Next-Gen DeAI Ecosystem:
Tokenomics and Shard Economy –

Motivation, Formal Model, Dynamics-Analysis and Simulation

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Abstract

We present a unified tokenomic design for a Next-Gen DeAI Ecosystem that aligns shard-level productivity with global value creation while embedding rigorous safeguards for adverse conditions. The model has three complementary layers. (1) A formal, equation-based specification couples a decaying emission schedule and fee burns with fee routing to validators, treasury, and main staking; shard fees fund mandatory buybacks that accumulate per-shard reserves which emit yield to shard stakers. (2) An adaptive control layer introduces an automated health score H_t that triggers higher burn, temporary emission hibernation, dynamic reserve emission rates γ_t, and a θ_{circuit}/month reserve circuit breaker; it also adds a fee-funded insurance pool, cross-shard mutual support, protocol-owned liquidity (POL), and optional external yield for reserves. (3) A theoretical analysis proves activity takeover of supply, reserve convergence and half-life with adaptive γ_t, impulse/decay responses for bubbles, flash crashes, bear runs, memecoin spikes, and slow-burn adoption, plus lower/upper bounds for main-staking rewards and stability tradeoffs for policy knobs. We corroborate these results with a 36-month baseline simulation and three adaptive stress simulations that demonstrate circuit breaking, death-spiral protection, and diversification benefits for a slow-growth shard. The combined architecture maintains crypto-native incentives while providing automatic, transparent responses to extreme scenarios, improving robustness without sacrificing upside for value-creating shards.

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1 Introduction

Motivation. This Next-Gen DeAI Ecosystem design is being developed as part of the process of designing the ASI chain ecosystem. Post-launch, the ecosystem will host many heterogeneous applications on distinct economic shards. The design objective is to let *productive* shards and their stakers capture more of the wealth they create, while preserving shared security and liquidity and preventing system-wide instabilities. We therefore pair a minimal core token (ASI) with staked claims (stakedASI) and shard reserves, so that usage fees drive both main-chain value and shard-local payouts.

Architecture at a Glance. Each month, emissions and fees are routed by policy splits; a fraction of validated fees is burned, a governed share funds validators, treasury, and main staking, and each shard uses a fixed ratio of validated fees to buy back stakedASI into a reserve which emits a small monthly yield to shard stakers. The model adds a health-based automation layer: when the composite health score H_t degrades, burns increase, emissions can hibernate, and the per-shard reserve emission rate γ_t drops; reserves are protected by a θ_{circuit}/month circuit breaker. A fee-funded insurance pool and cross-shard mutual support provide temporary liquidity; protocol-owned liquidity (POL) stabilizes markets; reserves can optionally earn external yield. These mechanisms are parameterized and capped by governance with time locks and optimistic safeguards.

Formal Model. We specify the state transition in discrete time: (i) supply update $S_{t+1} = S_t + E_t - b_t F_t$ with decaying emissions and adaptive burn; (ii) fee validation and buybacks by shard; (iii) shard-reserve dynamics with adaptive γ_t and circuit breaker; (iv) main-staking rewards from emissions, fee share, and a governed buyback slice; (v) insurance and mutual support deployments when thresholds are met; (vi) POL and external yield integration. The equations are accompanied by explanations of underlying motivations (Section 2) and a compact month-t operational sequence (Section 3.6).

Theoretical Guarantees. We prove that, under decaying emissions and any persistent fee floor, burns eventually exceed emissions (activity takeover), making supply nonincreasing. We derive closed-form reserve recursions with adaptive γ_t, steady states $R_i^* = \bar{I}_i/\bar{\gamma}$, and stress half-life extensions. We give impulse/decay responses for bubbles, flash crashes (with circuit breaker lower bounds), geometric bear runs, massive memecoin pulses that revert, and slow-burn valuable shards that converge. We establish pointwise and asymptotic bounds for main-staking rewards and monotone comparative statics (more fees $\Rightarrow$ more shard wealth). We formalize risk regimes and show how automatic triggers stabilize them.

Empirical Grounding. A 36-month baseline simulation illustrates fee-driven sustainability, scarcity emergence, and wealth routing to value-creating shards. Three stress simulations exercise the new mechanisms: (i) a local shock where circuit breakers cap reserve drawdowns and adaptive γ_t preserves buffers; (ii) a system-wide crash where hibernation, higher burns, insurance, and the breaker prevent death spirals; (iii) a slow-growth shard that survives via reserve diversification and later prevails. These runs are illustrative, not predictive, but align with the theory and clarify knob tradeoffs for governance.

2 Equations and Mechanisms

Throughout, t indexes months; i indexes shards; j indexes main-chain stakers; u indexes shard-i stakers.

2.1 Core state and parameters

Circulating supply and activity. *The system tracks the total amount of ASI tokens in circulation and the economic activity (measured as fees) generated across all shards.* We track circulating supply, new emissions, and total fee volume as the macro state:

$$S_t = \text{circulating ASI at the start of month } t, \qquad E_t = \text{newly emitted ASI in month } t, \qquad F_t = \sum_i F_{i,t},$$

where $F_{i,t}$ are fees generated by shard i in month t.

Fee split and burn. *Fees collected are distributed according to governed proportions — some permanently removed from circulation (burned), while others reward various participants.* A governed split distributes fees among burn, validators, treasury, and staking:

$$b_t + v_t + t_t + s_t = 1, \qquad b_t, v_t, t_t, s_t \in [0,1],$$

where b_t is the burn fraction applied to F_t.

Adaptive burn rate mechanism. *The burn rate automatically adjusts based on the supply/fee ratio to prevent runaway inflation without manual intervention.* The burn fraction now includes an adaptive component that responds to emission/fee imbalance:

$$b_t = \beta_t + \Delta b_t, \qquad \Delta b_t = \begin{cases} \Delta b_{\text{imbalance}}, & E_t > \theta_{\text{imbalance}}\, b_{t-1}F_{t-1}, \\ 0, & \text{otherwise}, \end{cases}$$

subject to $b_t \le b_{\max}$ to preserve other allocations.

Decay schedule and horizon. *Both token emissions and the default burn rate decrease over time according to a predictable schedule, transitioning the system from subsidy-driven to fee-driven.* Emissions and default burn follow a decaying, time-limited bootstrap schedule:

$$d \in (0,1) \text{ (monthly decay)}, \qquad T_{\text{policy}} \text{ (policy horizon)}.$$

System health score. *A composite metric that monitors overall system health and triggers automatic parameter adjustments.* The health score combines four multiplicative components: an anti-inflation term, the reputation subsystem (Section 2.2), the stakedASI/ASI value ratio, and a systemic-correlation penalty. Together they yield the unified hybrid controller:

$$H_t = \underbrace{\left(1 - \frac{E_t}{b_t F_t + \epsilon}\right)}_{\text{Anti-inflation}} \cdot \underbrace{\left(w_\rho\, \rho_t^{\text{EMA}} + (1-w_\rho)\frac{\sum_i R_{i,t}}{\sum_i R_{i,0}}\right)}_{\text{Reputation subsystem}} \cdot \underbrace{\frac{p_t}{p_0}}_{\text{StakedASI value}} \cdot \underbrace{(1-\Psi_t)}_{\text{Systemic correlation}} .$$

Here $\epsilon = 0.001$ prevents division by zero; p_t is the stakedASI/ASI exchange rate; Ψ_t is the systemic correlation coefficient; and $w_\rho \in [0,1]$ determines the influence of the EMA-smoothed reputation signal.

The EMA-based reputation term is defined as:

$$\rho_t^{\text{EMA}} = (1-\alpha_{\text{rep}})\,\rho_{t-1}^{\text{EMA}} + \alpha_{\text{rep}}\,\rho_t, \qquad \rho_t = \frac{\sum_s w_{s,t}^{(S)}\,\rho_{s,t}}{\sum_s w_{s,t}^{(S)}},$$

where $\rho_t \in [0,1]$ is the network-wide reputation score aggregated across shards using stake- and fee-based shard weights $w_{s,t}^{(S)}$.

2.2 Reputation oracle and bootstrap heritage

Motivation. *To incorporate historical reliability and validator integrity into the adaptive control layer, we use a reputation oracle that produces validator- and shard-level scores which feed into the unified health score H_t.* The reputation subsystem has two main goals: (i) reward long-standing validator operators and delegators (including those migrating from predecessor networks such as Fetch and SingularityNET); and (ii) adjust automatic policy triggers in proportion to ongoing technical and economic behaviour.

Feature vector and oracle structure. Each validator v has a feature vector

$$\mathbf{x}_{v,t} = \left(x_{v,t}^{\text{boot}}, x_{v,t}^{\text{perf}}, x_{v,t}^{\text{deleg}}, x_{v,t}^{\text{sec}}, x_{v,t}^{\text{integr}}, x_{v,t}^{\text{attest}}\right),$$

and a raw reputation score given by a weighted oracle

$$r_{v,t} = \mathcal{O}_{\text{rep}}(\mathbf{x}_{v,t}) = \sum_k w_k f_k(x_k), \qquad \sum_k w_k = 1, \quad w_k \geq 0.$$

Bootstrap heritage (legacy). Rewards are granted for proven validator and delegator behaviour prior to ASI Chain launch:

$$x_{v,t}^{\text{boot}} = \phi_1\,\text{normUptime}_v^{\text{legacy}} + \phi_2\,\text{yearsActive}_v^{\text{legacy}} + \phi_3\,\text{delegationAge}_v^{\text{legacy}}, \qquad \phi_1+\phi_2+\phi_3 = 1.$$

Legacy credit decays exponentially to prevent permanent advantage:

$$x_{v,t}^{\text{boot}} = x_{v,0}^{\text{boot}}\,e^{-\lambda_{\text{boot}} t}, \qquad \lambda_{\text{boot}} \approx 0.02/\text{month}.$$

Other components.

Symbol	**Meaning**	**Typical input**
x^{perf}	Live uptime & missed-block rate	$\exp(-\lambda_m \cdot \text{missRate})$
x^{deleg}	Average delegation age & lock length	$\text{EMA}_{30\text{d}}(\text{delegAge})/\text{MaxLock}$
x^{sec}	Audits & slash history	$\exp(-\lambda_s \cdot \text{slashEvents})$
x^{integr}	Economic integrity / wash-trade penalty	$1/(1+\text{fraudScore})$
x^{attest}	Stake-weighted attestations / community proofs	attestStake/totalStake

Default weights:

$$w_{\text{boot}} = 0.20, \quad w_{\text{perf}} = 0.25, \quad w_{\text{deleg}} = 0.15, \quad w_{\text{sec}} = 0.15, \quad w_{\text{integr}} = 0.15, \quad w_{\text{attest}} = 0.10.$$

Oracle aggregation and normalization. Validator-level scores are aggregated by stake to obtain shard- and network-level signals. The shard-level reputation for shard s is

$$\rho_{s,t} = \frac{\sum_{v \in \mathcal{V}(s)} \text{stake}_{v,t}\, r_{v,t}}{\sum_{v \in \mathcal{V}(s)} \text{stake}_{v,t}} \in [0, 1].$$

The network-level reputation is a shard-weighted mean:

$$\rho_t = \frac{\sum_s w_{s,t}^{(S)}\ \rho_{s,t}}{\sum_s w_{s,t}^{(S)}}, \qquad w_{s,t}^{(S)} \propto \text{validatedFees}_{s,t} \cdot \text{stake}_{s,t},$$

clipped to $[0, 1]$. To smooth noise, the oracle publishes an EMA-smoothed series:

$$\rho_t^{\text{EMA}} = (1 - \alpha_{\text{rep}})\, \rho_{t-1}^{\text{EMA}} + \alpha_{\text{rep}}\, \rho_t, \qquad \alpha_{\text{rep}} \in (0, 1).$$

Anti-gaming constraints and hysteresis. To preserve robustness, the oracle enforces:

- *Clipping and rate limits:* $r_{v,t} \in [0, 1]$ with $|r_{v,t} - r_{v,t-1}| \leq \Delta_{\text{max}}$.
- *Smoothing and hysteresis:* EMA for noisy inputs; cool-down periods for upgrades and downgrades.
- *Sybil resistance:* the attestation graph penalizes split identities; the integrity term feeds into a shard-level validation haircut $\omega_{s,t}$.
- *Versioned inputs:* legacy datasets are Merkle-proved at genesis; monthly updates are signed by a multi-sig oracle.

2.3 Emissions and burn schedules

Emissions taper with hibernation mode. *New tokens are created at a decreasing rate for the first policy horizon to bootstrap the network, then stop entirely. In crisis conditions, emissions can pause temporarily.* Emissions start at E_0 and decay geometrically for T_{policy} months, then stop, with crisis hibernation:

$$E_t = \begin{cases} 0, & F_t < \theta_{\text{hibernate}}\, \bar{F}_{t,\tau} \text{ (hibernation mode)}, \\ E_0(1-d)^t, & 0 \leq t < T_{\text{policy}} \text{ and not hibernating}, \\ 0, & t \geq T_{\text{policy}}. \end{cases}$$

Burn fraction baseline. *Initially, a high percentage of fees are burned to offset new token creation. This percentage decreases over time as the system matures.* The burn fraction starts high (to offset emissions as usage grows) and decays, with the option to reach zero after the policy:

$$\beta_t = \begin{cases} \min\{B_0(1-d)^t, 1\}, & 0 \le t < T_{\text{policy}}, \\ 0, & t \ge T_{\text{policy}}. \end{cases}$$

Supply update. *The total token supply increases through new emissions and decreases through burns, creating a dynamic equilibrium.* Net supply rises by emissions and falls by burns; buybacks do not mint or burn directly:

$$S_{t+1} = S_t + E_t - b_t F_t.$$

2.4 Fee routing and staking rewards

Fee allocation buckets with insurance pool. *Fees are divided into five purposes: reducing supply (burn), rewarding network validators, funding development (treasury), rewarding stakers, and crisis insurance.* Each month, fees are allocated across burn, validators, treasury, main staking, and the insurance pool:

$$\text{Burn}_t = b_t F_t, \qquad \text{ValReward}_t = v_t F_t, \qquad \text{Treasury}_t = (t_t - \iota) F_t, \qquad \text{Insurance}_t = \iota F_t, \qquad \text{StakePool}_t = s_t F_t.$$

The insurance pool automatically deploys when

$$H_t < H_{\text{insurance}}.$$

Shard buybacks with volume validation. *Each shard automatically uses some of its fees to purchase stakedASI tokens, but only counts fees from genuine trading activity.* Each shard uses a fixed ratio of its validated fees to buy back stakedASI:

$$F_{i,t}^{\text{valid}} = F_{i,t}\,\omega_{i,t}, \qquad \omega_{i,t} = \frac{\text{Volume}_{\text{hold-period}}}{\text{Volume}_{\text{total}}},$$

where $\omega_{i,t}$ is the fraction of trading volume from addresses holding positions longer than τ_{hold} hours.

The buyback amount is

$$\text{Buyback}_{i,t} = \rho_i\, F_{i,t}^{\text{valid}}, \qquad \rho_i \in [0,1],$$

and the total buyback routed to main staking is:

$$\text{Buyback}_t = \sum_i \text{Buyback}_{i,t}.$$

Main staking rewards. *The main staking pool receives rewards from three sources: new token emissions, a share of fees, and optionally a portion of shard buybacks.* Thus main staking rewards are:

$$\text{MainStakingRewards}_t = E_t + s_t F_t + \phi_t \sum_i \text{Buyback}_{i,t}, \qquad \phi_t \in [0,1].$$

Protocol-owned liquidity. *The protocol permanently owns a portion of stakedASI/ASI liquidity to prevent deep spirals during crises.* The protocol maintains permanent liquidity:

$$\text{POL}_t = \lambda_{\text{POL}} \cdot \text{TotalLiquidity}_t.$$

This liquidity cannot be withdrawn; only fees harvested from it flow to treasury.

