Model Extension: Author-Journal Game with Competition and Capacity Constraints

December 4, 2025

1 Motivation and Problem Statement

In our previous evolutionary game-theoretic model of the author-journal interaction, we observed that the equilibrium strategies were largely insensitive to the population size N. This phenomenon arises because, in the original formulation, the payoff of a focal author depends solely on their own strategy and the journal's acceptance policy, but is independent of the actions of other authors. Consequently, there is no *congestion effect* or *competition* for limited resources.

To address this and model a more realistic academic publishing environment (e.g., conferences with fixed acceptance rates or journals with limited pages), we introduce a capacity threshold K. This mechanism creates a zero-sum element: as the number of submissions increases, the probability of acceptance for a passed paper decreases, potentially disincentivizing opportunistic strategies like *Always Submit* (AS).

2 The Threshold Competition Model

The updated interaction proceeds in the following stages:

1. **Submission:** N authors choose a strategy $s \in \{OG, AS, \dots\}$.
2. **Peer Review (Perception):** All submissions undergo peer review characterized by false negative rate ϵ and false positive rate λ. Papers that pass peer review enter a "Perception Pool" of size M.
3. **Competition (Threshold Cut):** The journal has a maximum capacity K.
   - If $M \leq K$, all papers in the pool are accepted.
   - If $M > K$, the journal randomly selects K papers from the pool to accept. The remaining $M - K$ papers are rejected despite passing review.

Let α be the probability an author produces a good paper. The probability that a single author's submission passes the peer review stage, denoted as $P_{pass}(s)$, depends on their chosen strategy s:

$$P_{pass}(OG) = \alpha(1-\epsilon) \tag{1}$$
$$P_{pass}(AS) = \alpha(1-\epsilon) + (1-\alpha)\lambda \tag{2}$$

Here, OG authors only submit good papers, while AS authors submit both good and bad papers, benefiting from the false positive rate λ.

3 Derivation of the Competition Factor γ

The key addition to the payoff function is the competition factor γ, which represents the probability that a paper is finally accepted *given that it has already passed peer review.*

Let us consider a *focal author* who has passed peer review. Let M_{-i} be the random variable representing the number of *other* authors (out of $N-1$) whose papers also passed peer review.

The total number of passed papers is therefore $M = 1 + M_{-i}$.

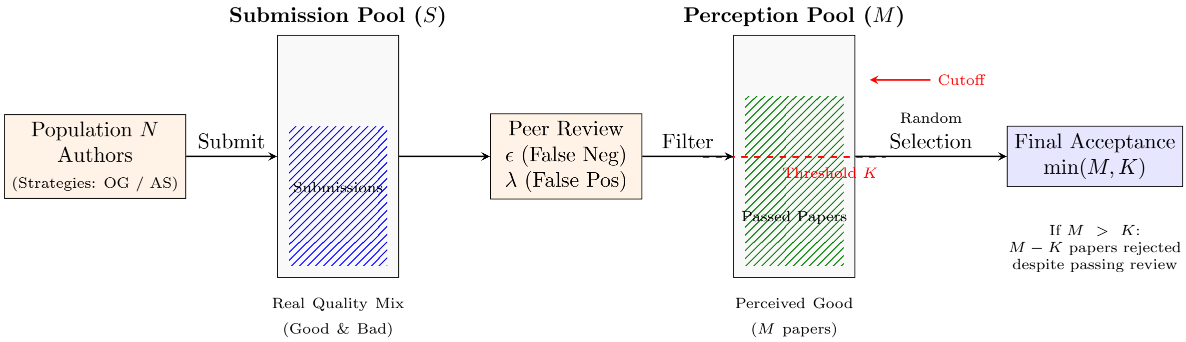

Figure 1: **Schematic representation of the Threshold Competition Model.** The process unfolds in three stages: (1) Submission into a pool S; (2) Peer review filtering into a perception pool M; and (3) A hard capacity constraint K (red dashed line). If $M > K$, a random cutoff occurs, rejecting surplus papers even if they passed review. This introduces the competition factor γ.

