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: 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.

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.

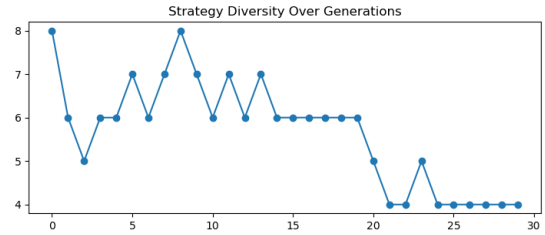
Market Impact Game: Baseline BUY/SELL/HOLD agents completed; LLM trader class stubbed. *Next step:* evaluate market depth feedback loops.

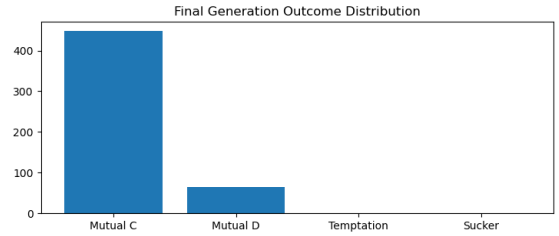
Oligopoly Simulation: Price grid, demand noise and cost asymmetry variations ready; LLM agents optional. *Next step:* measure time-to-collusion with different temperature settings.

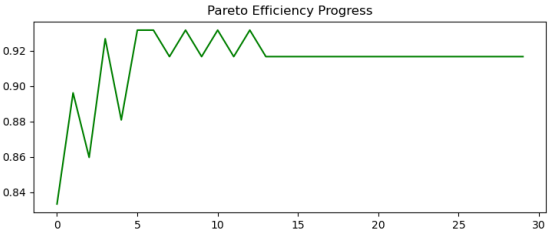
Chinese Whispers SQL (v1 / v2): End-to-end pipeline: story rewrite $\rightarrow$ SQL generation $\rightarrow$ execution drift measurement. Organised results, story library, LangGraph orchestration, LangSmith tracing in place. *Next step:* expand student DB and add automated unit tests.

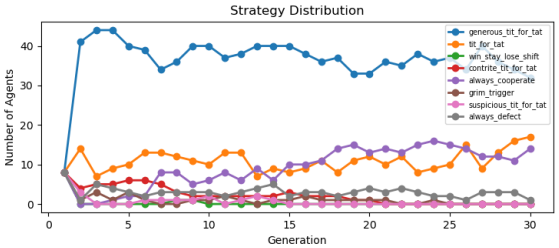
Security Dilemma: Core turn-based simulation finished. No communication or memory yet. *Next step:* enable multi-agent chat before each arms-investment decision.

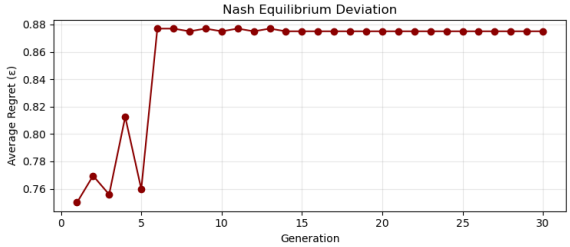
Key Simulation Outputs

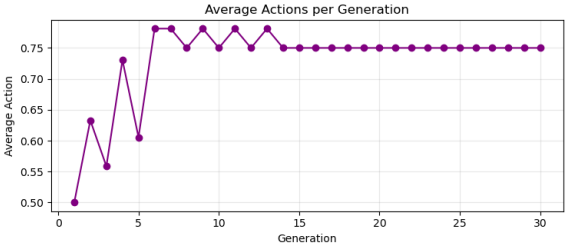


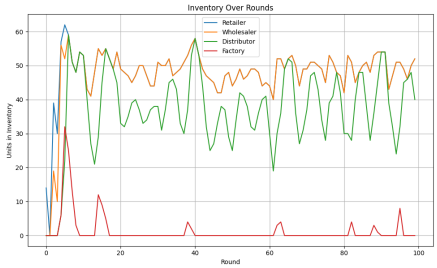


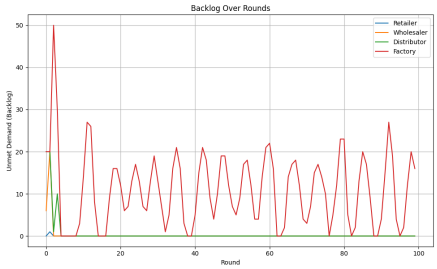


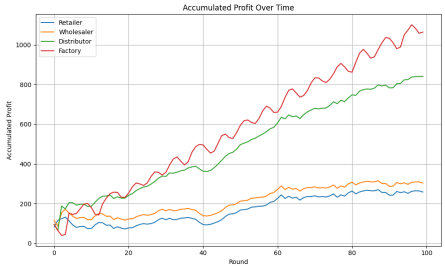


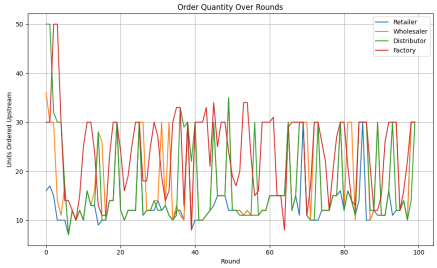


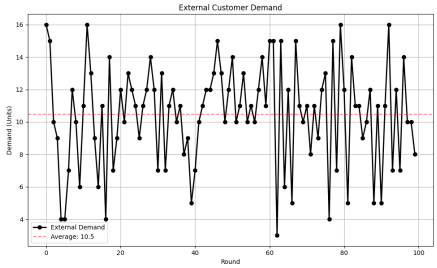


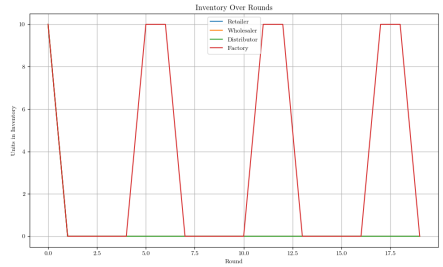

Inventory Over Rounds
Retailer
Wholesaler
Distributor
Factory
Units in Inventory
Round

