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Evolutionary Game Modeling of Collusion in Public Procurement

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INTRODUCTION & AIM

Public procurement is a key area where competitive behavior may be distorted by collusive arrangements among firms and bidders. Traditional static models often fail to capture how such behaviors evolve over time or react to regulatory incentives.

This study develops an evolutionary game-theoretic model of collusion in public tenders involving three types of agents—proposers, bidders, and regulators—whose strategies evolve according to replicator dynamics. The model incorporates monetary payoffs, sanctions, reputation costs, and regulatory incentives to analyze how corruption and enforcement interact dynamically.

The aim is to identify the conditions under which regulatory intervention sustains fair competition or, conversely, fails to prevent systemic collusion. By simulating different parameter configurations, the analysis reveals multiple evolutionary equilibria that reflect the robustness or fragility of institutional control mechanisms.

METHOD

The model is formulated as an evolutionary game involving three agent types: tenderers, proponents, and regulators. Tenderers may act corruptly with probability x or honestly with probability $(1-x)$; proponents may collude with probability y or compete fairly with probability $(1-y)$; and the regulator may adopt an active enforcement stance with probability z or remain passive with probability $(1-z)$.

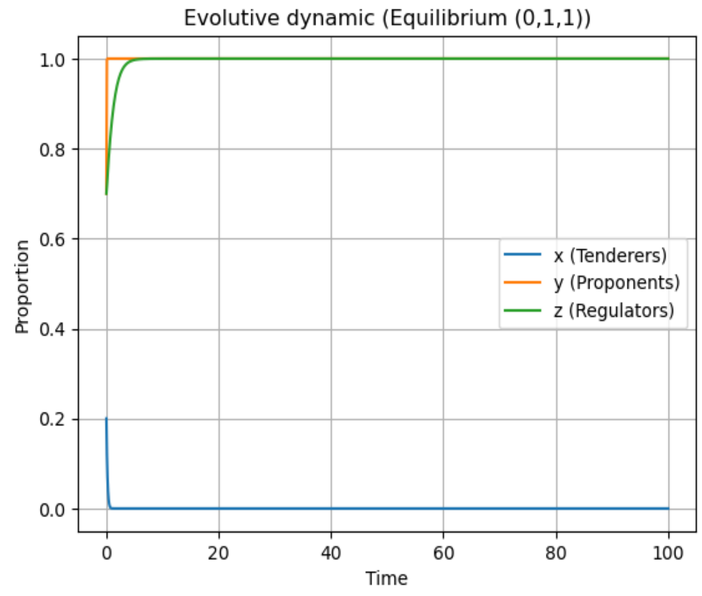
The dynamics of strategy evolution follow the replicator equations: $\dot{x}_i = x_i\left(\pi_i(x,y,z) - \bar{\pi}(x,y,z)\right)$, where π_i denotes the expected payoff of strategy i and $\bar{\pi}$ the population's average payoff. Payoff functions incorporate contract value (L), bribes, collusive surplus (SS), sanctions (MP, ML), reputation costs (CS, SW), and regulatory incentives (BCP, BCL, c_1, c_2), all modeled as monetary or probabilistic parameters.

Equilibria occur when $\dot{x} = \dot{y} = \dot{z} = 0$. Their local stability is assessed through the Jacobian matrix, J, evaluated at each stationary point. The eigenvalues of J determine whether small perturbations decay or amplify; for instance, if $Re(\lambda) < 0$, there is an asymptotically equilibrium. This procedure allows a rigorous classification of the system's eight pure equilibria before numerical exploration of their trajectories, which is the next phase of our work to better analyze what happens with the agents.

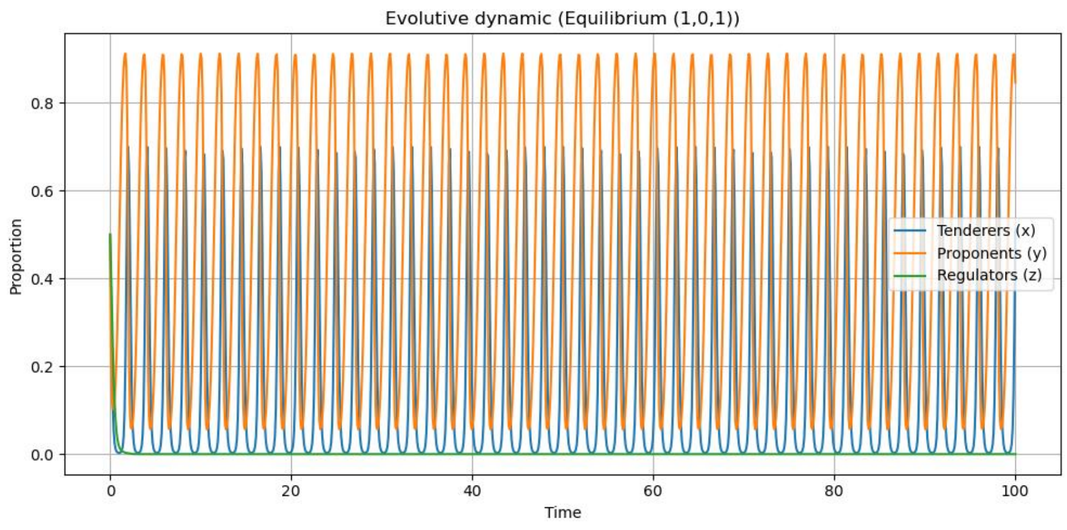
RESULTS & DISCUSSION

The model yields eight pure equilibria from the combinations of strategies (x,y,z). The analysis of the Jacobian eigenvalues shows that five equilibria are asymptotically stable, while three—(1,0,0), (0,0,1), and (1,0,1)—are unstable, each with at least one eigenvalue having a positive real part. Stable equilibria exhibit convergence of population shares, whereas unstable ones lead to divergent trajectories, suggesting that effective enforcement requires a balanced mix of regulatory vigilance and competitive discipline among agents.

In this case, we simulate the equilibrium (0,1,1), a scenario where the contracting authority remains honest, proponents engage in collusion, and the regulator is active. Using parameter values that satisfy the model's stability conditions, the simulation shows convergence toward this configuration. The results illustrate how collusion can persist even under active regulation when the expected private gains from coordination outweigh the deterrent effects of monitoring and sanctions.



In the case of the (1,0,1) equilibrium, shown below,—where the contracting authority is corrupt, proponents act legally, and the regulator is active—the model predicts inherent instability due to a positive eigenvalue. Despite its instability, this configuration is conceptually relevant because it represents a transitory or fragile institutional state: even under active supervision, regulatory incentives alone cannot sustain integrity if the benefits of corrupt coordination remain positive.



CONCLUSIONS

The evolutionary framework highlights how corruption and regulatory behavior co-evolve within public procurement systems. The existence of multiple equilibria—some stable, others fragile—shows that institutional outcomes depend critically on the balance between sanctions, reputational costs, and enforcement incentives. Stable equilibria emerge only when active regulation is sustained and proponents face credible disincentives to collude. Conversely, weak or asymmetric enforcement leads to instability, allowing corruption to persist or re-emerge. These findings underscore that anticorruption policy cannot rely solely on deterrence but must also reinforce the adaptive feedback mechanisms that sustain honest behavior over time, ensuring that regulatory vigilance remains evolutionarily stable.