The competition factor for the focal author is defined as:

$$\gamma_{\text{focal}} = \min\left(1, \frac{K}{1 + M_{-i}}\right) = \begin{cases} 1 & \text{if } 1 + M_{-i} \leq K \\ \frac{K}{1+M_{-i}} & \text{if } 1 + M_{-i} > K \end{cases} \tag{3}$$

3.1 Expected Competition Factor

Since M_{-i} is a random variable, authors base their decisions on the expected value $E[\gamma_{\text{focal}}]$.

Assume the population consists of N_{OG} authors playing OG and N_{AS} authors playing AS (where $N_{OG} + N_{AS} = N - 1$, excluding the focal author). The variable M_{-i} is the sum of two independent binomial distributions:

$$M_{-i} = X_{OG} + X_{AS} \tag{4}$$

where $X_{OG} \sim B(N_{OG}, P_{pass}(OG))$ and $X_{AS} \sim B(N_{AS}, P_{pass}(AS))$.

The expected competition factor is given by:

$$E[\gamma_{\text{focal}}] = \sum_{m=0}^{N-1} \Pr(M_{-i} = m) \cdot \min\left(1, \frac{K}{1+m}\right) \tag{5}$$

4 Analysis of Dominated Strategies in Threshold Competition Model

In this section, we analyze the strategic interactions between authors and journals under the Threshold Competition Model. We provide mathematical proofs to demonstrate that certain strategies become dominated under specific parameter constraints, thereby simplifying the evolutionary dynamics to the interaction between *Only Good* (OG) and *Always Submit* (AS) strategies for authors, and the strict selection strategy for journals.

4.1 Definitions and Payoff Parameters

We define the following parameters governing the author-journal game:

- α: The probability that an author produces a high-quality paper.
- γ: The competition factor, representing the probability of acceptance after passing peer review, where $\gamma \in (0, 1]$.
- r: The reward for an author when a paper is accepted.
- c: The cost of submission incurred by the author.
- ϵ: The false negative rate (probability that a good paper is rejected).

- λ: The false positive rate (probability that a bad paper is accepted).
- B: The benefit to the journal for accepting a good paper.
- D: The penalty to the journal for accepting a bad paper.

The set of possible strategies for an author is $S_A \in \{OG, AS, OB, NS\}$. We analyze the conditions under which the "irrational" strategies OB (Only Bad) and NS (Never Submit) are strictly dominated.

The *Only Bad* (OB) strategy implies that an author only submits papers when they are of low quality (with probability $1-\alpha$). The *Never Submit* (NS) strategy yields a payoff of zero.

The expected payoff for OB is given by:

$$U_A(OB) = (1-\alpha) \cdot [\lambda \cdot \gamma \cdot r - c] \tag{6}$$

where $\lambda \cdot \gamma \cdot r$ is the expected reward from a "lucky" acceptance of a bad paper.

For NS to strictly dominate OB, we require $U_A(NS) > U_A(OB)$, which implies $U_A(OB) < 0$. Since $\gamma \leq 1$, a sufficient condition for this domination to hold in all competitive scenarios is:

$$c > \lambda \cdot r \tag{7}$$

Condition 1: As long as the submission cost c exceeds the maximum theoretical expected reward of a bad paper (λr), rational authors will never adopt the OB strategy. This condition holds true in high-standard academic environments where λ is typically very low.

The *Only Good* (OG) strategy involves submitting only high-quality papers. Its expected payoff is:

$$U_A(OG) = \alpha \cdot [(1-\epsilon) \cdot \gamma \cdot r - c] \tag{8}$$

For OG to strictly dominate NS (where $U_A(NS) = 0$), we require $U_A(OG) > 0$. Solving for γ, we obtain the condition:

$$\gamma > \frac{c}{r(1-\epsilon)} \tag{9}$$

Condition 2: NS is a dominated strategy providing that the system is not excessively congested. Specifically, as long as the competition factor γ remains above the critical threshold $\frac{c}{r(1-\epsilon)}$, the expected return of a good paper covers the submission cost, making participation rational.

