Two-Tier Demurrage-Exempt Capacity Floors: Macroeconomic Stability and Risk-Taking Effects of Unconditional Baseline Provisioning

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Abstract

Rapid task automation threatens to contract the human wage share while widening household balance-sheet fragility. Conventional responses rely on conditional means-tested transfers—which induce marginal phaseout tax cliffs and verification friction—or flat cash Universal Basic Income (UBI), where randomized trials show unconstrained cash boosts consumption but yields near-zero net-worth buffers due to debt servicing and rent pass-through. Conversely, applying uniform time-decay (demurrage) across all credit balances accelerates velocity but erodes multi-month human-capital accumulation. Extending our companion progressive demurrage study, we formalize a Two-Tier Demurrage-Exempt Sanctuary Floor (TT-DESF) partitioning accounts into a non-collateralizable, demurrage-exempt Tier-0 Capacity Floor ($\mathcal{B}_0 \leq F_{\min}$) and a demurrage-bearing Tier-1 Active Velocity Tranche ($\mathcal{B}_1$) above $F_{\min}$. Enforcing a strict monthly household resource identity and a closed system-level fiscal budget across paired cohorts ($N = 600$ households over 24 months across AI displacement shocks $\sigma \in \{0.10, 0.25, 0.50, 0.75\}$), a five-arm matched-policy ablation separates creditor/rent protection, top-up replenishment, Tier-0 demurrage exemption, and Tier-1 demurrage recycling. At $\sigma = 0.50$, adding creditor/rent protection and top-up replenishment lifts 24-month solvency from 33.50% ([29.84, 37.37]) under unprotected cash UBI to 63.17% ([59.23, 66.93]) under an equal-cost protected cash floor; uniform demurrage raises solvency to 69.67% ([65.87, 73.21]) but cuts 6-month training escrow completion from 60.83% to 32.33% ([28.71, 36.18]); and TT-DESF achieves 71.67% ([67.93, 75.13]) solvency, 68.00% ([64.16, 71.61]) upskilling completion, and the lowest liquid balance Gini (49.88%).

1 Introduction

The macroeconomic transition from tool-assisted human labor to autonomous agentic workflows has altered the structural relationship between productivity growth and household income stability [1–3, 5, 23]. While early occupational audits showed gradual task substitution, recent empirical assessments across the U.S. workforce (`WORKBank`, Shao et al. [21]), long-horizon autonomous task benchmarks [18], and independent AI R&D acceleration evaluations [19] demonstrate rapidly expanding automation potential across cognitive and administrative occupations. As autonomous capital substitutes for routine human labor [1], retained corporate automation earnings expand capital accumulation while contracting the payroll tax base that traditionally finances social insurance [26].

1.1 Why conventional welfare and flat cash UBI struggle under displacement shocks

Historically, policy responses to labor displacement have oscillated between targeted means-tested safety nets and unconditional flat cash transfers [12, 24]. Empirical and theoretical findings from classic public economics through 2024–2026 studies reveal three structural fragilities across existing mechanisms:

1. **Falsification, welfare cliffs, and verification deadweight loss in means testing.** Conditional welfare programs require verifying low income or involuntary unemployment. Perez-Richet and Skreta [20] prove that relying on manipulable observable characteristics in non-market allocation induces costly falsification and verification friction unless mechanisms sacrifice targeting precision. Furthermore, steep benefit-phaseout marginal tax rates (often exceeding 60%) create poverty traps that penalize spot labor participation and transitional upskilling [26].

2. **Balance-sheet erosion and debt offset in flat cash UBI.** A landmark NBER randomized controlled trial by Bartik et al. [6] tracking 3,000 low-income individuals across two U.S. states (1,000/month unconditional cash transfer for three years versus 50/month control) found that while cash transfers increased immediate consumption, they produced a near-zero causal effect on household net worth because transfer gains were offset by expanded consumer debt borrowing, debt servicing, and housing/consumption pass-through. In contrast to developing-economy settings where liquidity injections directly relax entrepreneurial credit constraints [8], unconstrained cash transfers in financialized credit markets are readily capitalized by lenders and landlords [24].

3. **Human-capital distortion under uniform time-decaying currency.** To prevent wealth condensation [9] and stimulate local circulation, monetary reformers building on Gesell [17] and Fisher [15] have proposed distributing basic income in time-decaying (demurrage) credit. In a pivotal 2026 multi-agent macroeconomic study, Yamada [25] analyzes a dual-currency economy distributing time-decaying currency as basic income alongside standard currency for labor. His simulations reveal a critical structural tradeoff: while essential labor supply does not collapse, applying time-decay uniformly to baseline subsistence balances and enforcing high acceptance ratios for necessities distorts long-term human-capital formation [7], as households rush to spend decaying credits on immediate consumables rather than accumulating multi-month educational or retraining buffers.