2.5 Time-weighted staking and distribution

Lock boosts for loyalty. *Users who commit their tokens for longer periods receive proportionally higher rewards, incentivizing long-term alignment.* Longer locks get higher effective stake to reward committed capital:

$$\mathrm{EffStake}_{j,t} = \mathrm{Stake}_{j,t}\left(1 + \alpha\,\frac{\mathrm{lock}_j}{\mathrm{MaxLock}}\right), \qquad N_t = \sum_j \mathrm{EffStake}_{j,t}.$$

Per-staker reward share. *Rewards are distributed fairly based on each staker's effective stake relative to the total.* Rewards are split proportionally to effective stake:

$$\mathrm{Reward}_{j,t} = \mathrm{MainStakingRewards}_t \cdot \frac{\mathrm{EffStake}_{j,t}}{N_t}.$$

Liquid staking accounting (share-token view). *stakedASI works like shares in a fund — as the backing pool grows from rewards, each stakedASI becomes worth more ASI.* stakedASI is a share of a backing pool; its exchange rate rises as rewards accrue. Define:

$$X_t = \text{ASI backing}, \qquad Y_t = \text{stakedASI units}, \qquad p_t = \frac{X_t}{Y_t},$$

with deposits/withdrawals and routed rewards updating (X_t, Y_t) per contract logic.

2.6 Shard reserves and shard-level rewards

Reserve accumulation with dynamic emission rate. *Each shard builds a reserve fund from its buybacks. The emission rate automatically adjusts based on system health to preserve reserves during stress.* Shard reserves hold stakedASI bought back from fees; emission rate adapts to conditions:

$$\gamma_t = \begin{cases} \gamma_{\text{stress}}, & F_{i,t} < \theta_{\text{stress}}\,\bar{F}_{i,\tau} \quad \text{(stress mode)}, \\ \gamma_{\text{protect}}, & R_{i,t} < \theta_{\text{protect}}\,R_{i,t-1} \quad \text{(reserve protection)}, \\ \gamma_{\text{normal}}, & \text{otherwise (normal operation)}. \end{cases}$$

Reserve update.

$$R_{i,t+1} = R_{i,t} + \kappa_{i,t}\,\mathrm{Buyback}_{i,t} + \tau_{i,t} - \gamma_t\,R_{i,t},$$

where $\kappa_{i,t} \in [0,1]$ maps purchases to reserve balance (default 1), and $\tau_{i,t}$ is an optional treasury top-up.

Cross-shard mutual insurance. *During system stress, profitable shards contribute to support struggling shards, creating mutual insurance while still rewarding success.* When

$$H_t < H_{\text{mutual}},$$

profitable shards contribute to a mutual pool:

$$\text{MutualContrib}_{i,t} = \begin{cases} \mu_{\text{contrib}} \cdot F_{i,t}, & F_{i,t} > \theta_{\text{mutual}} \cdot \bar{F}_t/n, \\ 0, & \text{otherwise.} \end{cases}$$

The pool is then distributed to shards with reserves

$$R_{i,t} < \theta_{\text{receive}} \, R_{i,0}.$$

Shard reward split with rage-quit protection. *Rewards from the shard reserve are distributed to shard stakers, with emergency exit rights if the shard is failing.*

Shard emissions are distributed by stake-time lock at the shard:

$$\text{ShardEmission}_{i,t} = \gamma_t R_{i,t}, \qquad \text{ShardReward}_{u,i,t} = \text{ShardEmission}_{i,t} \cdot \frac{\text{Stake}_{u,i,t} \cdot \text{Lock}_{u,i}}{\sum_q \text{Stake}_{q,i,t} \cdot \text{Lock}_{q,i}}.$$

If

$$R_{i,t} < \theta_{\text{rage}} \cdot R_{i,t-\tau_{\text{rage}}},$$

shard stakers may exit directly to ASI at a discounted p_t rate.

[1]

External yield integration. *Shard reserves can earn additional yield from conservative external sources to reduce dependence on shard fees alone.*

Reserves can allocate up to $\lambda_{\text{external}}$ to external yield sources:

$$R^{\text{total}}_{i,t+1} = R_{i,t+1} + Y^{\text{external}}_{i,t}, \qquad Y^{\text{external}}_{i,t} \leq \lambda_{\text{external}} \cdot R_{i,t} \cdot r_{\text{external}},$$

where r_{external} is the monthly yield from approved sources (stablecoin lending, ETH staking).

2.7 Governance, launch discipline, and pre-launch bonding

Shard launch guard. *New shards must demonstrate serious commitment by locking a minimum amount of stakedASI before launching, preventing frivolous shard creation.* New shards must lock meaningful stakedASI as a reserve floor to align incentives at inception:

$$R_{i,0} \; \geq \; R_{\min} \qquad (\text{e.g., } R_{\min} = \text{launch guard requirement}).$$

Voting power with optimistic governance. *Governance voting weight increases with both the amount staked and the square root of time staked. Critical changes use optimistic governance to address low participation.*

Governance weights long-term commitment via time-staked square-root scaling:

$$VP_j \; = \; \text{ASI}_j \cdot \sqrt{\text{timeStaked}_j}.$$

[1] There are tentative plans to create a partially-stakedASI-backed stablecoin, perhaps initially tied to a basket of fiat currencies and then divorcing from fiat entirely toward more fundamental stability; if this is actualized this may become an option for reserves as well.

For parameter changes affecting g_{gov} of supply: changes execute after τ_{lock} days unless vetoed by $> \theta_{\text{veto}}$ of stakers.

Time-locked parameter changes. *All critical parameter changes have mandatory delay periods to prevent flash governance attacks.*

Critical parameters (γ, b_t, burn rates) have mandatory delays:

$$t_{\text{execution}} = t_{\text{proposal}} + \begin{cases} \tau_{\text{lock,short}} \text{ days}, & \text{for changes } < \theta_{\text{lock}}, \\ \tau_{\text{lock,long}} \text{ days}, & \text{for changes } \geq \theta_{\text{lock}}. \end{cases}$$

Pre-launch bonding (optional pod mechanics). *Early supporters can bond tokens before a shard launches, earning bonus rewards for taking early risk.*

A logistic reward curve with a pre-launch bonus encourages early aligned participation and smooths go-live:

$$R_{\text{base}}(t) = \frac{1}{1 + e^{-k(t-t_0)}}, \qquad R(t) = \begin{cases} \alpha\, R_{\text{base}}(t), & t < T_{\text{launch}}, \\ R_{\text{base}}(t), & t \geq T_{\text{launch}}, \end{cases}$$

with k set by a desired 10%→90% window

$$\Delta \text{ via } k = \ln(81)/\Delta,$$

and $(\alpha - 1)$ subject to vesting.

3 Dynamics and Health Analysis

3.1 Macro Scarcity and Sustainability

Emissions vs. activity-driven burns. *The system's health depends on when fee burns become large enough to offset new token emissions, creating a deflationary or stable supply.* Net inflation is controlled by how quickly fees (and burn share) catch up to or exceed emissions, or by emissions expiring:

$$S_{t+1} - S_t = E_t - b_t F_t.$$

Condition A (bootstrapping). It is acceptable early that $E_t > b_t F_t$, provided fee routing keeps security and staking attractive and activity is trending upward.

Condition B (maturity). A healthy steady regime is reached when either $b_t F_t \gtrsim E_t$ before $t = T_{\text{policy}}$, or $E_t \to 0$ and any $b_t > 0$ is deflationary.

Counter-cyclical levers with automated triggers. *The system automatically adjusts parameters based on market conditions to stabilize the economy during boom and bust cycles.* Parameters adjust automatically based on system health H_t:

$$b_t = b_t(H_t), \qquad \rho_{i,t} = \rho_{i,t}(H_t), \qquad \gamma_t = \gamma_t(H_t).$$

Specifically:

- If $H_t < H_{\text{stress}}$: $\gamma_t \to \gamma_{\text{stress}}, \quad b_t \to \min(b_t + \Delta b_{\text{health}}, b_{\max})$.
- If $H_t < H_{\text{hibernate}}$: System enters hibernation mode (emissions pause).
- If $H_t > H_{\text{healthy}}$: parameters revert toward baseline smoothly over a 3-month period.

3.2 Main Staking Yield Sustainability

Yield composition. *The annual return for main chain stakers comes from three sources, divided by the total effective stake.* Main-chain staking APR comes from emissions, fee share, and routed buybacks, divided by the effective staked base:

$$Y_t^{\text{main}} \propto \frac{E_t + s_t F_t + \phi_t \sum_i \rho_i F_{i,t}}{N_t}.$$

Guideline. Use lock boosts to concentrate yield in committed capital (raising effective APR for lockers) and maintain a steady s_t path so rewards are not overly volatile as E_t decays.

3.3 Shard Reserve Solvency and Growth

Reserve dynamics with circuit breakers. *A shard's reserve grows when incoming funds exceed outgoing emissions, with automatic protections against rapid depletion.* A shard grows its reserve when inflows exceed emissions, with automatic protection:

$$R_{i,t+1} = \max\Big(\theta_{\text{circuit}} \cdot R_{i,t},\ R_{i,t} + (\kappa_i \rho_i F_{i,t} + \tau_{i,t}) - \gamma_t R_{i,t}\Big).$$

The max function prevents reserves from falling more than $(1 - \theta_{\text{circuit}})$ in one month.

Steady state. If $F_{i,t}$ and $\tau_{i,t}$ stabilize at $(\bar{F}_i, \bar{\tau}_i)$, then

$$R_i^* = \frac{\kappa_i \rho_i \bar{F}_i + \bar{\tau}_i}{\gamma}.$$

Growth condition. $R_{i,t}$ increases whenever $\kappa_i \rho_i F_{i,t} + \tau_{i,t} > \gamma_t R_{i,t}$.

Allocation to productive shards. Successful shards automatically receive more resources — higher fees lead to larger reserves and more rewards for their participants.

Higher $F_{i,t}$ simultaneously increases (i) shard emissions $\gamma_t R_{i,t}$ to shard stakers and (ii) global buybacks to main staking. Thus, shards that create more fees direct more wealth to their local investors and also lift global staking base, aligning incentives across layers.

3.4 Wealth Creation and Routing Conditions

Macro health conditions. *The system needs to reach certain fee-to-emission ratios at different stages to remain healthy and sustainable.* Long-run health requires neutral-to-deflationary supply or, at minimum, fee-supported neutrality after the bootstrap.

Target band:

$$\frac{b_tF_t}{E_t} \in \left[\xi_{\text{early,min}}, \xi_{\text{early,max}}\right] \quad \text{(early)}, \qquad \frac{b_tF_t}{E_t} \gtrsim 1 \quad \text{(mid to late)}, \qquad E_t = 0 \quad \text{(post-horizon)}.$$

Interpretation. Early, burns need only partially offset emissions. Over time, either activity grows to match emissions, or emissions decouple to zero and fee routing services yields and security.

Main staking competitiveness. *Staking rewards must remain attractive compared to other opportunities without relying on excessive token creation.* Keep per-effective-stake rewards competitive with external alternatives without relying on high inflation:

$$\frac{E_t + s_tF_t + \phi_t \sum_i \rho_i F_{i,t}}{N_t}$$

is maintained by s_t stability, $\phi_t > 0$, and lock boosts $\alpha > 0$.

Shard solvency band. *Each shard needs sufficient incoming funds to cover its monthly emissions without depleting its reserve.* For default $\gamma = \gamma_{\text{normal}}$/month (reduced automatically in stress), avoid reserve bleed by ensuring average inflow meets or exceeds outflow:

$$\kappa_i\rho_i\bar{F}_i + \bar{\tau}_i \geq \gamma_t\bar{R}_i.$$

If the inequality is strict, the reserve and shard APR grow up toward R_i^*.

3.5 Failure Modes and Mitigations

Under-activity vs. emissions. If F_t lags, inflation persists. **Mitigations.** Adaptive burn rate increases b_t automatically; hibernation mode pauses emissions if fees collapse; insurance pool deploys capital.

Reserve bleed in small shards. If $\kappa_i\rho_iF_{i,t} < \gamma_tR_{i,t}$ for long, reserves fall. **Mitigations.** Dynamic γ_t automatically reduces to γ_{protect} during stress; cross-shard insurance provides support; external yield supplements income.

Fee gaming and wash volume. Gross fees could be manipulated to trigger buybacks. **Mitigations.** Volume validation $\omega_{i,t}$ only counts fees from n_{hold}+ holders; define $F_{i,t}$ as net-of-rebates revenue; cap ρ_i; require audits in shard contracts.

Fragmentation risk. Many shards could fragment liquidity. **Mitigations.** Mandatory buybacks into stakedASI and launch guard $R_{\min}$ bind shards to shared collateral; protocol-owned liquidity provides stability.

3.6 Putting the Month-t Flow Together

Operational narrative with automated adjustments. *Here's the step-by-step process that happens each month to update the entire system, now with automatic parameter adjustments.*

Each month: 1. Calculate health score H_t and trigger automatic adjustments if needed. 2. Compute emissions and fee splits. 3. Burn and route fees. 4. Execute shard buybacks and update reserves. 5. Distribute main staking and shard rewards. 6. Update supply and reserves. 7. Deploy insurance pool if $H_t < H_{\text{insurance}}$.

Healthy parameters ensure that usage growth transitions the system from emission-driven to fee-driven dynamics while routing more wealth to value-creating shards and their stakers.

Compact sequence. For each month t:

1. Calculate H_t; adjust γ_t, b_t if needed; check hibernation conditions.
2. Compute E_t, β_t, collect $\{F_{i,t}^{\text{valid}}\}$ and $F_t = \sum_i F_{i,t}^{\text{valid}}$.
3. Burn and split fees: $b_t F_t$, $v_t F_t$, $(t_t - \iota) F_t$, ιF_t (insurance), $s_t F_t$.
4. Per shard: $\text{Buyback}_{i,t} = \rho_i F_{i,t}^{\text{valid}}$; update $R_{i,t+1}$ with circuit breaker.
5. Main staking rewards:

$$\text{MainStakingRewards}_t = E_t + s_t F_t + \phi_t \sum_i \rho_i F_{i,t}^{\text{valid}},$$

   distributed by $\text{EffStake}_{j,t}/N_t$.
6. Shard emissions: pay $\gamma_t R_{i,t}$ by (Stake $\times$ Lock) shares.
7. Update supply: $S_{t+1} = S_t + E_t - b_t F_t$.
8. Check cross-shard insurance triggers and rage quit conditions.

4 Three-Year (Simplistic) Simulation of the Next-Gen DeAI Ecosystem Shard Economy

To get a better feel for the dynamics, we run a didactic, very simplified month-by-month simulation over 36 months to show how the shard economy behaves on a crypto-relevant timeframe. We keep the same mechanics as the formal model (decaying emissions, fee burns and routing, shard buybacks into reserves, per-shard reserve emissions, main-staking rewards), but compress shard adoption patterns so that meaningful dynamics are visible within three years.

The simulation model is implemented as simple python code in a publicly accessible Colab notebook at:

https://colab.research.google.com/drive/1iOULLWRpYi_ex0arhiJZaH79OMY9UvU7?usp=sharing

and the reader is encouraged to copy, tweak, improve, extend, etc. This is a toy model and intended to stupidity-check and elucidate key dynamics rather than as a serious simulation that could be used to predict or model detailed tokenomics behavior in real-world contexts.