We consider two primary strategies for the journal:

- **Always Accept (AA):** Accepting papers without screening (or random selection), effectively assuming $\epsilon = 0$ and $\lambda = 1$.
- **Selective (OG_J):** Implementing strict peer review with low ϵ and λ.

The journal's utility function is generally defined as:

$$U_J = \gamma N \cdot [\alpha_{pool} \cdot B - (1-\alpha_{pool}) \cdot D] - \text{Costs} \tag{10}$$

Assuming the worst-case scenario where authors play *Always Submit* (AS), the proportion of good papers in the submission pool is simply the natural rate α.

The expected utility for the *Always Accept* (AA) strategy is proportional to:

$$U_J(AA) \propto \alpha \cdot B - (1-\alpha) \cdot D \tag{11}$$

For AA to be a strictly dominated strategy (yielding negative utility compared to a selective strategy), we must satisfy $U_J(AA) < 0$. This leads to the condition:

$$D > \frac{\alpha}{1-\alpha} B \tag{12}$$

Condition 3: The *Always Accept* strategy is dominated if the penalty for accepting a bad paper (D) is sufficiently high relative to the benefit of a good paper (B). Specifically, D must exceed B by a factor determined by the odds ratio of good to bad papers in the population. Given that top-tier journals prioritize reputation, this condition ($D \gg B$) is typically satisfied.

In conclusion, the simplified game dynamics between OG and AS for authors, and the strict selection strategy for journals, are valid under the following parameter constraints:

1. $c > \lambda r$ (Prevents malicious submission of bad papers).
2. $\gamma > \frac{c}{r(1-\epsilon)}$ (Ensures good papers are profitable despite competition).
3. $D > \frac{\alpha}{1-\alpha} B$ (Ensures journals are motivated to filter quality).

5 Updated Payoff Functions

We incorporate $E[\gamma_{\text{focal}}]$ into the utility functions. Let r be the reward for acceptance and c be the cost of submission.

An *OG* author submits with probability α. If they submit, they pay cost c. They pass review with probability $1 - \epsilon$. If they pass, they are accepted with probability $E[\gamma_{\text{focal}}]$.

$$U_A(OG) = \alpha \left[(1 - \epsilon) \cdot E[\gamma_{\text{focal}}] \cdot r - c\right] \tag{13}$$

Note: Assuming cost is paid per submission regardless of acceptance.

An *AS* author always submits (probability 1), paying cost c. They pass review with probability $P_{pass}(AS)$. If they pass, they are accepted with probability $E[\gamma_{\text{focal}}]$.

$$U_A(AS) = [(\alpha(1 - \epsilon) + (1 - \alpha)\lambda) \cdot E[\gamma_{\text{focal}}] \cdot r] - c \tag{14}$$

The journal's utility depends on the quality of the final accepted papers and the cost of reviewing the total volume of submissions.

Let B be the benefit for accepting a good paper and D be the penalty for accepting a bad paper. The total submission volume S is given by:

$$E[S] = N_{OG} \cdot \alpha + N_{AS} \cdot 1 \tag{15}$$

The "Perception Pool" M contains a mix of good and bad papers that passed review. The expected number of good papers (M_G) and bad papers (M_B) in the pool are:

$$E[M_G] = (N_{OG} + N_{AS}) \cdot \alpha(1 - \epsilon) \tag{16}$$

$$E[M_B] = N_{AS} \cdot (1 - \alpha)\lambda \tag{17}$$

Note: Both OG and AS authors contribute to M_G, but only AS authors contribute to M_B.

Since the journal selects K papers randomly from M (if $M > K$), the final accepted papers maintain the same quality ratio as the pool. The expected acceptance rate for any paper in the pool is approximated by the system-wide competition factor $\bar{\gamma} = E[\min(1, K/M)]$.