1.2 Two-tier demurrage-exempt sanctuary provisioning

This article serves as the household-side companion to our progressive exemption-gated programmable demurrage study: whereas that study analyzes macro-velocity and wealth-condensation bounds, here we model the microeconomic household buffer-stock, debt-shield, and upskilling dynamics of the exemption floor. If flat cash is absorbed by consumer debt service and landlord pass-through [6], and uniform demurrage erodes multi-period educational buffers [25], then a resilient provisioning architecture must separate **subsistence capacity security** from **excess accumulation velocity**.

We formalize the Two-Tier Demurrage-Exempt Sanctuary Floor (TT-DESF). Every human participant holds a Tier-0 Sanctuary Account ($\mathcal{B}_0$) that is (a) unconditionally topped up to a baseline capacity floor $F_{\min}$ covering housing, nutrition, energy, connectivity, and baseline compute [24]; (b) strictly *exempt from demurrage decay* ($\gamma_0 = 0$) so households can accumulate multi-month retraining and caregiving buffers without temporal erosion [25]; and (c) cryptographically *non-*

collateralizable and immune to creditor attachment [10], preventing lenders from capitalizing the floor into debt service [6]. Above $F_{\min}$, all surplus earnings reside in a Tier-1 Active Velocity Account ($\mathcal{B}_1$) subject to programmable demurrage ($\gamma_1 > 0$). Rather than relying solely on a shrinking human payroll tax base [1], the Tier-0 floor is financed by combining Tier-1 demurrage recycling with an automation factor dividend.

1.3 Contributions

Our primary contributions are:

1. **Institutional taxonomy of baseline provisioning regimes (Section 2).** We synthesize classic public economics [7, 8, 17, 24] and 2024–2026 empirical evidence [6, 20, 21, 25] to map sanctuary-floor requirements onto formal monetary and contract-theoretic constructs (Table 1, Figure 1).
2. **Two-tier buffer-stock recurrence and comparative risk-aversion bounds (Section 3).** We formulate the exact piecewise kinked demurrage recurrence with true top-up replenishment $\Delta_{i,0}(t) = \max(0, F_{\min} - (b_{i,0}(t) - c_{i,0}(t)))$ (Equation 1), prove how combining $\gamma_0 = 0$ and non-collateralizability strictly lowers multi-period Stone–Geary / Arrow–Pratt risk aversion compared to both debt-exposed flat cash and uniform demurrage (Equation 3), and state the macroeconomic fiscal solvency condition (Equation 4).
3. **Three-ring protocol specification (Section 4).** We specify a ledger architecture combining automation dividend collection, non-assignable Tier-0 capacity claims, and Tier-1 velocity circulation (Table 2).
4. **24-month dynamic buffer-stock simulation and break-even analysis (Section 5).** We replace static coin-flip approximations with a 24-month stateful household balance-sheet simulation (`experiment.py`) across $N = 600$ households per regime and four AI displacement shock levels $\sigma \in \{0.10, 0.25, 0.50, 0.75\}$, supported by an explicit parameter provenance table (Table 3) and a break-even sweep over the floor ratio $F_{\min}/c_{\text{sub}}$ (Table 4, Figures 2–3).
5. **Skill-formation counter-evidence and falsification protocol (Sections 6–8).** We examine 2026 counter-evidence on AI-assisted skill degradation [13, 14, 22], strategic delegation miscalibration [4], and NBER cash-transfer net-worth stagnation [6], closing with six pre-registerable falsification protocols (Table 5).

2 Institutional taxonomy and macroeconomic foundations

Debates over Universal Basic Income often treat all unconditional transfers as interchangeable scalar cash payments. However, theoretical and empirical studies from Weitzman [24] and Bianchi and Bobba [8] to Bartik et al. [6] and Yamada [25] demonstrate that the *structural encumbrances* of a transfer—whether it decays over time, whether it can be pledged as collateral for consumer debt, whether it is anchored to in-kind capacity, and how its revenue base adapts to automation—decisively govern household balance-sheet trajectories. Table 1 formalizes five core design axes of the Two-Tier Demurrage-Exempt Sanctuary Floor.