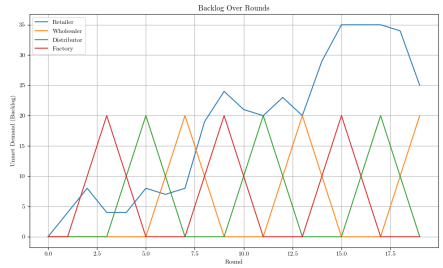

Backlog Over Rounds
Retailer
Wholesaler
Distributor
Factory
Unmet Demand (Backlog)
Round

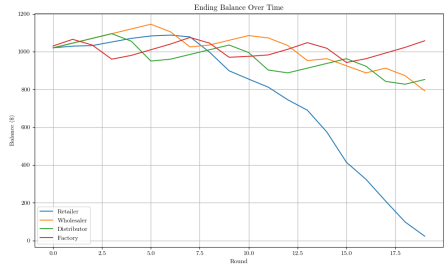

Accumulated Profit Over Time
Retailer
Wholesaler
Distributor
Factory
Accumulated Profit
Round

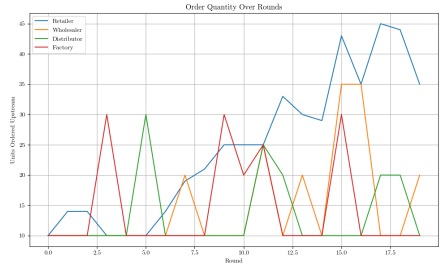

Order Quantity Over Rounds
Retailer
Wholesaler
Distributor
Factory
Units Ordered Upstream
Round

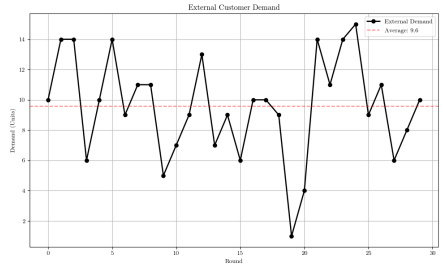

External Customer Demand
External Demand
Average: 10.5
Demand (Units)
Round

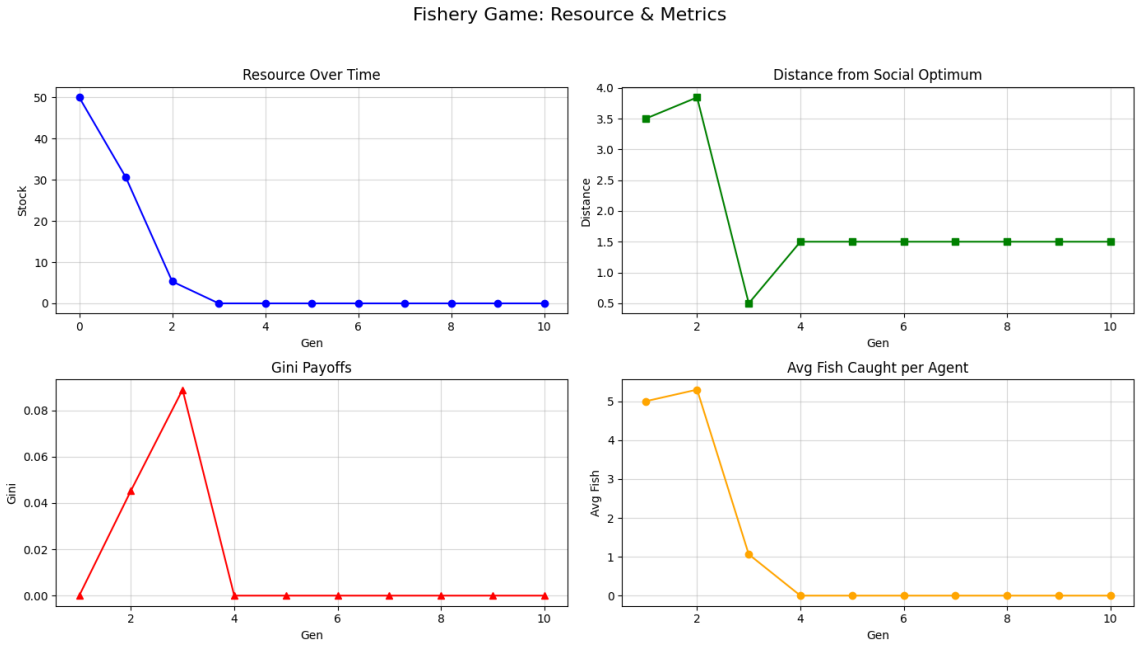

Inventory Over Rounds
Retailer
Wholesaler
Distributor
Factory
Units in Inventory
Round


Backlog Over Rounds
Retailer
Wholesaler
Distributor
Factory
Unmet Demand (Backlog)
Round


Ending Balance Over Time
Retailer
Wholesaler
Distributor
Factory
Balance ($)
Round


Order Quantity Over Rounds
Retailer
Wholesaler
Distributor
Factory
Units Ordered Upstream
Round


External Customer Demand
External Demand
Average: 9.6
Demand (Units)
Round



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.