The journal's expected payoff is:

$$U_J = B \cdot (E[M_G] \cdot \bar{\gamma}) - D \cdot (E[M_B] \cdot \bar{\gamma}) - C(E[S]) \tag{18}$$

Where $C(S)$ is the cost function (e.g., linear or convex with respect to total submissions). This formulation highlights that while K limits the absolute number of bad papers accepted (by reducing $\bar{\gamma}$), it does not improve the *ratio* of good to bad papers, which is still determined by ϵ and λ.

6 Discussion: The Effect of N

In this new model, the population size N plays a decisive role in shaping equilibrium outcomes, particularly when the journal's capacity K remains fixed or grows at a slower rate than N. As the number of authors increases, the expected number of papers passing peer review, $E[M]$, naturally rises. This effect is exacerbated if authors adopt the *Always Submit* (AS) strategy, which floods the perception pool with bad papers that pass due to the false positive rate λ. This surge in submissions shifts the probability distribution of M_{-i} toward higher values, thereby mechanically reducing the expected competition factor $E[\gamma_{\text{focal}}]$. Consequently, the effective reward for publication is diluted. If $E[\gamma_{\text{focal}}]$ drops below a critical threshold, the expected benefit of the indiscriminate *AS* strategy may no longer cover the submission cost c. This mechanism creates a congestion effect that can potentially restore the stability of the cooperative *Only Good* (OG) strategy or, in extreme cases of overcrowding, lead to a *No Submit* (NS) equilibrium. Thus, the model effectively reintroduces the "tragedy of the commons," demonstrating that population size and finite resource constraints are fundamental determinants of stability in the academic publishing ecosystem.

7 Determination of Capacity K

The parameter K represents the scarcity of resources (e.g., journal pages or conference presentation slots). To ensure the model reflects realistic dynamics, we propose determining K through two complementary approaches: empirical anchoring and regime analysis.

We can calibrate K based on historical data from top-tier venues. For instance, top computer science conferences (such as ICLR) typically maintain an acceptance rate between 20% and 30%. Therefore, in our simulations, we can anchor K such that:

$$K \approx \delta \cdot N, \quad \text{where } \delta \in [0.2, 0.3] \tag{19}$$

This ensures the baseline competition level matches real-world observations.

To fully explore the strategic implications of competition, we analyze the model across three distinct capacity regimes:

- **Resource Scarcity ($K \ll \alpha N$):** In this regime (e.g., $K \approx 0.1N$), competition is intense. The value of γ is significantly less than 1 even if all authors cooperate (play OG). Here, the primary driver is the raw capacity constraint, which may force authors into NS strategies to avoid sunk costs.
- **Balanced Resources ($K \approx \alpha N$):** This is the most strategically critical regime. The capacity is sufficient to accommodate most good papers, provided authors do not flood the system with bad ones. However, if a significant fraction of authors switches to AS, the system quickly becomes congested, causing γ to drop. This regime highlights the tension between individual opportunism and collective efficiency.
- **Resource Abundance ($K \to N$):** When capacity is abundant (e.g., $K \geq 0.8N$), the competition factor $\gamma \to 1$. In this limit, the model converges back to our original formulation without the threshold constraint, serving as a control group to isolate the effects of competition.

8 Simulation Analysis and Discussion

Based on the theoretical framework of the Threshold Competition Model, we conducted numerical simulations to examine how the capacity constraint (K) and population size (N) shape strategic outcomes for authors and journals. This section summarises the simulation design and discusses the main qualitative patterns that emerge.

The simulation environment is constructed as a "funnel selection" process, mirroring the constraints of top-tier conferences. Unless stated otherwise, we use $N = 100$, $K = 20$, $\epsilon = \lambda = 0.1$, $B = 1.0$, and $D = 3.0$. These values implement the following design choices:

- **Funnel mechanism:** The process has three stages: a *Submission Pool* (S) generated by N authors; a *Perception Pool* (M) filtered by noisy peer review; and a final *Threshold Cut* in which at most K papers are accepted.
- **Resource scarcity:** With $N = 100$ and $K = 20$, the baseline acceptance rate is only 20%, creating intense competition for limited slots.
- **Peer-review noise:** Reviewers misclassify good and bad papers with probability 0.1, providing a niche for the *Always Submit* (AS) strategy to exploit false positives.
- **High penalty for bad papers:** The journal incurs a much larger loss for publishing a bad paper than it gains from a good one ($D > B$), capturing the incentives of reputation-sensitive venues.