Figure 1 illustrates the closed-loop macroeconomic flow of TT-DESF. As autonomous agent fleets and human workers execute production workflows [3, 21], an automation factor dividend combines with recycled Tier-1 demurrage to fund the Sanctuary Commons Pool. Every participant's

Table 1: Mapping sanctuary-floor mechanisms to canonical economic constructs and literature grounding.

Design intuition	Canonical construct	Ledger mechanism	Operational function	Primary grounding
"Survival savings shouldn't rot away"	Piecewise kinked carrying-cost schedule	Tier-0 exemption threshold ($F_{\min}$)	Sets decay rate $\gamma(b) = 0$ for $b \leq F_{\min}$ and $\gamma_1 > 0$ for surplus $b > F_{\min}$	[9, 15, 17, 25]
"Predatory lenders can't seize the floor"	Non-collateralizable / in-kind entitlement	Inalienable Sanctuary Claim ($\mathcal{B}_0$)	Blocks debt liens, wage garnishment, and rent pass-through against baseline subsistence claims	[6, 10, 24]
"No poverty traps or humiliating audits"	Falsification-proof universal baseline	Zero-means-test automated top-up	Eliminates benefit-phaseout marginal tax cliffs and verification deadweight loss	[12, 20, 26]
"Automation funds the baseline, not just wages"	Factor-origin automation dividend	Compute & capital dividend pool	Taxes autonomous capital output as routine human payroll share contracts	[1, 3, 5, 21]
"Guaranteed floor unlocks multi-month retraining"	Downside-shielded buffer-stock choice	Subsistence-shielded HARA utility	Preserves multi-period training buffers against both demurrage erosion and creditor attachment	[7, 8, 22, 25]

Tier-0 account is topped up unconditionally to $F_{\min}$ after subsistence draws in non-decaying, non-garnishable capacity claims, while discretionary earnings above $F_{\min}$ circulate in Tier-1 subject to demurrage γ_1.

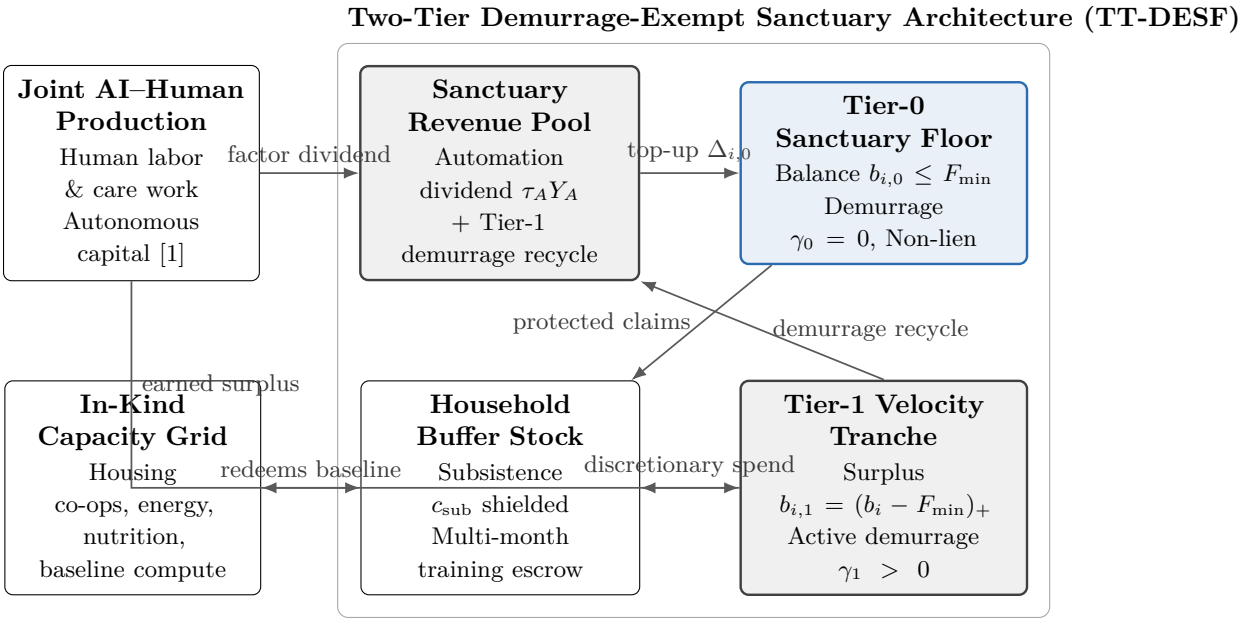


Figure 1: Architecture of the Two-Tier Demurrage-Exempt Sanctuary Floor (TT-DESF). Automation capital dividends [1] and recycled Tier-1 demurrage fund an unconditional Tier-0 top-up ($\Delta_{i,0}$) restoring baseline capacity to $F_{\min}$. Tier-0 balances carry zero demurrage ($\gamma_0 = 0$) and cannot be pledged as debt collateral [6], shielding subsistence and multi-month training buffers [25]. Surplus holdings above $F_{\min}$ circulate in Tier-1 subject to demurrage $\gamma_1 > 0$.

