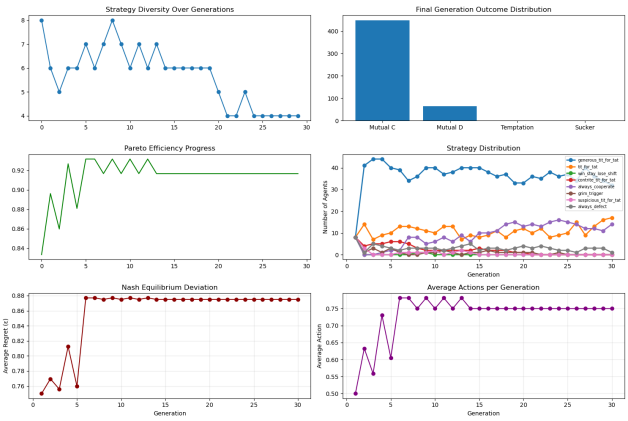
Multi-Agent Equilibria – Progress Report

This report summarises the work completed to date on the *Multi-Agent Equilibria* research project. The objective of the project is to explore emergent strategic behaviour in large-language-model (LLM) agents across a suite of classic game-theoretic environments and supply-chain simulations. The current codebase implements eight distinct games, extensive logging & visualisation utilities, and early support for LangGraph-based workflow orchestration. While each simulation is functional, the emphasis so far has been on building *foundational* pipelines rather than exhaustive scientific evaluation.

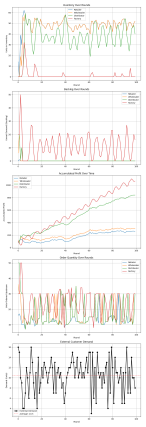
The repository now contains: • **Iterated Prisoner’s Dilemma** (evolutionary, 8 classic strategies) • **MIT Beer Game** (four-tier supply-chain, memory & communication hooks) • **Fishery Game** (common-pool resource extraction) • **Market Impact Game** (multi-agent trading) • **Oligopoly Simulation** (price-setting competition) • **Chinese Whispers SQL – v1 & v2** (story-to-SQL drift study) • **Security Dilemma** (arms-race interaction)

Game-by-Game Status

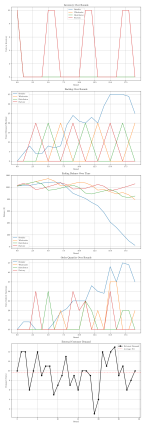
Iterated Prisoner's Dilemma (IPD): Functional evolutionary simulation with 30 generations and 64 agents. Generates strategy-distribution, Pareto efficiency, Nash deviation and action-regret plots. *Next step:* incorporate LLM-driven adaptive strategies.



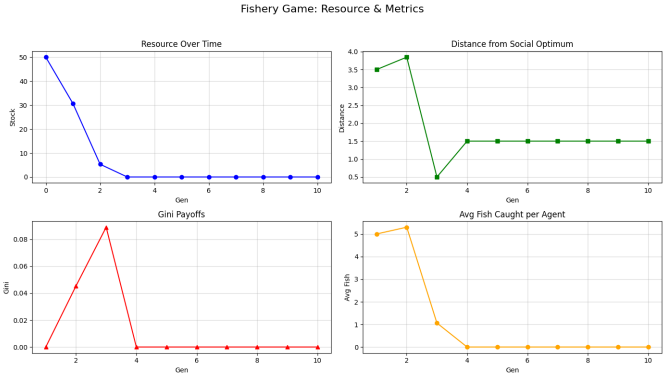
MIT Beer Game – Stable Run 100: Robust supply-chain simulator with inventory, backlog and profit tracking. Memory & communication scaffolding implemented; preliminary 100-round stability run completed. *Next step:* parameter sweep on memory length and shared vs individual memory.



MIT Beer Game – Run 163: Same environment with revised parameters to stress-test communication constraints.



Fishery Game: Implements logistic stock growth, extraction decisions and inequality metrics. Resource collapses under aggressive harvest – highlighting need for incentive redesign. *Next step:* agent heterogeneity and side-payments.



Market Impact Game: Baseline BUY/SELL/HOLD agents completed; LLM trader class stubbed. *Next step:* evaluate market-depth feedback loops.

Oligopoly Simulation: Price grid, demand noise and cost asymmetry variations ready; LLM agents optional. *Next step:* measure time-to-collusion with different temperature settings.

Chinese Whispers SQL (v1 / v2): End-to-end pipeline: story rewrite → SQL generation → execution drift measurement. Organised results, story library, LangGraph orchestration, LangSmith tracing in place. *Next step:* expand student DB and add automated unit tests.

Security Dilemma: Core turn-based simulation finished. No communication or memory yet. *Next step:* enable multi-agent chat before each arms-investment decision.

Future Work: We are exploring a shift from isolated game-theoretic environments toward a more holistic *world-model* in which heterogeneous LLM agents reason, plan and negotiate across interconnected sub-games. Initial experiments on a dedicated *LangGraph_Branch* are prototyping cross-game memory pools and event-driven workflow orchestration.