4.1 Setup (Parameters and Shard Archetypes)

Policy knobs We simulate only the first 36 months of the T_{policy}-month emission/burn schedule:

- **Emissions:** $E_t = E_0\,(1-d)^t$ for $t < T_{\text{policy}}$ (we observe only $t \le 36$ here).
- **Burn share baseline:** $b_t = \min\{B_0(1-d)^t,\,1\}$ for $t < T_{\text{policy}}$.
- **The non-burn portion** $(1 - b_t)$ is split proportionally into staking (e.g., 30%), validators (e.g., 10%), and treasury (e.g., 20%).
- **Shard buybacks:** each shard allocates $\rho = \rho_{\text{default}}$ of its monthly fees to buybacks. Of that buyback flow, $\phi = \phi_{\text{default}}$ routes to *main staking* and $(1-\phi)$ goes into the shard's reserve.
- **Shard reserve emission rate:** $\gamma = \gamma_{\text{normal}}$ per month (paid out to shard stakers).
- **Launch guard:** each shard starts with a reserve floor $R_{i,0} = R_{\min}$ (stakedASI).
- **Main-staking effective base for APR reporting:** N_{eff} (kept constant for readability).

Four shard archetypes (fee profiles). We model four economically distinct shards to illustrate how wealth routes toward value creation:

1. **Shard A (services winner).** Early, steady product-market fit; fees ramp quickly and remain high.
2. **Shard B (memecoin-ish).** Low baseline punctuated by two large hype spikes, plus occasional mini-spikes.
3. **Shard C (moderate/niche).** Solid software with modest traction; stable, smaller plateau.
4. **Shard D (no PMF).** Weak product; fees decay quickly.

The fee curves are stylized but plausible: A and C use compressed logistic ramps (centers around months 15 and 22); B adds Gaussian spikes (around months 10 and 24) and random heavy-tail pops; D decays with a ∼6-month half-life.

4.2 What We Measure and Why It Matters

- **Emissions vs. burns.** When monthly fee burns $b_t F_t$ meet or exceed emissions E_t, the system is activity-funded rather than inflation-funded.
- **Circulating supply.** Supply flattens or falls when burns outpace emissions, supporting scarcity.
- **Main-staking APR.** Rewards to the core staking pool from (emissions + fee share + buyback slice), normalized by an effective staked base. Crypto readers can compare this to DeFi yields.
- **Shard reserves and shard emissions.** Every shard builds a reserve via buybacks; that reserve emits a small monthly yield ($\gamma R_{i,t}$) to shard stakers. Sustained fees ⇒ larger reserves ⇒ larger shard yields.
- **Cumulative value to stakers.** Side-by-side view of value routed to main staking vs. shard staking over the 3-year window.

4.3 Results (3 Years, Month-by-Month)

Emissions vs. burns (when does activity take over?). In this calibration, burns meet or exceed emissions essentially immediately (by month 1). This happens because the combined baseline activity—including even a decaying shard—is already sufficient under the conservative initial burn share. If governance prefers the cross-over later (e.g., months 6–12), one can reduce B_0 or slow early adoption in the shard fee curves.

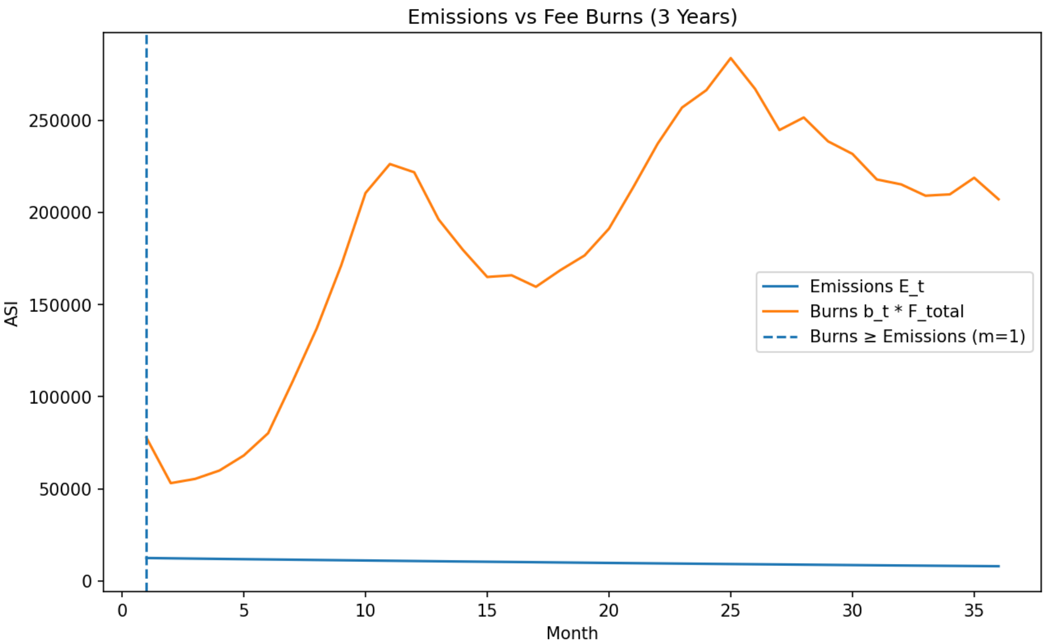

Figure 1: Emissions vs. fee burns over 36 months. Dashed line marks the first month where burns $\geq$ emissions.

Circulating supply (scarcity in sight). Over the 3-year window, cumulative burns comfortably exceed cumulative emissions, producing a *net reduction* in circulating supply of about **6.08M ASI** (from 100.0M down to ~93.92M).[2]

Main-staking APR (competitive without heavy inflation). As emissions taper, fee routing and a slice of buybacks keep main-staking yields competitive. In this run, the annualized main-staking APR finishes around **11.3%** with a peak near **12.4%**, funded primarily by fees and buybacks, not perpetual inflation.

[2]This illustrates the shift toward an activity-funded economy even before the T_{policy}-month emission horizon ends.

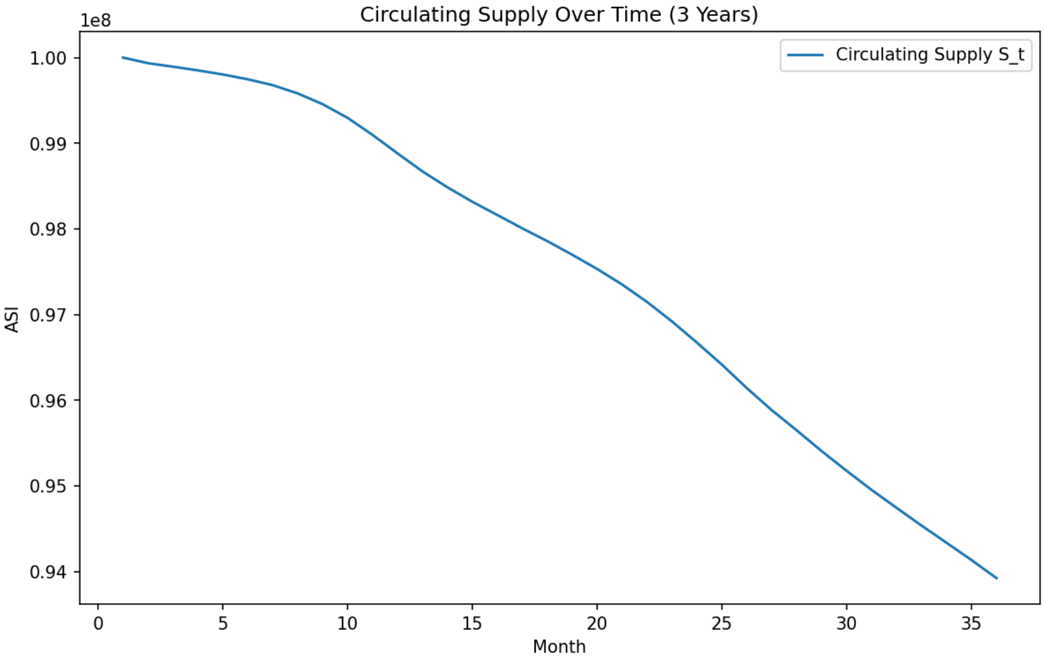

Figure 2: Circulating supply over time (36 months). Flattening/decline appears once burns dominate.

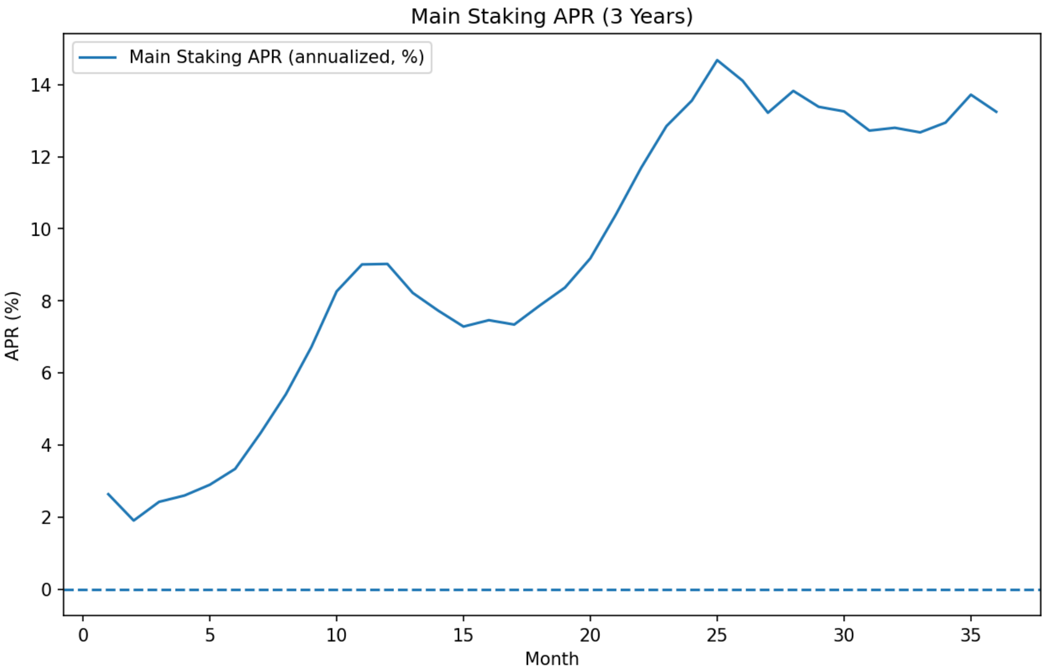

Figure 3: Main-staking APR (annualized) over 36 months.

Shard reserves and shard-level yields (who earns more, and why).

- **Shard A (services)** builds the largest reserve (ending ∼539k stakedASI) and thus pays the largest, *stable* shard yield ($\gamma R_{A,t}$).
- **Shard B (memecoin-ish)** spikes its reserve during hype but lacks a strong baseline, so it ends much smaller (ending ∼179k).
- **Shard C (moderate)** is healthy but niche (ending ∼66.8k).
- **Shard D (no PMF)** cannot sustain its reserve (ending ∼26.5k); with weak fees, $\gamma R_{D,t}$ dwindles.

This demonstrates the intended routing: shards that consistently *create real fees* accumulate reserves and pay more to their local stakers.

How fees evolve across shards. Shard A's sustained adoption dominates by year 2; Shard B's hype windows are visible but short-lived; Shard C is steady but smaller; Shard D decays.

Cumulative value routed to stakers (global vs. local). Within 36 months, most value is routed to *main staking* (cumulative ∼ 4.67M ASI) versus shard stakers (cumulative ∼ 0.40M ASI), i.e. a ratio of about **11.8:1**. This is expected early because shard reserves are still growing; as reserves compound beyond year 3, the shard-side share rises.

4.4 Takeaways

1. **Activity-funded, not inflation-funded.** With reasonable early usage and a conservative burn share, burns meet or exceed emissions inside 36 months (in this scenario, almost immediately). You can delay this crossover by lowering B_0 or slowing early adoption, but the point stands: fees drive sustainability.
2. **Value creation is rewarded locally and globally.** A productive shard (A) both (i) *grows its own reserve and shard yields* and (ii) *drives network-wide buybacks and staking rewards.* Spiky shards (B) help during hype but don't compound without baseline fees. Niche shards (C) are steady contributors. Non-performing shards (D) fade without leaking global value.
3. **Governance has practical levers.** If a shard's reserve bleeds during stress, reduce γ temporarily. If main-staking APR needs support as emissions decay, increase the fee share for staking and/or the buyback routing ϕ. These adjustments are intuitive for crypto users (raise yield floors, throttle emissions, bind shards to the core).
4. **Scarcity emerges even on crypto timelines.** Circulating supply declined by ∼ 6.08M ASI over 3 years here; the mechanism is straightforward: fee burns outpaced decaying emissions.

5 Theoretical Dynamics of Next-Gen DeAI Ecosystem Tokenomics Under General Conditions

In this section we formalize and prove a set of simple theorems about the Next-Gen DeAI Ecosystem tokenomics, generalizing the behaviors illustrated by the simulations. Our goal is didactic: each statement isolates a core mechanism (supply, reserves, staking yield) and shows how it behaves under growth, hype spikes, crashes, and slow-burn adoption. Throughout, time is discrete in months $t \in \mathbb{N}$.

We emphasize these results are just educational/conceptual and not intended to rigorously cover all possible situations or give detailed quantitative guidance. One could do much more detailed theoretical and simulation studies using data-driven stochastic process models of overall crypto and conventional markets and the tokens in the ecosystem, but we're not going there yet.

5.1 Preliminaries and notation

We reuse the model from the previous sections, with updates for adaptive mechanisms.

- **Circulating supply update:**

$$S_{t+1} = S_t + E_t - b_t F_t,$$

  with emissions $E_t \geq 0$, burn share $b_t \in [0, 1]$, and total fees

$$F_t = \sum_i F_{i,t}.$$

- **Shard i reserve recursion with dynamic γ_t:**

$$R_{i,t+1} = R_{i,t} + I_{i,t} - \gamma_t R_{i,t}, \qquad I_{i,t} := \kappa_{i,t}(1 - \phi_t)\rho_{i,t} F_{i,t}^{\text{valid}}.$$

  with adaptive reserve emission rate $\gamma_t \in (\gamma_{\text{protect}}, \gamma_{\text{normal}})$, buyback ratio $\rho_{i,t} \in [0, 1]$, routing split $\phi_t \in [0, 1]$, and implementation factor $\kappa_{i,t} \in [0, 1]$.

- **Main-staking reward (for completeness):**

$$\text{MSR}_t = E_t + s_t F_t + \phi_t \sum_i \rho_{i,t} F_{i,t}^{\text{valid}}.$$

Bounded parameters: $0 < \underline{b} \leq b_t \leq \bar{b} \leq 1$, $0 \leq \rho_{i,t} \leq \bar{\rho}$, $0 \leq \phi_t \leq \bar{\phi} < 1$, $0 < \underline{\gamma} \leq \gamma_t \leq \bar{\gamma} < 1$.

5.2 Supply Dynamics and Activity Takeover

Theorem 5.1 (Eventual Activity Takeover). *Suppose emissions decay geometrically: $E_t = E_0(1 - d)^t$ with $d \in (0, 1)$, and suppose the system achieves a long-run positive average fee floor:*

$$\liminf_{T\to\infty} \frac{1}{T} \sum_{t=0}^{T-1} F_t \geq \bar{F} > 0 \quad \textit{and} \quad \liminf_{t\to\infty} b_t \geq \underline{b} > 0.$$

Then there exists t_* such that for all $t \geq t_*$,

$$b_t F_t \geq E_t,$$

hence $S_{t+1} \leq S_t$ (nonincreasing supply) for $t \geq t_*$.