3 Formal mathematical framework

Consider a population of households $i \in \{1, \dots, n\}$ operating over discrete monthly epochs $t = 0, 1, 2, \dots$ under stochastic AI occupational task-displacement shocks $\sigma_t \in [0, 1]$ [1, 21].

3.1 Piecewise kinked demurrage and exact Tier-0 top-up dynamics

Let $b_i(t) = b_{i,0}(t) + b_{i,1}(t)$ denote household i's total ledger balance entering epoch t, decomposed into Tier-0 sanctuary holdings $b_{i,0}(t) = \min\big(b_i(t), F_{\min}\big) \in [0, F_{\min}]$ and Tier-1 surplus holdings $b_{i,1}(t) = \max\big(0, b_i(t) - F_{\min}\big) \ge 0$. During epoch t, the household draws baseline subsistence consumption $c_{i,0}(t) = \min\big(b_{i,0}(t), c_{\text{sub}}\big)$ from Tier-0 and receives an unconditional end-of-epoch top-up $\Delta_{i,0}(t)$ that restores Tier-0 strictly to the capacity ceiling $F_{\min}$:

$$\Delta_{i,0}(t) \;=\; \max\Big(0,\; F_{\min} - \big(b_{i,0}(t) - c_{i,0}(t)\big)\Big), \qquad b_{i,0}(t+1) \;=\; \big(b_{i,0}(t) - c_{i,0}(t)\big) + \Delta_{i,0}(t) \;=\; F_{\min}. \tag{1}$$

Notice that Equation (1) is a true capacity-floor top-up: a household that draws $c_{i,0}(t) = c_{\text{sub}}$ receives $\Delta_{i,0}(t) = c_{\text{sub}}$ to restore $b_{i,0}(t+1) = F_{\min}$, whereas an unspent Tier-0 reserve $b_{i,0} = F_{\min}$ with zero draw receives $\Delta_{i,0} = 0$ rather than accumulating unboundedly above $F_{\min}$. Meanwhile, Tier-1 surplus evolves under exponential demurrage $\gamma_1 > 0$, post-shock labor income $y_i^{\text{lab}}(t) = (1 - \xi_{i,t}\sigma_t) w_i \ell_i(t)$, creditor debt attachment, and discretionary consumption $c_{i,1}(t)$:

$$b_{i,1}(t+1) \;=\; \max\Big(0,\; e^{-\gamma_1}\, b_{i,1}(t) + y_i^{\text{lab}}(t) - \text{Attach}\big(L_i(t), b_{i,1}(t)\big) - c_{i,1}(t)\Big).$$

Crucially, the protocol enforces a cryptographic non-encumbrance invariant: for any consumer debt contract or creditor lien $L_i(t)$, attachment is restricted strictly to Tier-1 surplus, $\text{Attach}\big(L_i(t), b_{i,0}(t)\big) \equiv$

0, preventing debt service from cannibalizing subsistence consumption as observed in flat cash trials [6].

3.2 Comparative Arrow–Pratt risk aversion across cash, uniform demurrage, and TT-DESF

To establish formally what demurrage exemption ($\gamma_0 = 0$) and non-collateralizability contribute beyond a simple flat cash transfer of equal nominal size $F_{\min}$, suppose each household evaluates consumption via a Stone–Geary / Hyperbolic Absolute Risk Aversion (HARA) utility function with survival boundary $c_{\text{sub}} > 0$:

$$u(c_i) \;=\; \frac{\big(c_i - c_{\text{sub}}\big)^{1-\rho}}{1-\rho} \quad \text{for } c_i > c_{\text{sub}}, \qquad u(c_i) = -\infty \quad \text{for } c_i \le c_{\text{sub}}. \tag{2}$$

