risk parameters also exert threshold effects. As reported in Table 5, an increase in the monitoring cost C_f from 0.8 to 2.2 extends convergence time from approximately 3.0 to more than 34.0. Monitoring costs reduce the net return from supportive financing regardless of enterprise type. Expected default loss D_f primarily matters when the proportion of productive enterprises is low. A high D_f makes financial institutions particularly reluctant to provide financing during the early evolutionary stage, thereby delaying the positive feedback between y and z.

Figure 4 presents the joint effects of monitoring costs and expected default losses. The horizontal axis represents D_f, the vertical axis represents C_f, and the color scale reports the time required for all three strategy probabilities to exceed 0.95, capped at 60. The white boundary separates parameter combinations that reach the coordinated equilibrium within the simulation horizon from those that do not, while the dark contour

lines indicate different convergence-time levels. The star marks the baseline parameter combination. A higher opportunistic benefit V_o also delays productive strategy adoption, although its effect is weaker than that of monitoring costs and regulatory penalties.

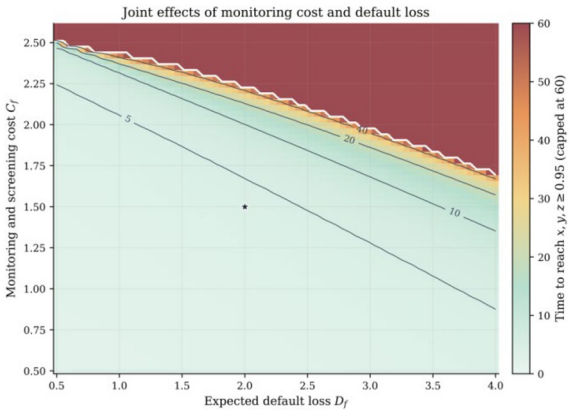


Fig. 4. Joint effects of monitoring costs and expected default losses.

5 Discussion and Conclusion

This study develops a tripartite evolutionary game framework to explain how financial support for the real economy emerges from the interaction among government regulators, financial institutions, and real-sector enterprises. The results show that effective financial support depends not simply on the volume of funds supplied, but on the alignment of public benefits, financial returns, risk control, and enterprise incentives. The coordinated equilibrium is locally stable when active guidance yields sufficient public returns, supportive financing provides higher risk-adjusted payoffs than conservative allocation, and productive operation is more attractive than opportunistic behavior. The simulations further reveal reciprocal reinforcement, threshold effects, and path dependence: productive enterprise behavior can improve project quality and encourage supportive financing, while stronger financial participation raises the return to productive investment and sustains government intervention. However, the system may remain trapped in a low-support equilibrium when intervention costs, monitoring costs, default losses, conservative returns, or opportunistic gains are high.

These findings suggest that financial governance should combine moderate incentives, credible penalties, efficient monitoring, information sharing, and enterprise discipline rather than relying primarily on broad subsidies. Governments should use targeted risk compensation and temporary intervention to help the system cross critical thresholds, financial institutions should strengthen screening and long-term risk management, and enterprises should improve disclosure and commit funds to productive activities. Once positive expectations are established, direct policy support can gradually give way to market-based risk pricing and self-sustaining cooperation. The model nevertheless simplifies agent heterogeneity and uses theoretically assigned benchmark

parameters rather than empirically calibrated estimates. Future research may incorporate heterogeneous institutions and firms, asymmetric information, policy withdrawal, network effects, and stochastic shocks, and may validate the model through empirical calibration or comparative case analysis.

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