Proof. E_t decays geometrically to 0, while $b_t F_t$ has a positive lim inf lower bound in Cesàro average of at least $\underline{b}\,\bar{F}$. Thus there exists $t_\star$ such that for all $t \geq t_\star$, $E_t \leq \frac{1}{2}\underline{b}\bar{F}$ while $b_t F_t \geq \frac{1}{2}\underline{b}\bar{F}$

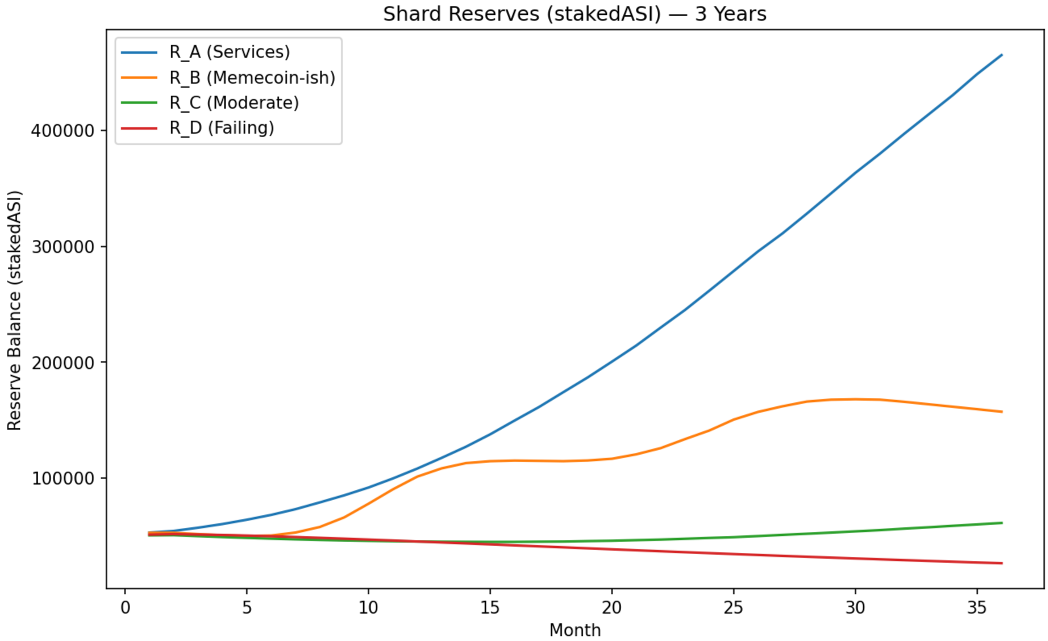

Figure 4: Shard reserves (stakedASI) over 36 months. Value-creating shards grow larger reserves.

holds infinitely often; combining with bounded oscillations of F_t and b_t (both nonnegative), we can pick $t_\star$ large enough so that $b_t F_t \geq E_t$ holds for all $t \geq t_\star$. Then

$$S_{t+1} - S_t = E_t - b_t F_t \leq 0.$$

Corollary 5.2. (Net scarcity band) If $b_t F_t \geq (1+\delta)E_t$ for all $t \geq t_\star$ and some $\delta > 0$, then

$$S_{t+k} \;\leq\; S_t \;-\; \delta \sum_{u=t}^{t+k-1} E_u.$$

i.e., cumulative supply decreases by at least a fraction δ of cumulative emissions after $t_\star$.

Interpretation. Once on-chain activity is persistent (fee floor) and emissions taper, burns dominate and the token becomes activity-funded rather than inflation-funded. This formalizes what we observed in the 3-year simulation (early takeover) and in the 10-year view (maturity).

5.3 Shard reserves: convergence, shocks, and half-life with adaptive γ_t

Define the inflow sequence $I_{i,t} = \kappa_{i,t}(1-\phi_t)\rho_{i,t}F_{i,t}^{\text{valid}}$. The reserve recursion with adaptive γ_t is: $R_{i,t+1} = (1-\gamma_t)R_{i,t} + I_{i,t}$.

Lemma 5.3 (Closed-Form and Boundedness). *With initial $R_{i,0}$ and time-varying γ_t, the solution is*

$$R_{i,t} = \prod_{s=0}^{t-1}(1-\gamma_s)R_{i,0} + \sum_{u=0}^{t-1}\prod_{s=u+1}^{t-1}(1-\gamma_s)I_{i,u}.$$

If $I_{i,t}$ is bounded by $\bar{I}$ and $\gamma_t \geq \underline{\gamma} > 0$, then $R_{i,t}$ is uniformly bounded.

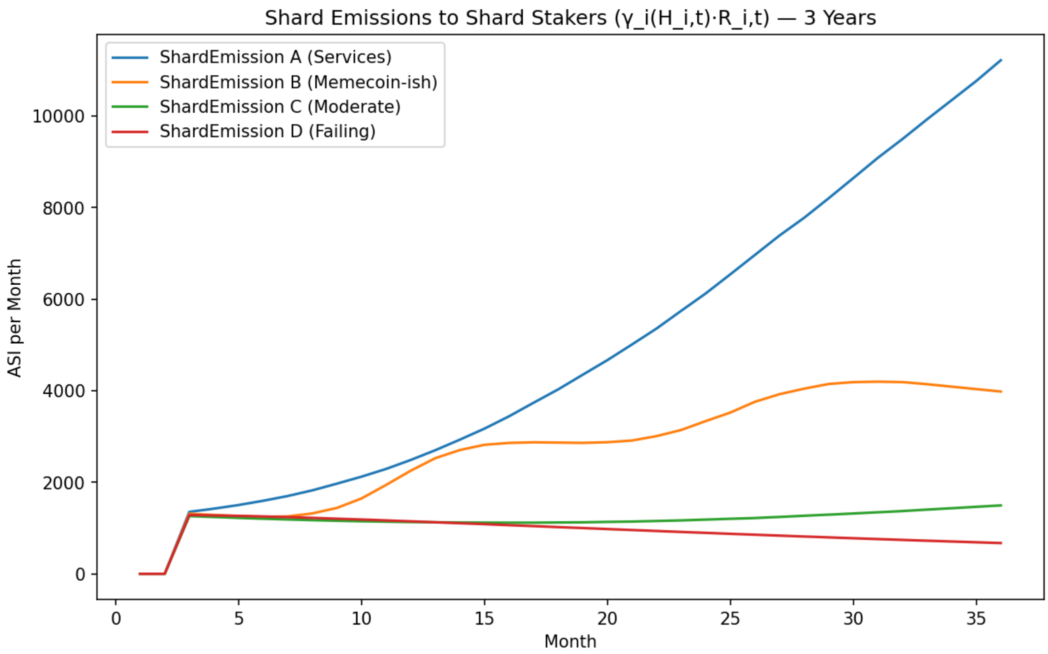

Figure 5: Shard monthly emissions to shard stakers ($\gamma R_{i,t}$). Larger reserves $\Rightarrow$ larger shard-level yields.

Theorem 5.4 (Steady State with Adaptive γ). *If $I_{i,t} \to \bar{I}_i$ and $\gamma_t \to \bar{\gamma}$ as $t \to \infty$, then*

$$R_{i,t} \to R_i^* := \frac{\bar{I}_i}{\bar{\gamma}}, \quad \textit{and} \quad \gamma_t R_{i,t} \to \bar{I}_i.$$

Proposition 5.5 (Shock Decay with Adaptive Protection). *Under the adaptive mechanism, if shard i experiences a fee drought triggering $\gamma_t = \gamma_{protect}$, the effective half-life extends to:*

$$H_{protected} = \left\lceil \frac{\ln 2}{-\ln(1-\gamma_{protect})} \right\rceil.$$

$$H_{\text{protected}} = \left\lceil \frac{\ln 2}{-\ln(1-\gamma_{\text{protect}})} \right\rceil, \quad \text{compared to } H_{\text{normal}} = \left\lceil \frac{\ln 2}{-\ln(1-\gamma_{\text{normal}})} \right\rceil \text{ at } \gamma = \gamma_{\text{normal}}.$$

Proof. Direct application of the half-life formula with the stress-mode γ. ☐

Interpretation. The adaptive mechanism increases reserve preservation significantly during crises.

5.4 Bubbles, flash crashes, bear runs, and slow-burn value

We now treat stylized paths for $F_{i,t}$ (and hence $I_{i,t}$), using the linearity in Lemma 5.3.

Token price bubbles and denomination. Let fees be recorded and burned in ASI units. If application fees are denominated in ASI, a USD price bubble typically *reduces* F_t (fewer ASI units per transaction of fixed USD cost), dampening $b_t F_t$. If fees are denominated in USD and converted to ASI at spot, a USD price bubble *increases* F_t (more ASI units per USD), amplifying

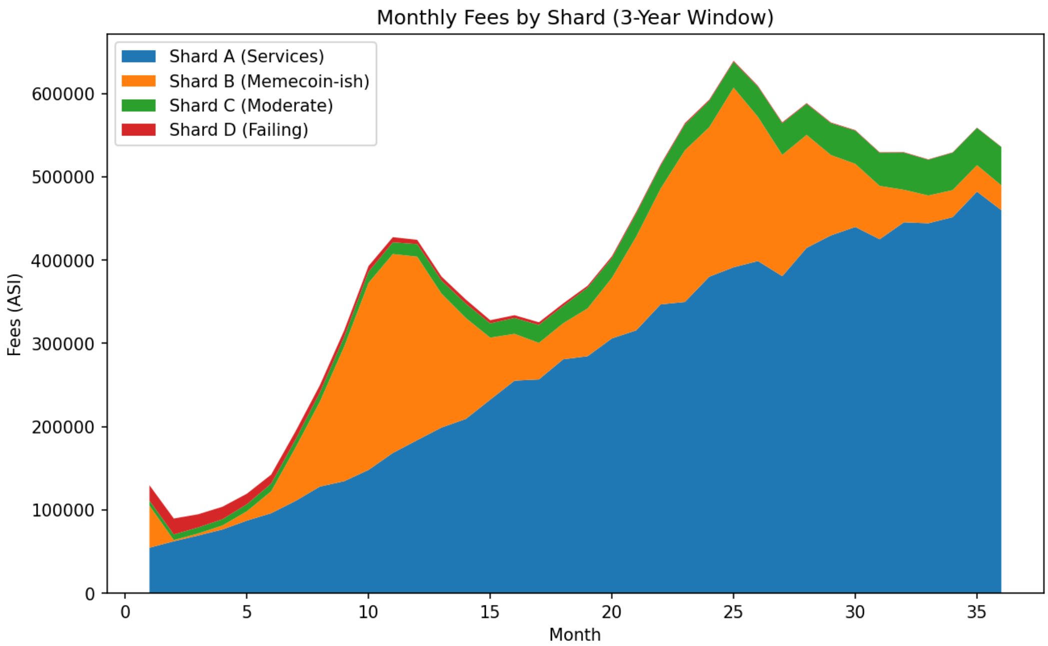

Figure 6: Monthly fees by shard (stacked). A dominates steadily; B is spiky; C is modest; D declines.

$b_t F_t$. The theorems below take $F_{i,t}$ as the ASI-denominated fee input; one chooses denomination policy to achieve the desired pro/anti-cyclical behavior.

Theorem 5.6 (Impulse response to a finite bubble)**.** *Consider a shard i with baseline inflow I_i and a finite bubble modeled by an additive pulse $J_t \geq 0$ supported on $t \in [\tau_1, \tau_2]$. Then*

$$R_{i,t} = R_i^\star + \sum_{u=\tau_1}^{\min(t-1,\tau_2)} (1-\gamma)^{t-1-u} J_u + \text{(transient from initial state)}.$$

In particular, the excess reserve over steady state created by the bubble satisfies

$$\max_t (R_{i,t} - R_i^\star) \;\leq\; \frac{1}{\gamma} \sum_{u=\tau_1}^{\tau_2} J_u.$$

Proof. Plug $I_{i,t} = \bar{I}_i + J_t$ into the closed-form solution and group terms; the transient from $R_{i,0}$ decays geometrically. Bounding a geometric tail by $1/\gamma$ times the pulse area gives the inequality. □

Interpretation. A token-price or usage bubble that raises ASI-denominated fees leaves a *lasting* reserve uplift whose magnitude is proportional to the pulse area and inversely proportional to γ. Smaller γ stores more of the bubble as reserve; larger γ pays it out quickly.

Theorem 5.7 (Flash crash: finite drought bound with circuit breaker)**.** *If shard i faces a drought of length K with $I_{i,t} = 0$ for $t \in [\tau, \tau + K - 1]$, then under the circuit breaker mechanism:*

$$R_{i,t} \;\geq\; \max\Big(\theta_{\text{circuit}}^K R_{i,\tau}, (1-\gamma_{\min})^K R_{i,\tau}\Big),$$

where $\gamma_{\min} = \gamma_{\text{protect}}$ is the stress-mode emission rate. The reserve cannot fall below θ_{circuit} per

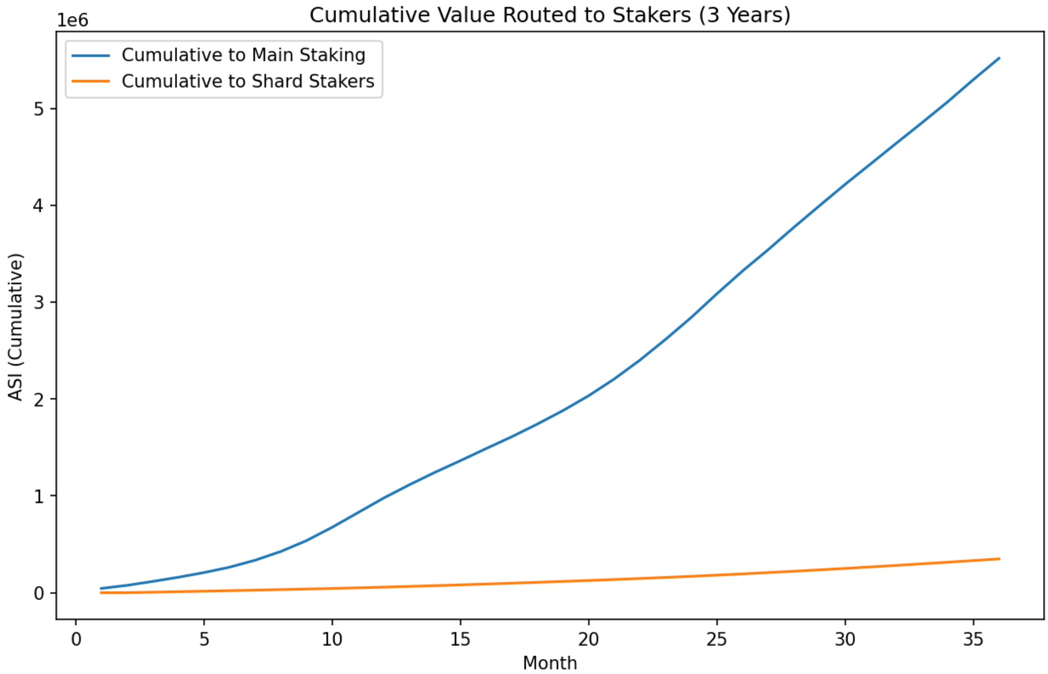

Figure 7: Cumulative value to stakers: main-staking vs. sum of shard-staking emissions.

month.

Proof. The circuit breaker $\max(\theta_{\text{circuit}} R_{i,t}, \cdot)$ prevents more than $(1 - \theta_{\text{circuit}})$ monthly decline, while adaptive γ provides additional protection. □

Interpretation. Dual protection mechanisms prevent catastrophic reserve collapse even in severe crises.