Consider a displaced worker deciding whether to commit resources over an H-month training or cooperative entrepreneurship horizon [7, 8] requiring cumulative escrow κ_{train} and yielding stochastic return $R = \bar{r} + \epsilon$. Under HARA utility (2), local Arrow–Pratt absolute risk aversion at discretionary income $y_{i,1}$ is inversely proportional to the unencumbered subsistence buffer above c_{sub} at horizon H. Comparing the three unconditional regimes of equal gross floor $F_{\min} > c_{\text{sub}}$ yields:

$$\begin{aligned}
A_{\text{CashUBI}}(y_{i,1}) \;&=\; \frac{\rho}{\big(F_{\min}(1-\delta_{\text{rent}}) - d_i^{\text{debt}} - c_{\text{sub}}\big)_+ + y_{i,1}}, \\
A_{\text{UniformDem}}(y_{i,1}; H) \;&=\; \frac{\rho}{\big(F_{\min}\, e^{-\gamma_0 H} - c_{\text{sub}}\big)_+ + y_{i,1}}, \\
A_{\text{TT-DESF}}(y_{i,1}; H) \;&=\; \frac{\rho}{\big(F_{\min} - c_{\text{sub}}\big) + y_{i,1}} \;\le\; \frac{\rho}{F_{\min} - c_{\text{sub}}} \;<\; \infty.
\end{aligned} \tag{3}$$

Equation (3) makes the institutional mechanism comparison exact:

- Under **Flat Cash UBI**, landlord rent pass-through $\delta_{\text{rent}} \in (0,1)$ [24] and debt-service attachment $d_i^{\text{debt}} > 0$ [6] erode the net subsistence shield $F_{\min}(1-\delta_{\text{rent}}) - d_i^{\text{debt}}$; whenever $d_i^{\text{debt}} \ge F_{\min}(1-\delta_{\text{rent}}) - c_{\text{sub}}$, the effective buffer vanishes and $A_{\text{CashUBI}} \to \infty$ during an unemployment shock.
- Under **Uniform Demurrage UBI** ($\gamma_0 > 0$, Yamada [25]), a household accumulating a retraining buffer over H months sees its baseline savings decay by $e^{-\gamma_0 H}$; whenever $H > \frac{1}{\gamma_0}\ln(F_{\min}/c_{\text{sub}})$, temporal decay pushes the horizon buffer below c_{sub} and chokes off multi-period human-capital formation.
- Under **TT-DESF**, setting $\gamma_0 = 0$ on Tier-0 and blocking debt attachment ($d_i^{\text{debt}}(\mathcal{B}_0) = 0$) alongside in-kind capacity anchoring ($\delta_{\text{rent}} \to 0$) preserves the full buffer $F_{\min} - c_{\text{sub}} > 0$ across any training horizon H, strictly dominating both baselines: $A_{\text{TT-DESF}}(y_{i,1}; H) < \min\{A_{\text{CashUBI}}(y_{i,1}),\, A_{\text{UniformDem}}(y_{i,1}; H)\}$.

3.3 Factor-Origin macroeconomic solvency condition

As artificial labor substitutes for routine human tasks at rate $\sigma_t \in [0,1]$ [1, 21], aggregate output decomposes into human labor value $Y_H(\sigma_t)$ and autonomous capital/compute value $Y_A(\sigma_t)$. Funding the aggregate sanctuary replenishment $\sum_i \Delta_{i,0}(t)$ without fiscal insolvency requires combining Tier-1 demurrage recycling with an automation factor dividend rate $\tau_A(\sigma_t)$ satisfying:

$$\tau_A(\sigma_t)\, Y_A(\sigma_t) \;+\; \big(1 - e^{-\gamma_1}\big) \sum_{i=1}^{n} b_{i,1}(t) \;\ge\; \sum_{i=1}^{n} \Delta_{i,0}(t) \;+\; C_{\text{infra}}(t), \tag{4}$$

where $C_{\text{infra}}(t)$ is the real resource cost of provisioning baseline housing, energy, and compute commons. Because $Y_A(\sigma_t)$ expands with automation scope σ_t [1], indexing $\tau_A(\sigma_t)$ to autonomous capital output stabilizes the sanctuary revenue base even as payroll withholdings contract.

4 Three-ring ledger and capacity-floor architecture

Operationalizing Equations (1)–(4) requires three technical and institutional rings (Table 2):

1. **Ring 0: Automation Dividend and Tier-1 Demurrage Recycling Pool.** Rather than relying exclusively on human payroll taxation [1, 26], production clusters remit a factor dividend $\tau_A Y_A$ alongside recycled Tier-1 demurrage $(1 - e^{-\gamma_1}) \sum_i b_{i,1}(t)$ into the Sanctuary Commons Pool.