To maintain mathematical control, we avoid Monte Carlo sampling and instead use two deterministic components:

1. **Exact probability convolution.** For a given mixture of cooperative (OG) and opportunistic (AS) authors, the distribution of the number of passing papers M_{-i} contributed by the rest of the population is obtained as the convolution of two binomial distributions. This yields an exact value for the expected competition factor $E[\gamma]$.
2. **Coupled replicator dynamics.** Author strategies evolve according to the expected payoffs determined by $E[\gamma]$, while journal strategies simultaneously adapt their selectivity (ϕ_{OG}) based on the expected quality of the accepted pool.

8.1 Static Analysis: Congestion and the Commons

Figure 2 presents the static analysis of the competition factor $E[\gamma]$, isolating the effects of strategy mix and population size.

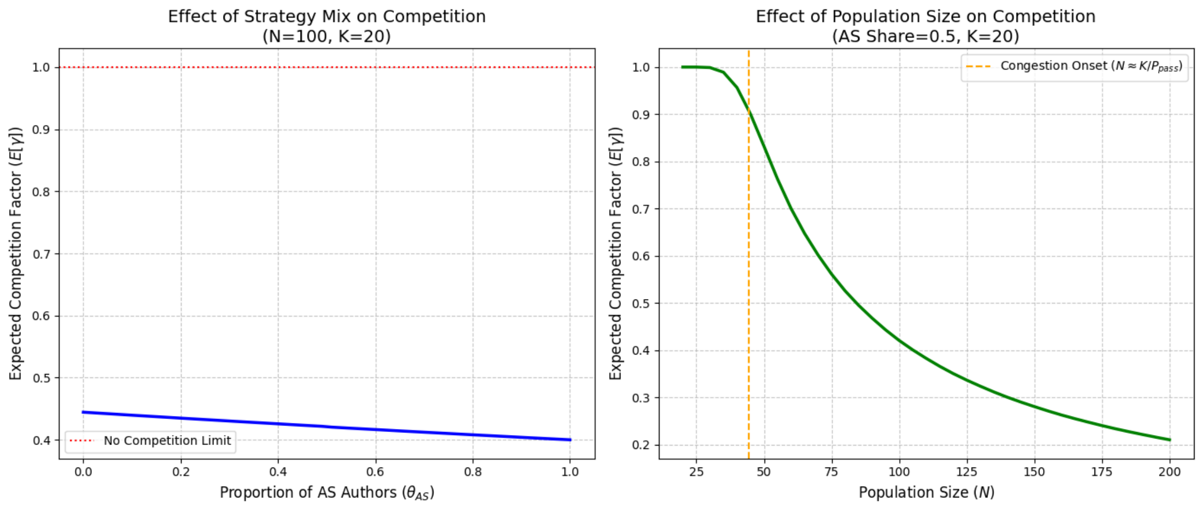

Figure 2: **Static analysis of competition. Left:** Decline of $E[\gamma]$ as the proportion of AS authors increases ($N = 100$, $K = 20$), illustrating a tragedy-of-the-commons effect. **Right:** Dependence of $E[\gamma]$ on population size N (with $K = 20$), highlighting the onset of congestion.

The right panel resolves the earlier anomaly that payoffs appeared insensitive to N in simpler models. For small populations ($N \lesssim 40$), the expected number of passing papers remains below the capacity K, so $E[\gamma] = 1$ and the capacity constraint is non-binding. In this pre-congestion regime, enlarging the population does not affect individual acceptance probabilities, which explains why purely linear models fail to detect any N-dependence. Once N crosses the approximate saturation threshold $N \approx K/P_{pass}$, the system enters a congestion regime in which $E[\gamma]$ falls sharply towards $K/M \approx 0.2$. The threshold K thus acts as a critical link between macroscopic population size and microscopic strategic payoffs.