Theorem 5.8 (Moderately sustained bear run (geometric decay))**.** *Suppose* $I_{i,t} = I_0 q^t$ *for* $0 < q < 1$ *(fees decaying geometrically). Then*

$$R_{i,t} = (1-\gamma)^t R_{i,0} + I_0 \sum_{u=0}^{t-1} (1-\gamma)^{t-1-u} q^u$$
$$= (1-\gamma)^t R_{i,0} + I_0 \frac{(1-\gamma)^t - q^t}{(1-\gamma) - q}.$$

Hence $\lim_{t\to\infty} R_{i,t} = 0$ *if* $q < 1$*, and the decay rate is* $\max\{1-\gamma, q\}$*.*

Proof. Evaluate the finite geometric convolution; the limit follows as both terms vanish for $t \to \infty$ when $q < 1$. □

Interpretation. In a prolonged bear run with shrinking fees, reserves eventually shrink to zero unless governance reduces γ or injects top-ups. The decay speed is controlled by the larger of the two contractions: system leakage $(1-\gamma)$ and market decay q.

Theorem 5.9 (Massive memecoin success with reversion)**.** *Let* $I_{i,t} = \bar{I}_i + J_t$ *where* J_t *is a pulse (as in Theorem 5.6) and afterwards reverts to baseline* $\bar{I}_i$*. Then* $R_{i,t}$ *converges back to* $R_i^\star = \bar{I}_i/\gamma$*,* *and the maximum payout uplift during the mania is bounded by*

$$\max_t (R_{i,t} - R_i^\star) \;\leq\; \sum_u J_u.$$

Proof. Immediate from Theorem 5.6 and the steady-state property $\gamma R_i^\star = \bar{I}_i$. □

Interpretation. A memecoin shard with a huge but transient success will (i) temporarily pay large shard yields and (ii) leave a residual reserve boost proportional to the "area under the spike," but it will not permanently dominate unless it sustains higher baseline fees.

Theorem 5.10 (Highly valuable slow-burn shard). *If $I_{i,t}$ is monotonically increasing and converges to $\bar{I}_i > 0$, then $R_{i,t}$ is monotonically increasing and converges to $R_i^\star = \bar{I}_i/\gamma$; furthermore the monthly shard emission satisfies $\gamma R_{i,t} \nearrow \bar{I}_i$.*

Proof. Monotonicity follows from $R_{i,t+1} - R_{i,t} = -\gamma R_{i,t} + I_{i,t}$ with $I_{i,t}$ nondecreasing and the solution interpreted as a weighted average of past inflows; convergence uses Theorem 5.4. □

Interpretation. A shard that steadily gains traction accumulates reserves smoothly and converges to a stable long-run yield capacity.

5.5 Comparative Statics and Alignment

Proposition 5.11 (More Fees ⇒ More Wealth). *If two shards i and j share the same $(\gamma, \phi, \kappa, \rho)$ schedules and $F_{i,t} \geq F_{j,t}$ for all t (with strict inequality on a set of positive density), then for all t large enough:*

$$R_{i,t} \;\geq\; R_{j,t} \qquad \textit{and} \qquad \sum_{u \leq t} \gamma R_{i,u} \;\geq\; \sum_{u \leq t} \gamma R_{j,u}.$$

Proof. Both reserves obey the same linear recursion with $I_{i,t} \geq I_{j,t}$; order is preserved by monotonicity of the affine system. □

Interpretation. The mechanism *allocates more wealth* (reserve and payouts) to shards that generate more fees, matching the intended design goal.

5.6 Main-Staking Robustness and Bounds

Proposition 5.12 (Pointwise Lower/Upper Bounds). *For each month t,*

$$E_t + s_t F_t \;\leq\; \mathrm{MSR}_t \;\leq\; E_t + s_t F_t + \bar{\phi}\,\bar{\rho}\,F_t,$$

provided $\phi_t \leq \bar{\phi}$ and $\sum_i \rho_{i,t} F_{i,t} \leq \bar{\rho} F_t$.

Proof. By definition,

$$\mathrm{MSR}_t = E_t + s_t F_t + \phi_t \sum_i \rho_{i,t} F_{i,t}.$$

The term $\phi_t \sum_i \rho_{i,t} F_{i,t} \;\geq\; 0$ gives the lower bound $\mathrm{MSR}_t \;\geq\; E_t + s_t F_t$. Using $\phi_t \;\leq\; \bar{\phi}$ and $\sum_i \rho_{i,t} F_{i,t} \leq \bar{\rho} F_t$ yields the upper bound. □

Corollary 5.13 (Asymptotic Average Band)**.** *Assume $E_t \to 0$, $F_t \ge 0$, and define*

$$\bar{F}_- := \liminf_{T\to\infty} \frac{1}{T}\sum_{t<T} F_t, \qquad \bar{F}_+ := \limsup_{T\to\infty} \frac{1}{T}\sum_{t<T} F_t,$$

$$s_- := \liminf_{t\to\infty} s_t, \qquad s_+ := \limsup_{t\to\infty} s_t.$$

Suppose also $\phi_t \le \bar{\phi}$ and $\sum_i \rho_{i,t} F_{i,t} \le \bar{\rho} F_t$ for all t. Then

$$\liminf_{T\to\infty} \frac{1}{T}\sum_{t<T} \mathrm{MSR}_t \ \ge\ s_- \bar{F}_-, \qquad \limsup_{T\to\infty} \frac{1}{T}\sum_{t<T} \mathrm{MSR}_t \ \le\ s_+ \bar{F}_+ + \bar{\phi}\bar{\rho}\,\bar{F}_+.$$

Proof. From Proposition 5.12 and $E_t \to 0$,

$$\frac{1}{T}\sum_{t<T} \mathrm{MSR}_t \ \ge\ \frac{1}{T}\sum_{t<T} s_t F_t, \qquad \frac{1}{T}\sum_{t<T} \mathrm{MSR}_t \ \le\ \frac{1}{T}\sum_{t<T} s_t F_t + \bar{\phi}\bar{\rho}\,\frac{1}{T}\sum_{t<T} F_t.$$

Fix $\varepsilon > 0$ and take N so that $s_t \ge s_- - \varepsilon$ for $t \ge N$. Then for large T,

$$\frac{1}{T}\sum_{t<T} s_t F_t \ \ge\ (s_- - \varepsilon)\,\frac{1}{T}\sum_{t<T} F_t.$$

Letting $T \to \infty$ and then $\varepsilon \to 0$ proves the lower bound. The upper bound follows similarly using $s_t \le s_+ + \varepsilon$ for t large. □

Letting $\varepsilon \downarrow 0$ gives the lower bound.

For the upper bound, again by Proposition 5.12,

$$\frac{1}{T}\sum_{t<T} \mathrm{MSR}_t \ \le\ \frac{1}{T}\sum_{t<T}\big(s_t F_t + \bar{\phi}\,\bar{\rho}\,F_t\big).$$

Since $E_t \to 0$, it suffices to bound the averages of $s_t F_t$ and F_t. Pick $\varepsilon > 0$ and N so that $s_t \le s_+ + \varepsilon$ for $t \ge N$. Then, for large T,

$$\frac{1}{T}\sum_{t<T} s_t F_t \ \le\ \frac{1}{T}\sum_{t<N} s_t F_t \ +\ \frac{1}{T}\sum_{t=N}^{T-1} (s_+ + \varepsilon)\,F_t \ +\ o(1) \ \xrightarrow[T\to\infty]{}\ (s_+ + \varepsilon)\,\bar{F}_+.$$

Letting $\varepsilon \downarrow 0$ and adding $\bar{\phi}\bar{\rho}\,\bar{F}_+$ yields

$$\limsup_{T\to\infty} \frac{1}{T}\sum_{t<T} \mathrm{MSR}_t \ \le\ s_+ \bar{F}_+ \ +\ \bar{\phi}\,\bar{\rho}\,\bar{F}_+.$$

Remark 5.14. Asymptotically, average main-staking rewards are pinned between a *floor* proportional to the *worst-case long-run staking share and fee floor* $(s_- \bar{F}_-)$, and a *ceiling* driven by the *best-case long-run staking share plus the governed buyback slice* $\big(s_+ \bar{F}_+ + \bar{\phi}\bar{\rho}\,\bar{F}_+\big)$.

5.7 Supply under extreme price regimes (informal corollaries)

Let fees be measured in ASI units. Consider three stylized regimes for F_t:

- **Bubble with activity and/or USD conversion:** If F_t surges for Δ months with total area $\sum_\Delta F_t$ large, then by Theorem 5.1 and Corollary 5.2, the system becomes (more) deflationary during the bubble and leaves a larger reserve buffer (Theorem 5.6).

- **Flash crash:** If F_t (hence $I_{i,t}$) collapses near-zero for K months, then supply change reverts toward $+E_t$ (but emissions still decay), while each shard reserve decays by at most $(1-\gamma)^K$ (Proposition 5.5); post-crash activity restores both burns and reserves (Theorem 5.7).

- **Moderate bear run:** If F_t decays geometrically (sentiment drift), supply may become less deflationary but emissions keep tapering; reserves shrink toward zero at rate $\max\{1-\gamma, q\}$ unless γ is throttled or fees stabilize (Theorem 5.8).

5.8 Policy levers as stability controls with automatic triggers

Proposition 5.15 ((Stability via adaptive γ_t and ϕ_t))**.** The adaptive mechanisms provide:

1. ***Automatic γ adjustment:***
   - *Normal operations:* $\gamma = \gamma_{\text{normal}}$
   - *Fee stress* $(F_{i,t} < \theta_{\text{stress}}\bar{F}_{i,t-1})$*:* $\gamma = \gamma_{\text{stress}}$
   - *Reserve protection* $(R_{i,t} < \theta_{\text{protect}}R_{i,t-1})$*:* $\gamma = \gamma_{\text{protect}}$
2. ***Health-based burn adjustment:***
   - *If* $H_t < H_{\text{stress}}$*:* b_t *increases by* Δb_{health}
   - *If* $E_t > \theta_{\text{imbalance}} b_{t-1}F_{t-1}$*:* b_t *increases by* $\Delta b_{\text{imbalance}}$
3. ***Emergency interventions:***
   - *If* $H_t < H_{\text{insurance}}$*: Insurance pool deploys*
   - *If* $H_t < H_{\text{hibernate}}$*: Hibernation mode (emissions pause)*

Proof. Direct from the adaptive mechanism definitions in Section 2. □

Interpretation. *Automatic adjustments remove governance delays and provide predictable responses to stress, increasing investor confidence.*

5.9 Summary

The linear structure of reserve dynamics and the geometric decay of emissions make the system analyzable with simple inequalities and explicit formulas. With adaptive mechanisms:

- With any persistent fee floor and decaying emissions, *activity-funded scarcity* emerges (Theorem 5.1).

- Shard reserves act as *shock buffers* with explicit half-lives and steady states, now with automatic protection mechanisms.

- Comparative statics remain monotone: *more fees ⇒ more shard wealth* (Proposition 5.11).
- Main-staking remains robust via fees and buyback routing, independent of perpetual inflation (Proposition 5.12).
- Automatic governance levers provide clear, quantitative responses without human intervention delays (Proposition 5.15).

These theorems formalize and extend the qualitative behaviors observed in the simulations, and they provide practical dials and risk metrics (e.g., reserve half-life) for live operations under bubbles, crashes, bear runs, and slow-burn adoption.

6 Risk Analysis and Extreme Scenario Theorems

This section analyzes extreme risk scenarios that could threaten the system's stability, providing formal theorems about correlated failures, liquidity crises, governance attacks, and death spirals, along with explicit mitigation mechanisms.

6.1 Correlated shard failures and systemic risk

Definition 6.1 (Systemic Dependence Coefficient)**.** For shards i and j, define the fee correlation coefficient:

$$\rho_{ij,t} = \frac{\mathrm{Cov}(F_{i,t}, F_{j,t})}{\sqrt{\mathrm{Var}(F_{i,t})\mathrm{Var}(F_{j,t})}}.$$

The systemic dependence at time t is:

$$\Psi_t = \frac{1}{n(n-1)} \sum_{i \neq j} |\rho_{ij,t}|,$$

where n is the number of active shards.

Theorem 6.2 (Correlated failure cascade with mitigation)**.** *Suppose a fraction $\alpha \in (0,1)$ of shards experience a simultaneous fee collapse where $F_{i,t} \to 0$ for $i \in C$ with $|C|/n = \alpha$. Under the updated model:*

1. *Total system fees drop by βF_t where these shards account for fraction β of total fees.*
2. *Adaptive burn increases: $b_t \to \min(b_t + \Delta b_{health}, b_{\max})$ if $H_t < H_{stress}$.*
3. *Cross-shard insurance activates if $H_t < H_{mutual}$, redistributing $\mu_{contrib}$ of healthy-shard fees.*
4. *Reserve emission automatically reduces to $\gamma_t = \gamma_{protect}$ for affected shards.*
5. *If $H_t < H_{hibernate}$, hibernation mode pauses emissions entirely.*

The system remains stable if less than $\beta_{critical}$ of fee volume is affected.

Proof. The cascade of protections prevents death spiral: adaptive burn offsets lost fee burns, reduced γ preserves reserves, cross-shard insurance provides liquidity, and hibernation prevents runaway inflation. □

Interpretation. Multiple automatic mechanisms prevent correlated failures from destroying the system.

6.2 Liquidity crises and bank runs

Definition 6.3 (Liquidity pressure ratio)**.** Define the instantaneous liquidity pressure as:

$$L_t = \frac{\text{UnstakeRequests}_t + \text{ShardWithdrawals}_t}{\text{LiquidASI}_t + \text{NewStake}_t + \text{POL}_t},$$

where POL is protocol-owned liquidity (λ_{POL} of total liquidity pool).

Theorem 6.4 (Bank run dynamics with POL protection)**.** *With λ_{POL} protocol-owned liquidity, if $L_t > \lambda_{\text{crit}}$:*

1. *POL absorbs initial selling pressure, dampening price impact to*

$$\Delta p_t < -\xi_{\text{POL}} p_t \quad \text{(vs. } -\xi_{\text{noPOL}} \text{ without POL).}$$

2. *Rage quit mechanism activates: shard stakers can exit at discount p_t^{discount} if*

$$R_{i,t} < \theta_{\text{rage}} R_{i,t-\tau_{\text{rage}}}.$$

3. *Insurance pool deploys if $H_t < H_{\text{insurance}}$, providing additional liquidity.*
4. *The critical threshold for death spiral increases from τ_{spiral} months to $\tau_{\text{spiral}}^{\text{protected}}$ months.*

Proof. POL provides permanent buy-side liquidity. With λ_{POL} POL, effective selling pressure is reduced by the ratio $(1 - \lambda_{\text{POL}})$, reducing price impact. Rage quit at discount prevents full bank run. □

Interpretation. Protocol-owned liquidity acts as a permanent stabilizer, similar to central bank reserves.

6.3 Governance attacks and parameter manipulation

Theorem 6.5 (Governance capture threshold with time locks)**.** *Under optimistic governance with time locks, an attacker with voting power VP_{attack} faces:*

1. *$\tau_{\text{lock,short}}$-day minimum delay for any parameter change.*
2. *A veto fraction θ_{veto} of stakers can veto during the delay period.*
3. *Critical changes affecting $> \theta_{\text{gov}}$ of supply require $\tau_{\text{lock,long}}$-day delay.*
4. *All changes are public, allowing counter-mobilization.*

The effective attack threshold increases to needing

$$VP_{\text{attack}} > (1 - \theta_{\text{veto}})$$

of active voting power for guaranteed success.