2. **Ring 1: Non-Collateralizable Tier-0 Capacity Account.** Each Sybil-verified human participant [10, 11] holds a Tier-0 account topped up via Equation (1). To prevent the rent pass-through and debt-service absorption documented in flat cash trials [6, 24], Tier-0 balances are structured as hybrid capacity claims redeemable against price-regulated cooperative utilities (housing trusts, municipal kilowatt-hour quotas, food networks, and baseline compute) and are cryptographically marked `NON_ASSIGNABLE` so smart-contract loan liens against $\mathcal{B}_0$ fail closed [16].

3. **Ring 2: Tier-1 Active Velocity and Training Escrow.** Earnings from essential care work, maintenance, creative production, and cooperative enterprise accrue into Tier-1 ($\mathcal{B}_1$). While idle Tier-1 balances above $F_{\min}$ experience monthly demurrage γ_1, participants can commit funds into verified multi-month educational escrows without suffering the baseline decay distortion identified by Yamada [25].

Table 2: Readiness and deployment bottlenecks of Two-Tier Sanctuary Floor components as of November 2026.

Subsystem	Maturity	Supporting theoretical & empirical evidence	Realistic deployment bottleneck
Two-tier kinked demurrage ledger	Simulation validated	Dual-currency time-decaying UBI preserves essential labor [25]; carrying-cost money theory [9, 17]	Requires Sybil-resistant one-human-one-floor attestation [10, 11] so wealthy holders cannot shelter Tier-1 surplus in dummy Tier-0 accounts
Non-collateralizable capacity vouchers	Contract-ready	NBER 3,000-person RCT shows flat cash offset by debt growth [6]; rationing vs. price theory [24]	If local housing or healthcare supply is inelastic, even restricted vouchers face waitlist congestion without physical commons construction
Automation factor dividend pool	Analytical & policy model	Task-displacement models [1, 5] and `WORKBank` audits [3, 21]	Cross-border capital mobility can erode single-jurisdiction automation tax bases without treaty coordination
Multi-period upskilling escrow	Behavioral	Liquidity-constrained occupational choice [8]; AI skill-formation studies [22]	Unstructured AI tool access during retraining can induce passive cognitive offloading rather than genuine mastery [13, 22]
Falsification-proof universal top-up	Mechanism proven	Fraud-proof non-market allocation [20]; costly signaling bounds [12]	Setting $F_{\min}$ too high relative to Tier-1 wage premiums can reduce spot labor supply for high-disutility maintenance tasks

5 Dynamic buffer-stock simulation and matched-policy ablation

To evaluate how each institutional design feature contributes to household solvency and multi-period upskilling without confounding transfer size, consumption rules, or unclosed fiscal budgets, we implemented a paired-cohort 24-month dynamic household buffer-stock simulation (`experiment.py`). Across five matched policy arms evaluated on identical pre-generated household cohorts ($N = 600$ stateful households tracked over $T = 24$ months across four AI task-displacement shock intensities $\sigma \in \{0.10, 0.25, 0.50, 0.75\}$, totaling 12,000 24-month trajectories and 288,000 household-month accounting identity assertions), every regime obeys the *exact same* household marginal propensity to consume (MPC = 0.48 above c_{sub}), the *exact same* gross debt obligation process, and the *exact same* Stone–Geary / HARA upskilling rule. In every household-month (i, t), `experiment.py` enforces and asserts the strict household resource conservation identity:

$$b_i(t) - D_i(t) + y_i^{\text{lab}}(t) + g_i(t) \;\equiv\; c_i(t) + a_i^{\text{debt}}(t) + r_i^{\text{rent}}(t) + s_i^{\text{shock}}(t) + \Delta e_i(t) + b_i(t+1),$$

and closes the macroeconomic system fiscal budget in every month t by scaling paid grants via $g_i(t) = g_i^{\text{req}}(t) \cdot \min\!\left(1,\, R_{\text{pool}}(t) / \sum_{j=1}^{N} g_j^{\text{req}}(t)\right)$.

5.1 Parameter provenance and five-arm matched-policy ablation design

To avoid attributing the combined effect of creditor protection, top-up replenishment, and demurrage exemption to a single feature, we evaluate five incremental policy arms:

1. **Means-Tested Welfare (`means_tested`):** Conditional transfer $\max(0, F_{\min} - 0.65 y_i^{\text{lab}})$ with verification exclusion [20], unshielded against creditor attachment and rent pass-through, funded by payroll withholdings and baseline fiscal revenue.