The left panel shows how opportunism feeds back on itself. As the share of AS authors increases, both genuine contributions and false positives inflate the perception pool M. Because only K papers can be accepted, the per-paper competition factor $\gamma = K/M$ shrinks for everyone. Individually profitable deviations towards AS therefore generate a tragedy-of-the-commons outcome at the population level.

8.2 Co-evolutionary Dynamics

Figure 3 turns to the full co-evolutionary dynamics of authors and journals.

The time series (left panel) reveals a clear separation of time scales. The journal population reacts almost instantly: under high penalties for bad publications and strong congestion ($K = 20$), the *Always Accept* policy becomes prohibitively costly, and journals rapidly converge to strict selection ($\phi_{OG} \approx 1$). By contrast, authors adapt more slowly. Starting from $\theta_{AS} = 0.5$, the share of opportunistic authors gradually declines towards $\theta_{AS} \approx 0.2$ as AS becomes doubly penalised: first by strict peer review (via ϵ), and second by the reduced competition factor ($\gamma < 1$) caused by congestion.

8.3 Global Stability and Robustness

To ensure the observed outcome is robust to initial conditions, Figure 4 provides a global view of the system's dynamics using a detailed phase plane.

The horizontal axis represents the authors' behaviour (from fully cooperative on the left to fully opportunistic on the right); the vertical axis represents journal policy (from permissive at the bottom to strict at the top). Grey streamlines act as "evolutionary currents," indicating the system's inherent drive at any given state.

Across all starting points, trajectories display a characteristic inverted "L" shape. They first move almost vertically upward as journals swiftly adopt strict screening, and only then drift horizontally

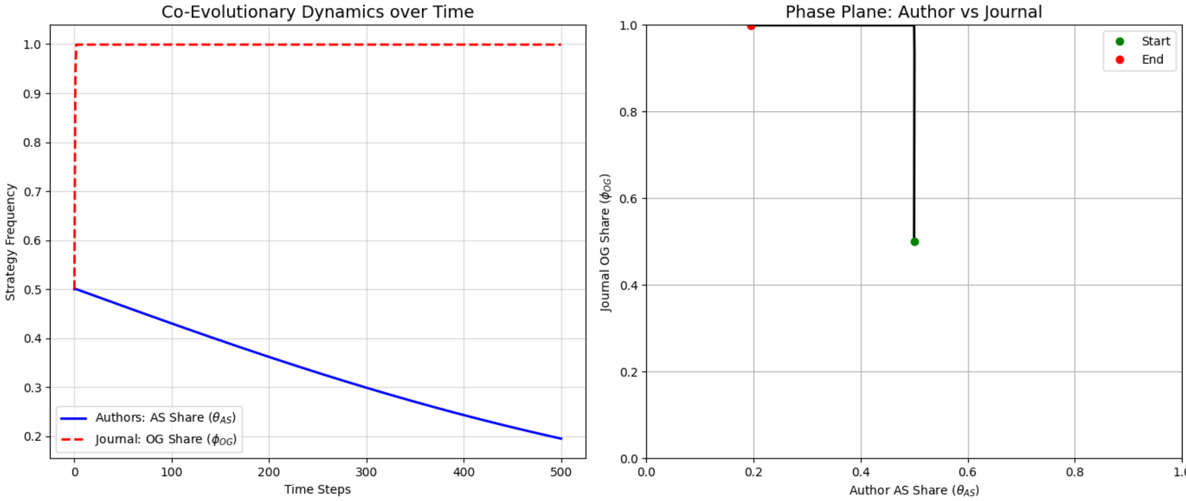

Figure 3: **Co-evolutionary dynamics. Left:** Time series of the share of AS authors (θ_{AS}, blue) and OG journals (ϕ_{OG}, red dashed). **Right:** Phase-plane trajectory showing the specific evolution from the initial state ($\theta_{AS} = 0.5, \phi_{OG} = 0.5$).