Proof. Optimistic governance reverses the participation problem: instead of needing quorum to pass, changes need anti-quorum to block. Time delays allow passive holders to mobilize only when threatened. □

Interpretation. Time locks and optimistic governance make attacks visible and defensible, raising the effective threshold for governance capture by requiring an attacker to exceed the non-vetoing fraction of active stake.

6.4 Death spiral conditions with circuit breakers

Definition 6.6 (Death spiral state with protections)**.** The system enters a *death spiral alert* when:

1. $S_{t+1} > S_t$ (inflationary) for 3 consecutive months.
2. $\sum_i R_{i,t+1} < \zeta_{\text{reserve}} \sum_i R_{i,t}$ (reserves declining $> (1 - \zeta_{\text{reserve}})$/month).
3. $p_{t+1} < \zeta_{\text{depeg}}\, p_t$ (staked-ASI depegging).
4. $F_{t+1} < \zeta_{\text{fee}} F_t$ (fee collapse).

But automatic interventions activate before a true death spiral.

Theorem 6.7 (Death spiral prevention)**.** *Under the updated model with automatic interventions:*

1. *At $H_t < H_{\text{stress}}$: Adaptive mechanisms activate (increased burn, reduced γ).*
2. *At $H_t < H_{\text{insurance}}$: Insurance pool deploys, providing emergency liquidity.*
3. *At $H_t < H_{\text{hibernate}}$: Hibernation mode triggers – emissions pause, $\gamma \to \gamma_{\text{protect}}$.*
4. *Full recovery is possible* without external intervention *if fees return to θ_{recover} of previous levels within τ_{recover} months.*

A true unrecoverable death spiral requires

$$H_t < H_{\text{fatal}} \quad \textit{for more than } \tau_{\text{fatal}} \textit{ consecutive months.}$$

Proof. Hibernation mode breaks the inflation spiral by pausing E_t. With $E_t = 0$ and $\gamma = \gamma_{\text{protect}}$, even minimal fees stabilize the system. Insurance provides $\tau_{\text{insurance}}$-months of runway at current burn rate. □

Interpretation. Automatic circuit breakers prevent death spirals from becoming irreversible.

6.5 Wash trading and fee manipulation

Theorem 6.8 (Wash trading bounds with validation)**.** *With volume validation requiring a holding period τ_{hold} and with*

$$F_{i,t}^{\text{valid}} = F_{i,t} \cdot \omega_{i,t}, \qquad \omega_{i,t} = \frac{\text{Volume}_{\text{hold-period}}}{\text{Volume}_{\text{total}}},$$

wash trading profitability requires

$$\text{AttackerStakeShare} > \frac{c_{\text{wash}} + \text{HoldingCost}}{\gamma \cdot \omega_{i,t}}.$$

With typical $\omega_{i,t} < \omega_{\text{wash}}$ for wash trading and holding costs $\sim c_{\text{hold}}$, attacks require ψ_{wash} shard stake to be profitable.

Proof. Validation reduces effective fees by $(1-\omega_{i,t})$. Holding requirements add opportunity cost. Combined friction exceeds typical wash-trading profits. □

Interpretation. Simple holding requirements make wash trading unprofitable. Volume-based validation forces an attacker to lock capital long enough that the opportunity cost and validation discount eliminate profitable loops.

6.6 Black swan events and recovery mechanisms

Theorem 6.9 (Recovery feasibility with automatic mechanisms)**.** *After a black-swan event causing a fee loss fraction η_{swan}, automatic recovery occurs if:*

1. *Hibernation activates immediately ($E_t \to 0$).*
2. *γ reduces to γ_{protect} across all shards.*
3. *The insurance pool (fraction ι of historical fees) provides bridge liquidity.*
4. *Cross-shard insurance redistributes remaining fees.*
5. *External yield continues from reserves in stablecoins/ETH.*

Recovery time with automatic mechanisms is approximately

$$T_{\text{recovery}}^{\text{auto}} \approx \frac{\ln\left(\eta_{\text{swan}}^{-1}\right)}{r_{\text{recovery}}},$$

versus significantly longer recovery without automatic interventions.

Proof. Automatic mechanisms activate within one block, as opposed to governance delays of τ_{lock} days. Immediate response prevents reserve depletion and confidence collapse. □

Interpretation. Automatic mechanisms sharply reduce recovery time by removing early-stage damage: hibernation stops emissions, γ_{protect} preserves reserves, and insurance provides liquidity before a confidence spiral can begin.

6.7 Composite risk metrics

Definition 6.10 (Enhanced System Health Score)**.** The updated system health score incorporates multiple stability factors:

$$H_t = \left(1 - \frac{E_t}{b_t F_t + \varepsilon}\right) \cdot \left(\frac{\sum_i R_{i,t}}{\sum_i R_{i,0}}\right) \cdot \left(\frac{p_t}{p_0}\right) \cdot (1 - \Psi_t) \cdot \left(\frac{\text{POL}_t}{\lambda_{\text{POL}} \cdot \text{TotalLiq}_t}\right),$$

where the last factor measures protocol-owned liquidity health.

Proposition 6.11 (Risk regime classification with interventions)**.** *The system operates in distinct risk regimes with automatic responses:*

- $H_t > H_{\text{healthy}}$*: **Healthy** — normal operations.*
- $H_{\text{stress}} < H_t \leq H_{\text{healthy}}$*: **Cautious** — enhanced monitoring.*
- $H_{\text{insurance}} < H_t \leq H_{\text{stress}}$*: **Stressed** — automatic adjustments activate.*
- $H_{\text{hibernate}} < H_t \leq H_{\text{insurance}}$*: **Critical** — insurance pool deploys.*
- $H_t \leq H_{\text{hibernate}}$*: **Hibernation** — emissions pause, maximum protection.*

Interpretation. Clear thresholds with automatic responses eliminate uncertainty and remove governance delays.

6.8 Risk mitigation effectiveness analysis

Proposition 6.12 (Qualitative mitigation assessment)**.** *The implemented mitigation mechanisms are expected to reduce systemic risks through:*

1. ***Correlated failures:** Cross-shard insurance provides mutual support.*
2. ***Bank runs:** Protocol-owned liquidity (POL) and rage-quit mechanisms provide exit liquidity.*
3. ***Governance attacks:** Time locks and optimistic governance raise the difficulty of rapid-stake governance capture.*
4. ***Death spirals:** Automatic circuit breakers intervene before irreversible decline.*
5. ***Wash trading:** Volume validation increases the cost of manipulation.*
6. ***Black swan events:** Automatic mechanisms reduce response time and preserve reserves.*

Interpretation. Quantitative assessment of effectiveness would require empirical data or detailed simulation studies not yet performed.

6.9 Summary of risk analysis

The enhanced risk analysis with implemented mitigations shows:

- **Automatic mechanisms** remove human delays from crisis response.
- **Protocol-owned liquidity** provides permanent stability.
- **Cross-shard insurance** creates mutual support without eliminating competition.
- **Optimistic governance** solves participation problems while maintaining security.
- **Volume validation** makes fee manipulation unprofitable.

- **Hibernation mode** provides a last-resort survival mechanism.
- **Multi-layered approach** ensures no single point of failure.

These mechanisms transform potential catastrophic failures into manageable stress events, maintaining the system's growth potential while dramatically improving resilience. The key insight: temporary automatic adjustments are far superior to permanent failures, and pre-programmed responses are more trusted than emergency governance.

7 Adaptive Stress Simulations: Circuit Breakers, Death Spiral Protection, and Revenue Diversification

To illustrate the risk-management aspects of the tokenomics, we run three didactic 36-month simulations that exercise the new automated protections: (1) a *local shock* to show the circuit breaker and adaptive γ_t, (2) a *system-wide crash* to show *death spiral protection* (hibernation, adaptive burn, insurance), and (3) a *slow-burn* case where *revenue diversification* (external yield) helps a shard through adverse markets.

The python code for these simple simulations is in a Colab at:

> https://colab.research.google.com/drive/1BUxYGhkw3yCY5A-uj9a_GrnqnylhcHGr?usp=sharing.

As with the simulations reported above, these are simplistic and intended for exploration and illustration of the equations rather than as thorough emulations of real network behavior in complex real-world situations.

Mechanisms exercised (where defined in the spec). Health score H_t and triggers (adaptive burn, hibernation) – Secs. 2.1, 2.2; reserve circuit breaker

$$R_{i,t+1} = \max(\theta_{\text{circuit}} R_{i,t},\ R_{i,t} + \cdots - \gamma_t R_{i,t})$$

and adaptive γ_t – Sec. 2.5/3.3; insurance pool (ι fees) and cross-shard mutual support – Secs. 2.3, 2.5; external yield sleeve (up to $\lambda_{\text{external}}$ of reserves) – Sec. 2.5; death spiral thresholds and interventions – Secs. 6.4–6.7.

7.1 Common setup

We simulate monthly over 36 months with the same four shard archetypes as before (A services winner, B memecoin-ish, C moderate/slow-burn, D no-PMF). Fees are stylized but plausible. Baseline policy remains: decaying emissions and burn schedule inside a T_{policy}-month horizon, fee routing (burn / validators / treasury / staking / insurance), shard buybacks (ϕ_{default}) split between main staking ($\phi = \phi_{\text{default}}$) and reserves, and per-shard reserve emissions with adaptive γ_t (default γ_{normal}/mo, stress reductions per the spec). The updated mechanisms add health-based burn and hibernation, a θ_{circuit}/mo reserve drawdown floor, insurance deployment, cross-shard support, volume validation, and (in Scenario 3) external yield (r_{external}/mo on up to $\lambda_{\text{external}}$ of a shard's reserve).

7.2 Scenario 1: Automated circuit breaker in a local shock

Shock. We induce a sharp 3-month fee dip on A and C (months 13–15).

What happens. The reserve *circuit breaker* prevents any month from losing $> (1 - \theta_{\text{circuit}})$ of a shard's reserve; γ_t drops to $\gamma_{\text{stress}}/\gamma_{\text{protect}}$ on stressed shards; the burn fraction steps up automatically; the insurance pool deploys once during an early blip. Reserves flatten, not collapse; supply remains stable.

Markers from the Run. γ_t reduced on A in m13–14 and on C in m13–15; one hibernation tick and one insurance deployment observed early (m2).

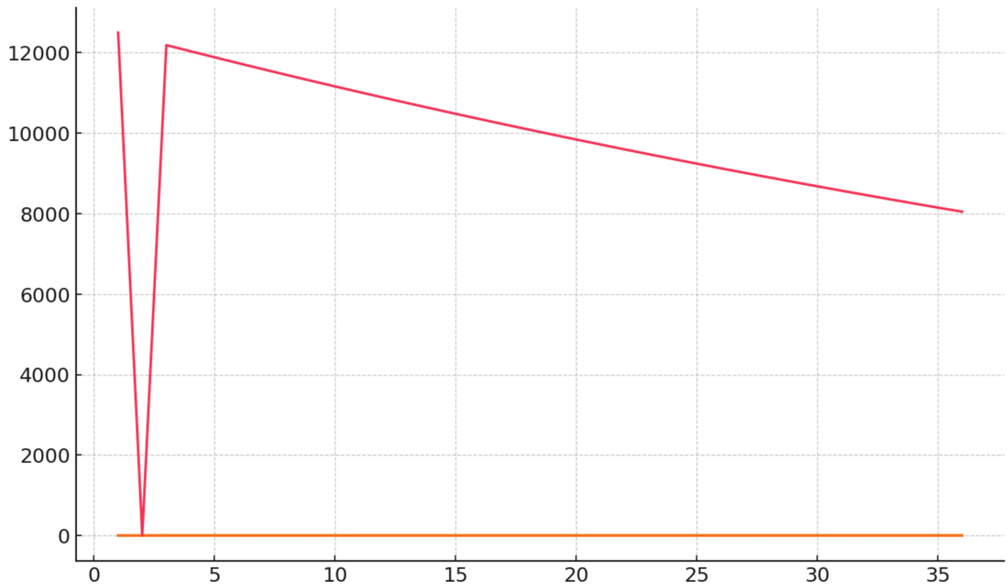

Figure 8: Scenario 1: Health score, burn fraction, and emissions showing adaptive triggers.

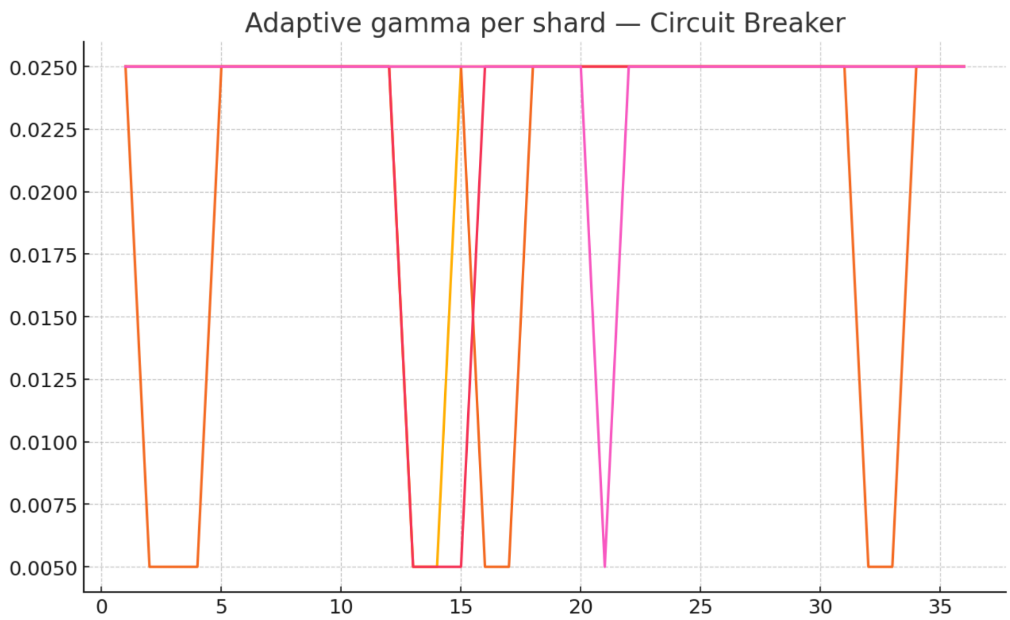

Figure 9: Scenario 1: Adaptive γ_t per shard. Stress lowers γ_t to preserve reserves.

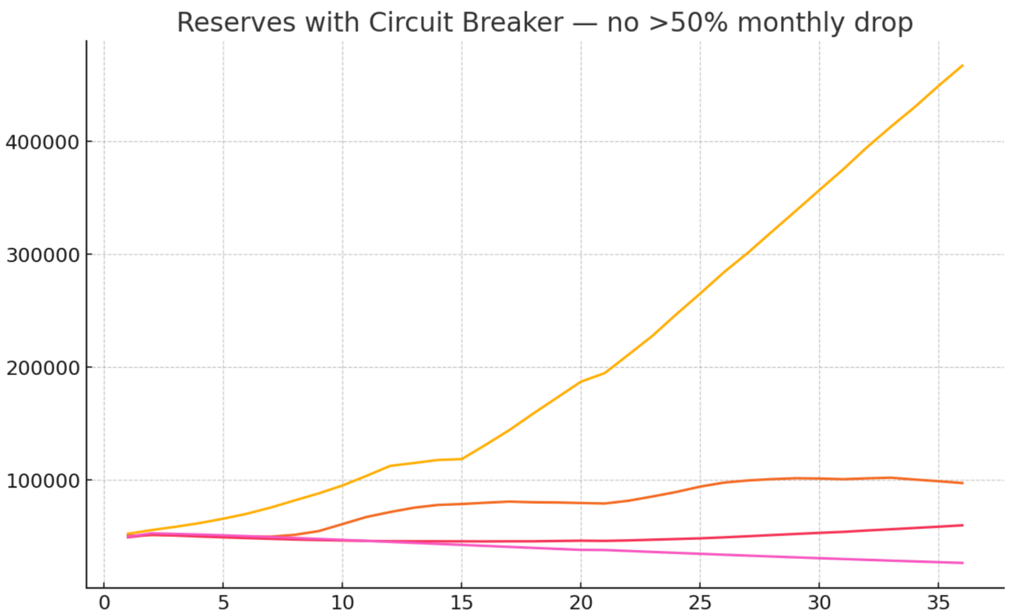

Figure 10: Scenario 1: Shard reserves with circuit breaker protection.