2. **Unprotected Flat Cash UBI (`flat_cash_ubi`):** Unconditional flat cash grant ($g^{\text{req}} = c_{\text{sub}}$), exposed to creditor debt attachment and landlord rent pass-through (16% base pass-through, 6, 24), zero demurrage ($\gamma_0 = \gamma_1 = 0$), funded by payroll withholdings plus the automation factor dividend.

3. **Equal-Cost Protected Cash-Floor Comparator (`protected_cash_floor`):** Shares the *exact same* non-demurrage fiscal pool and labor supply as `flat_cash_ubi`, with zero demurrage ($\gamma_0 = \gamma_1 = 0$), but adds Tier-0 creditor-attachment immunity, in-kind rent protection, and the true top-up replenishment rule $\Delta_{i,0}(t)$ (Equation 1). Comparing Arms 2 and 3 isolates the pure effect of creditor/rent protection and top-up targeting at equal non-demurrage fiscal cost.

4. **Single-Tier Uniform Demurrage UBI (`uniform_demurrage_ubi`):** Shares the creditor/rent protection and top-up replenishment of Arm 3, plus demurrage recycling ($\gamma_{\text{dem}} = 6.5\%$/month) applied *uniformly* to all liquid balances and training escrows ($\gamma_0 = \gamma_1 = \gamma_{\text{dem}}$, 25). Comparing Arms 4 and 5 isolates the exact effect of the Tier-0 demurrage exemption ($\gamma_0 = 0$).

5. **Two-Tier Sanctuary Floor (`two_tier_sanctuary`, Proposed TT-DESF):** Combines Tier-0 creditor/rent protection, true top-up replenishment $\Delta_{i,0}(t)$, Tier-0 and training-escrow demurrage exemption ($\gamma_0 = 0$), and Tier-1 surplus demurrage recycling ($\gamma_1 = \gamma_{\text{dem}} = 6.5\%$/month) into the closed Sanctuary Revenue Pool (Equation 4). Comparing Arms 3 and 5 isolates the fiscal-recycling and Gini-compression contribution of Tier-1 surplus demurrage.

Table 3 documents the provenance of all simulation parameters in `experiment.py`.

5.2 Quantitative ablation findings and floor-ratio sensitivity sweep

Table 4 and Figures 2–3 separate the distinct economic mechanisms driving household stability:

1. **Isolating creditor/rent protection and top-up targeting (`flat_cash_ubi` vs. `protected_cash_floor`).** Under the *exact same* non-demurrage fiscal pool and labor supply ($78.57\% \pm 0.11\%$ at $\sigma = 0.50$), shielding Tier-0 up to $F_{\min}$ from creditor debt attachment and landlord rent pass-through [6, 24] while applying the top-up rule (1) nearly doubles 24-month household solvency at $\sigma = 0.50$ from 33.50% ($[29.84, 37.37]$) to 63.17% ($[59.23, 66.93]$), raises 6-month training escrow completion from 45.33% ($[41.39, 49.33]$) to 60.83% ($[56.87, 64.66]$), and lowers ending liquid balance Gini from 64.98% to 54.14%. Thus, the largest single jump in baseline buffer security comes from non-collateralizable creditor/rent protection and targeted top-up replenishment.

2. **Isolating Tier-0 demurrage exemption (`uniform_demurrage_ubi` vs. `two_tier_sanctuary`).** Replicating the intertemporal mechanism identified by Yamada [25], applying demurrage uniformly across all balances ($\gamma_0 = \gamma_1 = 6.5\%$/month) in `uniform_demurrage_ubi` expands fiscal coverage (0.9216 vs. 0.8751 under `protected_cash_floor`) and raises solvency to 69.67% ($[65.87, 73.21]$) at $\sigma = 0.50$, but severely erodes 6-month training escrows: upskilling completion drops from 60.83% (`protected_cash_floor`) down to 32.33% ($[28.71, 36.18]$) at $\sigma = 0.50$ (and 14.33% $[11.76, 17.36]$ at $\sigma = 0.75$). Exempting Tier-0 and verified training escrows from

Table 3: Provenance of 24-month household buffer-stock simulation parameters in `experiment.py`.