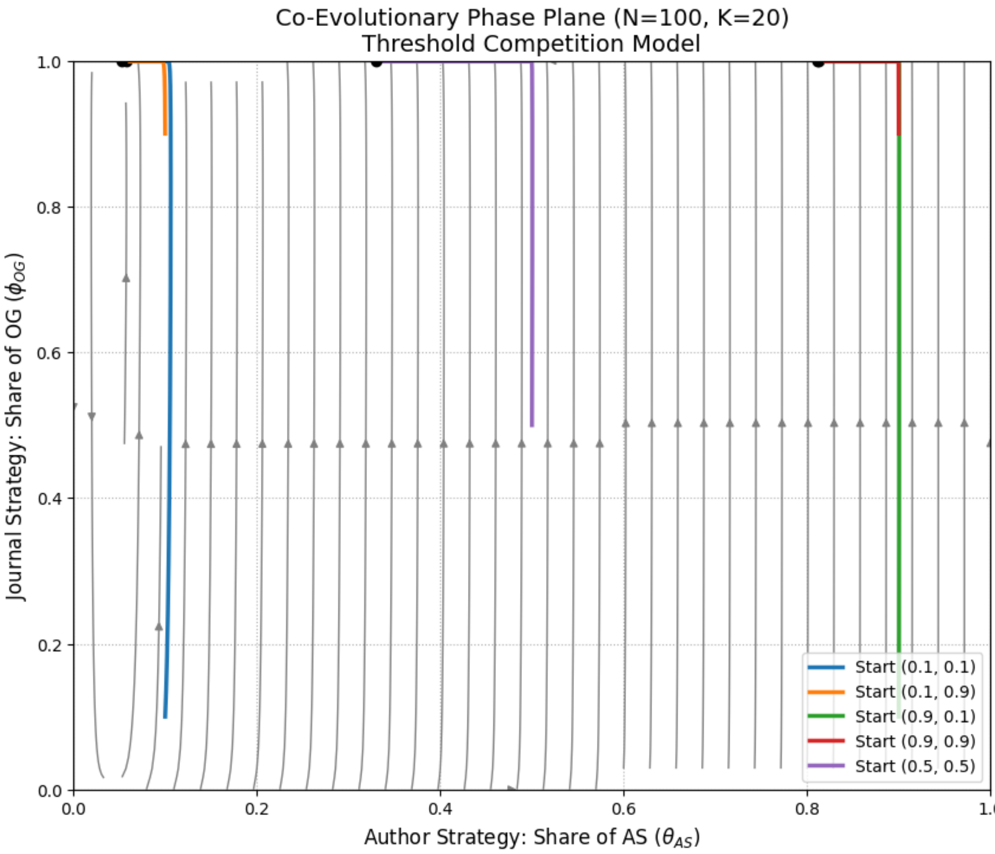

Figure 4: **Global stability analysis.** Phase-plane trajectories in the (θ_{AS}, ϕ_{OG}) plane starting from various initial conditions (coloured lines). Grey streamlines represent the evolutionary vector field, indicating the direction of drift under replicator dynamics.

leftwards as authors slowly abandon the AS strategy. This asymmetry confirms that institutions act as the *fast variable*, while cultural adaptation among authors is the *slow variable*.

Crucially, all trajectories converge to the top-left region of the phase plane, characterised by high journal selectivity and a low prevalence of opportunistic submission. This global convergence demonstrates the robustness of the threshold mechanism: once capacity constraints and penalties for bad papers are strong enough, journals are forced to establish credible quality control, and authors subsequently evolve towards high-effort, high-quality behaviour. Institutions must therefore lead so that culture can follow; cooperative norms among authors emerge as a consequence of credible, resource-constrained screening rather than as an exogenous assumption.