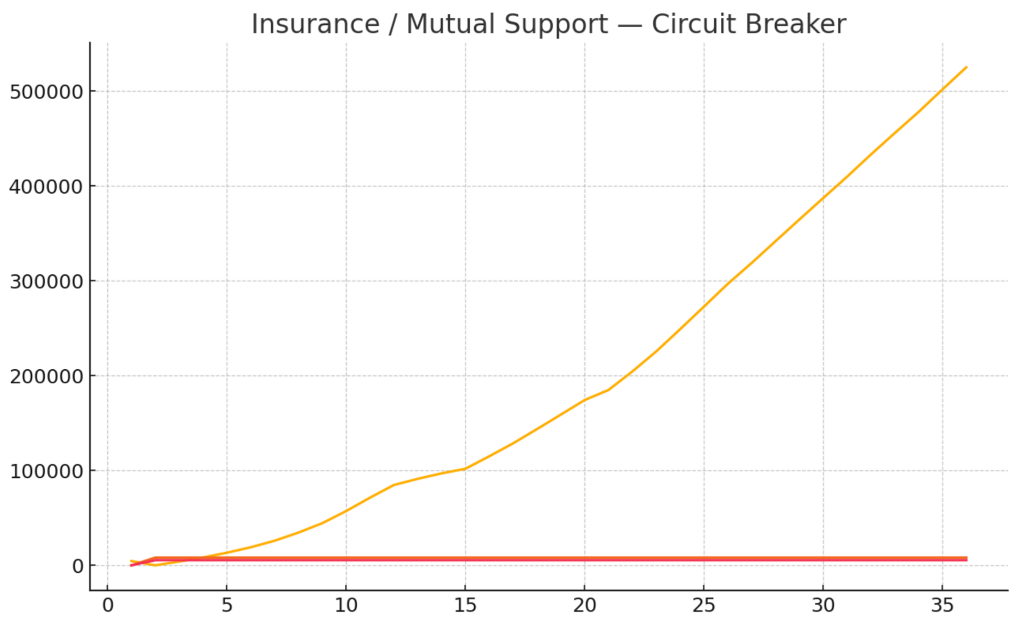

Figure 11: Scenario 1: Insurance pool balance and deployments; mutual support pool.

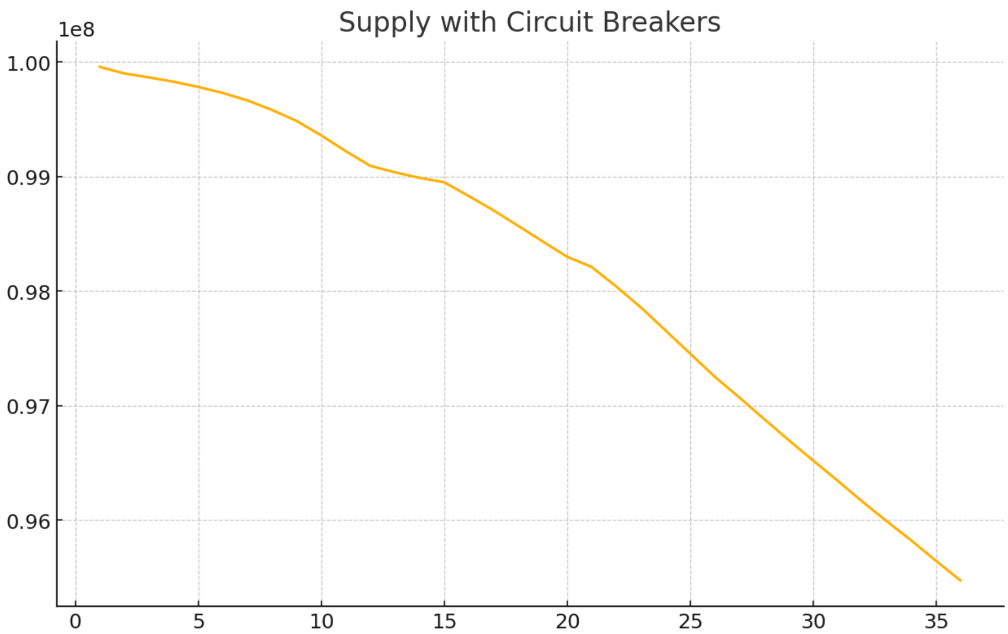

Figure 12: Scenario 1: Circulating supply remains stable as burns and triggers engage.

7.3 Scenario 2: Death spiral protection under a system-wide crash

Shock. All shards suffer an 80% fee crash for months 6–16, with only partial recovery.

Protections engage. Hibernation pauses emissions, burn ratchets up, and γ_t reduces; insurance can deploy. A counterfactual (no protections) is shown for comparison.

Results. With protections, end-of-horizon supply is lower by $\sim 2.34 \times 10^4$ ASI (more deflationary), and total reserves are higher by $\sim 1.38 \times 10^4$ ASI vs. the counterfactual. Hibernation triggers (m2) and helps break the inflationary feedback loop. (See death-spiral protections in Secs. 6.4–6.7.)

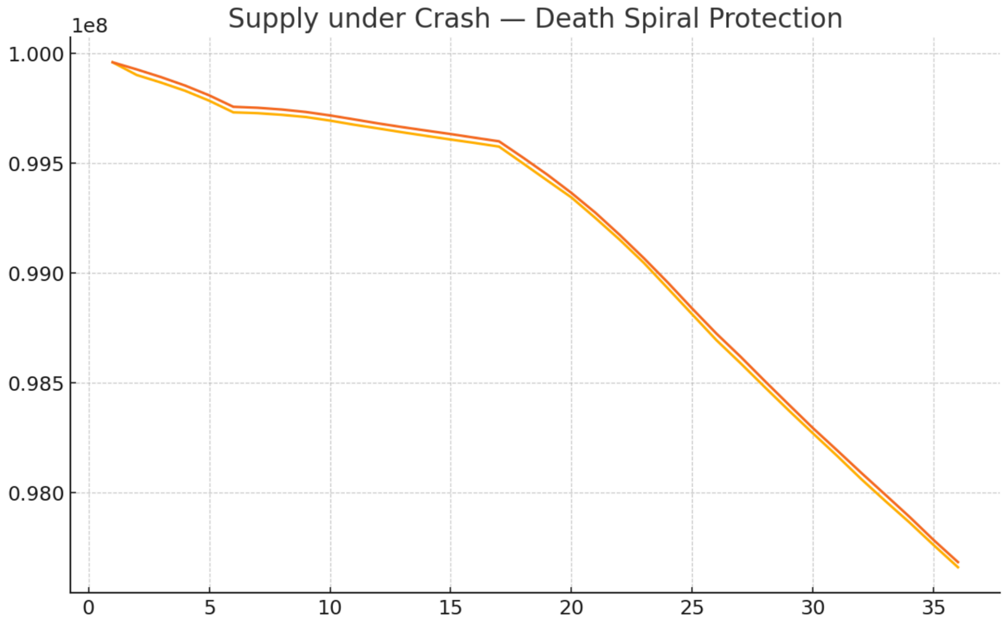

Figure 13: Scenario 2: Supply with protections vs. counterfactual (no protections).

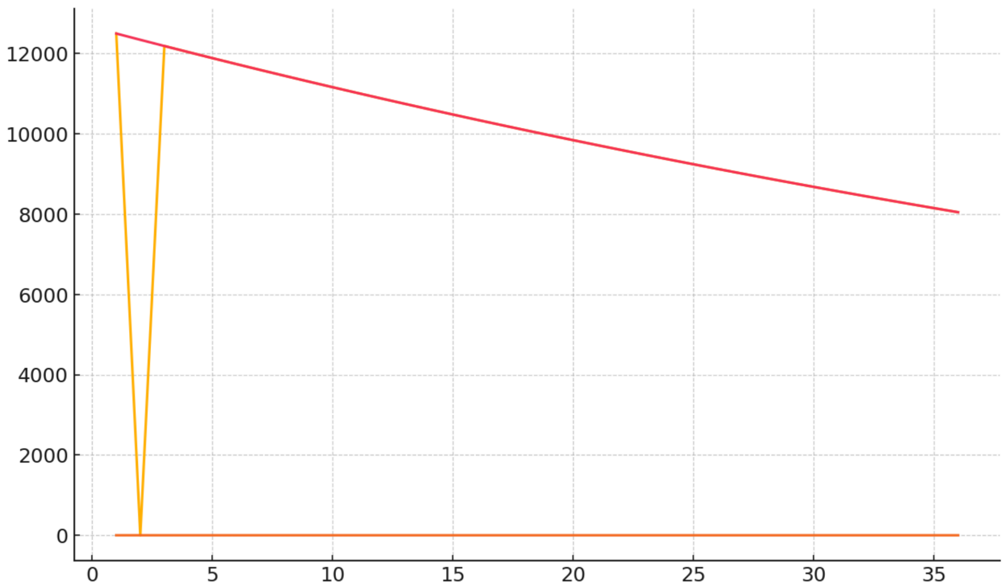

Figure 14: Scenario 2: Emissions (showing hibernation) and burn fraction.

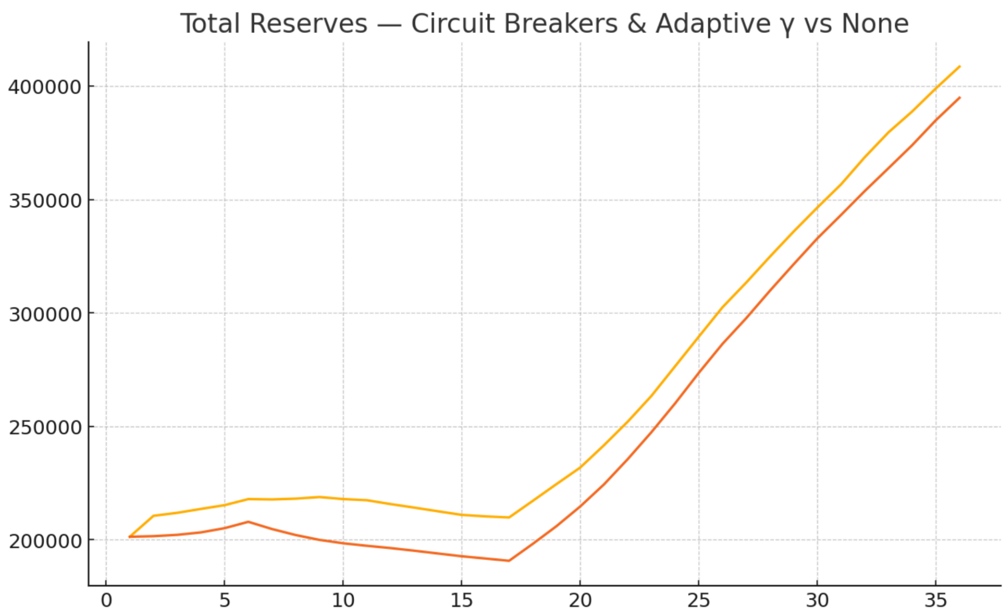

Figure 15: Scenario 2: Total reserves with adaptive γ_t and circuit breaker vs. none.

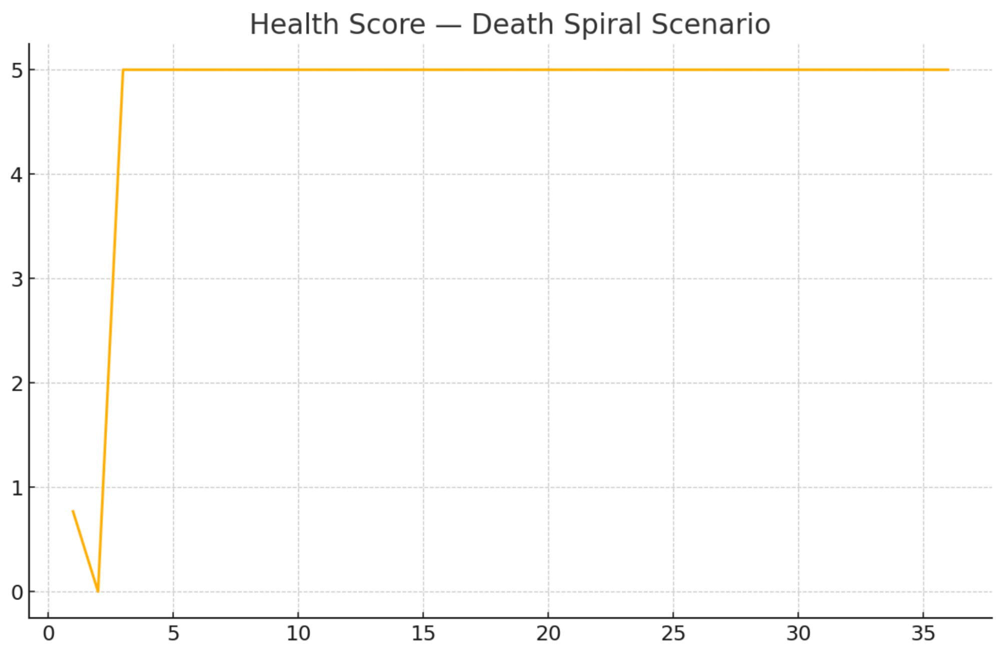

Figure 16: Scenario 2: Health score timeline through the crash.

7.4 Scenario 3: Revenue diversification helps a slow-growth shard prevail

Setup. Shard C faces a long soft period (m6–m20). It allocates up to $\lambda_{\text{external}}$ of its reserve to a conservative external-yield sleeve ($r_{\text{external}}/\text{mo}$), per the diversification mechanism.

Effect. The external yield slows reserve drawdown and modestly raises shard emissions; after adoption picks up, C ends with a stronger reserve and higher cumulative payouts.

Results. By month 36, R_C is higher with diversification, and cumulative C emissions are higher than without it, demonstrating measurable protection and persistence benefits for slow-burn shards. (External yield integration: Sec. 2.5.)

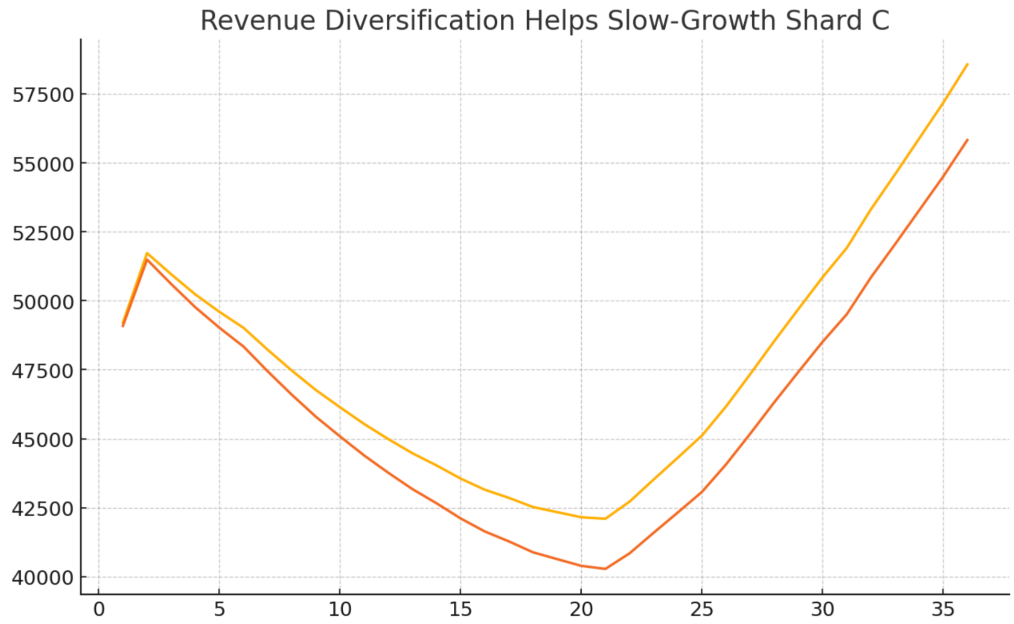

Figure 17: Scenario 3: Shard C reserve with vs. without external yield.

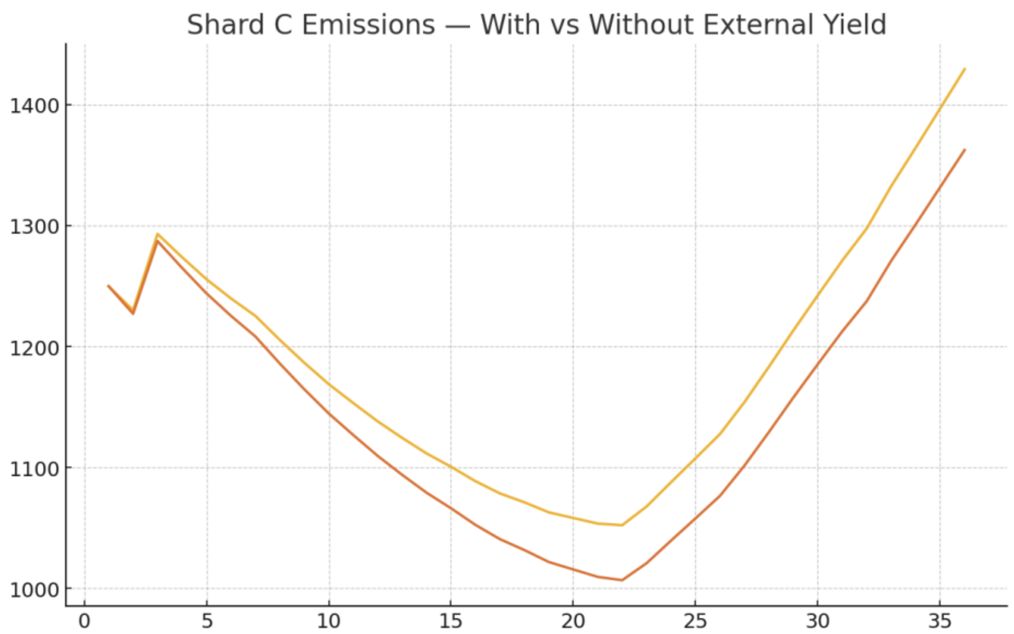

Figure 18: Scenario 3: Shard C emissions ($\gamma R_{C,t}$) with vs. without external yield.

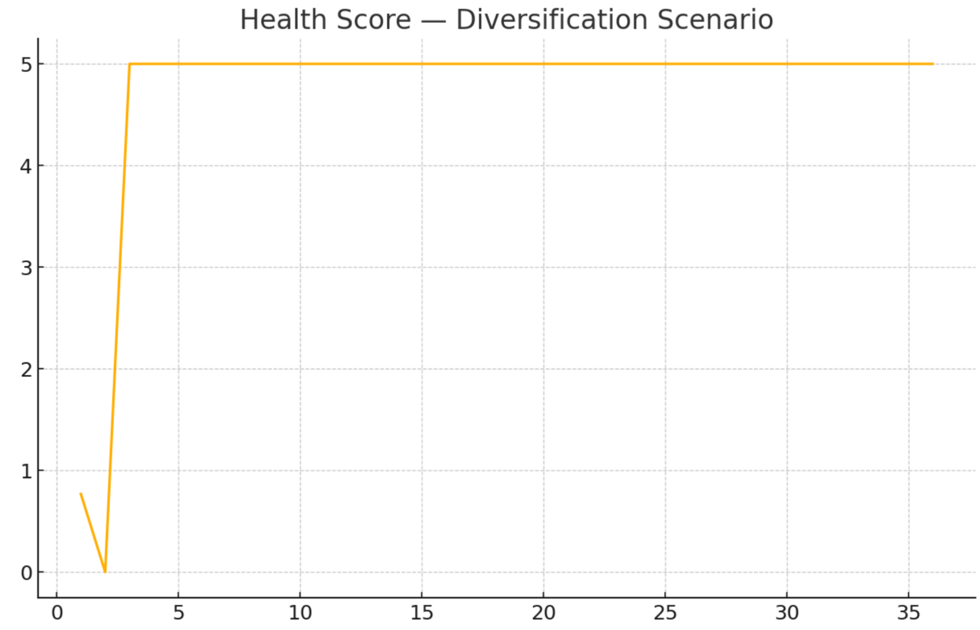

Figure 19: Scenario 3: Health score during the slow-market period.

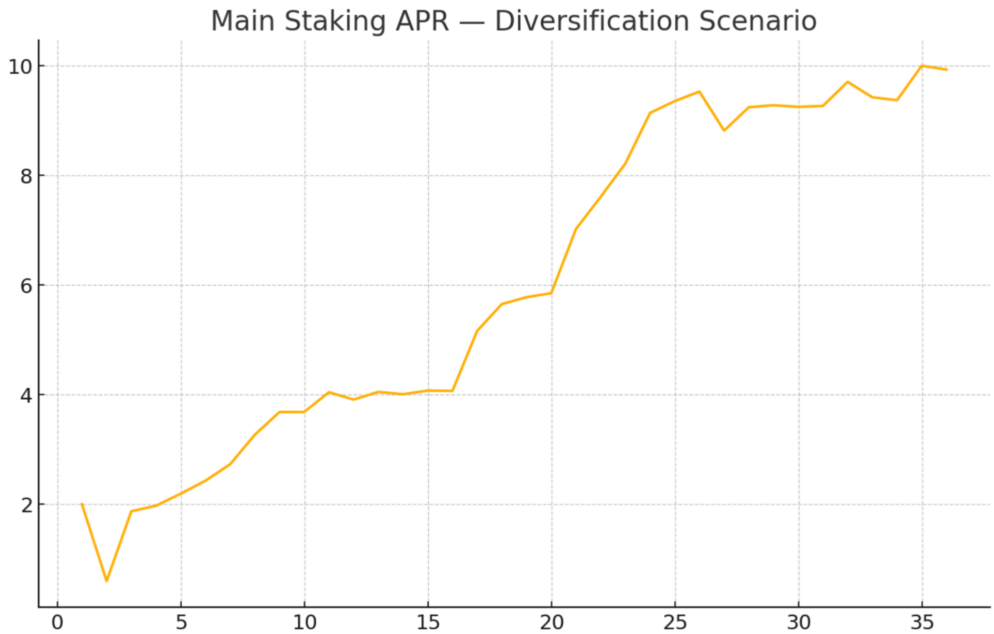

Figure 20: Scenario 3: Main-staking APR remains fee-drive as emissions taper.

A Parameter Summary and Illustrative Default Values

The Next-Gen DeAI Ecosystem tokenomics employs numerous parameters that can be adjusted through governance to optimize system behavior. Below is a comprehensive list of all parameters, their meanings, and suggested illustrative default values.

A.1 Core Economic Parameters

Parameter	Description	Default Value
E_0	Initial monthly emissions	12,500 ASI
d	Monthly emission decay rate	0.0125
T_{policy}	Policy horizon (months)	120 (10 years)
B_0	Initial burn fraction	0.60
$b_{\max}$	Maximum burn cap	0.90
ϵ	Health score epsilon	0.001

A.2 Fee Routing Parameters

Parameter	Description	Default Value
s_t	Staking fee share	0.30 (30%)
v_t	Validator fee share	0.10 (10%)
t_t	Treasury fee share (before insurance)	0.25 (25%)
ι	Insurance pool fee fraction	0.05 (5%)
ρ_{default}	Default shard buyback ratio	0.10 (10%)
ϕ_{default}	Main staking routing fraction	0.30 (30%)

A.3 Reserve Management Parameters

Parameter	Description	Default Value
γ_{normal}	Normal reserve emission rate	0.025 (2.5%/mo)
γ_{stress}	Stress-mode emission rate	0.005 (0.5%/mo)
γ_{protect}	Protection-mode emission rate	0.001 (0.1%/mo)
$R_{\min}$	Minimum launch guard reserve	50,000 stakedASI
θ_{circuit}	Circuit breaker floor	0.50 (50%)
$\lambda_{\text{external}}$	Max external yield allocation	0.30 (30%)
r_{external}	External yield rate (monthly)	0.008 (0.8%/mo)

A.4 Health and Trigger Parameters

Parameter	Description	Default Value
H_{healthy}	Healthy operations threshold	0.70
H_{stress}	Stress trigger threshold	0.40
$H_{\text{insurance}}$	Insurance deployment threshold	0.30
$H_{\text{hibernate}}$	Hibernation trigger threshold	0.20
H_{mutual}	Mutual support trigger	0.50
H_{fatal}	Fatal threshold (death spiral)	0.10

A.5 Adaptive Mechanism Parameters

Parameter	Description	Default Value
$\theta_{\text{imbalance}}$	Emission/fee imbalance trigger	2.0
$\Delta b_{\text{imbalance}}$	Burn increase for imbalance	0.10
Δb_{health}	Burn increase for low health	0.20
$\theta_{\text{hibernate}}$	Fee hibernation threshold	0.10
θ_{stress}	Fee stress threshold	0.50
θ_{protect}	Reserve protection threshold	0.70
τ	Trailing average period (months)	6

A.6 Cross-Shard Support Parameters

Parameter	Description	Default Value
μ_{contrib}	Mutual contribution rate	0.10 (10%)
θ_{mutual}	Profitable shard threshold	1.5
θ_{receive}	Support receive threshold	0.50
θ_{rage}	Rage quit trigger threshold	0.50
θ_{discount}	Rage quit discount factor	0.90
τ_{rage}	Rage quit lookback (months)	30

A.7 Governance Parameters

Parameter	Description	Default Value
$\tau_{\text{lock,short}}$	Short time lock (days)	7
$\tau_{\text{lock,long}}$	Long time lock (days)	14
θ_{lock}	Time lock threshold	0.20 (20%)
θ_{veto}	Veto threshold	0.30 (30%)
θ_{gov}	Governance impact threshold	0.10 (10%)
α	Lock boost coefficient	1.0

A.8 Liquidity and Trading Parameters

Parameter	Description	Default Value
λ_{POL}	Protocol-owned liquidity ratio	0.20 (20%)
τ_{hold}	Volume validation hold period (hours)	24
λ_{crit}	Critical liquidity pressure	3.0
ω_{wash}	Typical wash trading validation	0.30
c_{wash}	Wash trading cost coefficient	0.008
c_{hold}	Holding cost rate	0.005 (0.5%)
ψ_{wash}	Wash attack stake requirement	0.50 (50%)

A.9 Risk Management Parameters

Parameter	Description	Default Value
β_{critical}	Critical fee volume fraction	0.60 (60%)
ζ_{reserve}	Reserve decline threshold	0.90
ζ_{depeg}	Depeg threshold	0.95
ζ_{fee}	Fee collapse threshold	0.80
θ_{recover}	Recovery threshold	0.50
τ_{recover}	Recovery period (months)	12
τ_{fatal}	Fatal period (months)	12
$\tau_{\text{insurance}}$	Insurance runway (months)	6
η_{swan}	Black swan fee loss	0.90 (90%)
r_{recover}	Recovery growth rate	0.15 (15%/mo)

A.10 Simulation Parameters

Parameter	Description	Default Value
N_{eff}	Effective staking base for APR	20,000,000 ASI
$\xi_{\text{early,min}}$	Early burn/emission min ratio	0.30
$\xi_{\text{early,max}}$	Early burn/emission max ratio	0.80
ξ_{POL}	Price impact with POL	0.05 (5%)
ξ_{noPOL}	Price impact without POL	0.10 (10%)
τ_{spiral}	Death spiral threshold (months)	3
$\tau_{\text{spiral}}^{\text{protected}}$	Protected spiral threshold	6

Notes on Parameter Selection

- These default values are illustrative and should be refined through simulation and empirical observation.
- Many parameters can be adjusted through governance with appropriate time locks.
- Critical safety parameters should be conservative initially.
- Parameters should be regularly reviewed and adjusted based on system performance.
- Some parameters may vary by shard or be customizable within bounds.

B Conclusion

This work proposes a Next-Gen DeAI Ecosystem shard economy, being developed as part of the ASI chain ecosystem design process, where real usage–not perpetual inflation–funds both network security and participant rewards. The formal model ties validated fees to burns, main-staking rewards, and shard reserves; productive shards therefore earn larger reserves and shard-level payouts while raising the value of the core token via buybacks and burns.

A health-based automation layer adds circuit breakers, adaptive γ_t, hibernation, insurance, mutual support, POL, and optional external yield, turning potentially catastrophic conditions into manageable, transient stresses.

Our theory establishes activity takeover of supply under broad conditions; reserve convergence and half-life with adaptive rates; impulse/decay responses for bubbles, crashes, and bear runs; as well as lower/upper bounds for main-staking rewards and monotone allocation to value-creating shards. The baseline 3-year simulation and three adaptive stress simulations illustrate how these properties appear in practice: the circuit breaker caps reserve drawdowns during local shocks; death-spiral protections pause emissions, raise burns, and deploy insurance during system crashes; diversification measurably aids slow-growth shards through difficult markets.

The upshot is a design that remains crypto-native (simple, rules-based, incentive compatible) while offering institutional-grade resiliency (automatic, transparent responses with governance time locks).

Further work would be needed to gain fuller understanding of the framework's dynamics robustness in various real-world scenarios. Future work would sensibly include calibrating thresholds with empirical data, deepening market microstructure modeling (including fee denomination choices under volatile ASI-USD conversions), and expanding simulations to multi-year, multi-agent settings with strategic behaviors. However, even the level of analysis presented here gives significant confidence that this is a viable direction for the ecosystem. As the network launches and real measurements arrive, the same framework can be continuously tuned by decentralized governance tightening the link between shard value creation, ecosystem wealth, and system robustness.

Future Work

Further work would be needed to gain fuller understanding of the framework's dynamics robustness in various real-world scenarios. Future work would sensibly include:

- Calibrating thresholds with empirical data
- Deepening market microstructure modeling (including fee denomination choices under volatile ASI-USD conversions)
- Expanding simulations to multi-year, multi-agent settings with strategic behaviors
- Implementing and testing the system in a testnet environment
- Conducting agent-based modeling of governance participation
- Analyzing game-theoretic equilibria under various attack scenarios

However, even the level of analysis presented here gives significant confidence that this is a viable direction for the ecosystem. As the network launches and real measurements arrive, the same framework can be continuously tuned by decentralized governance–tightening the link between shard value creation, ecosystem wealth, and system robustness.