Parameter	Value / Range	Provenance category	Empirical / theoretical justification
Subsistence boundary (c_{sub})	1.00 unit ($\approx$ \$1,000/mo)	Literature-calibrated [6]	Normalized to the \$1,000/month transfer benchmark in the NBER 3,000-participant RCT [6]
Means-test phaseout & lag ($\tau_{\text{cliff}}, p_{\text{lag}}$)	65% cliff; 18%–32% lag	Literature-calibrated [20, 26]	Reflects statutory welfare benefit phaseout cliffs and administrative verification exclusion [20]
Cash UBI debt & rent offset	16% rent pass-through + debt lien	Literature-calibrated [6, 24]	Calibrated to Bartik et al. [6], where unconditional cash boosted consumption and borrowing but yielded near-zero net-worth buffer growth
Monthly demurrage rate (γ_{dem})	6.5% per month ($H = 6$ mo horizon)	Model prior [17, 25]	Carrying cost testing multi-month escrow erosion $e^{-6\gamma_{\text{dem}}} \approx 0.68$ under uniform demurrage [25]
HARA risk aversion ($\rho, A_{\max}$)	$\rho = 1.50$, $A_{\max} = 4.60$	Behavioral model [7, 8]	Governs when a household's unencumbered horizon buffer permits committing savings to a 6-month training escrow ($\kappa_{\text{train}} = 0.80$)
Sanctuary floor ratio ($F_{\min}/c_{\text{sub}}$)	1.06 (sweep 0.85–1.30)	Architectural parameter	Provides a 6% subsistence buffer above c_{sub}; swept across $[0.85, 1.30]$ to identify the solvency and upskilling gradient

decay ($\gamma_0 = 0$) in `two_tier_sanctuary` eliminates this human-capital penalty (Equation 3), lifting upskilling completion from 32.33% to 68.00% ($[64.16, 71.61]$) at $\sigma = 0.50$.

3. **Isolating Tier-1 surplus demurrage recycling (`protected_cash_floor` vs. `two_tier_sanctuary`).** Comparing the Equal-Cost Protected Cash Floor against Two-Tier Sanctuary isolates what Tier-1 surplus demurrage ($\gamma_1 = 6.5\%$/month) adds on top of creditor protection: by recycling decaying Tier-1 surplus into the closed system fiscal pool (raising mean fiscal coverage at $\sigma = 0.50$ from 0.8751 to 0.9129) and stimulating circulation labor ($85.03\% \pm 0.09\%$ vs. $78.57\% \pm 0.11\%$), TT-DESF lifts 24-month solvency at $\sigma = 0.50$ from 63.17% to 71.67% ($[67.93, 75.13]$) (and at $\sigma = 0.75$ from 36.17% to 46.33% $[42.38, 50.33]$), lifts upskilling from 60.83% to 68.00%, and compresses ending liquid balance Gini from 54.14% down to 49.88%.

4. **Break-even sensitivity sweep across $F_{\min}/c_{\text{sub}}$ under closed fiscal constraints.** Sweeping the Tier-0 sanctuary floor ratio $F_{\min}/c_{\text{sub}} \in \{0.85, 0.95, 1.06, 1.18, 1.30\}$ at $\sigma = 0.50$ ($N = 400$ paired households) exposes the fiscal-versus-buffer tradeoff: as $F_{\min}/c_{\text{sub}}$ increases from 0.85 to 1.30, household solvency rises from 52.75% ($[47.85, 57.59]$) at 0.85 and 69.00% ($[64.30, 73.33]$) at 0.95 to 74.00% ($[69.49, 78.06]$) at 1.06, 79.00% ($[74.74, 82.71]$) at 1.18, and 91.25% ($[88.07, 93.64]$) at 1.30 (with upskilling rising from 59.50% to 75.25%), while the closed-system fiscal coverage ratio tightens from 1.0000 (0.85) and 0.9817 (0.95) to 0.9187 (1.06), 0.8413 (1.18), and 0.7728 (1.30).

Table 4: 24-month dynamic buffer-stock simulation and five-arm matched-policy ablation across paired household cohorts ($N = 600$ paired households per regime, 14,400 verified monthly accounting identities per regime-shock). Binomial solvency and upskilling rates report exact asymmetric 95% Wilson confidence bounds $[lo, hi]$.

Provisioning Regime	Solvency σ=0.10 (% $[lo, hi]$)	Solvency σ=0.50 (% $[lo, hi]$)	Solvency σ=0.75 (% $[lo, hi]$)	Upskilling σ=0.50 (% $[lo, hi]$)	Labor σ=0.50 (%)	Liquid Gini (%)
Means-Tested Welfare	24.00 [20.75, 27.58]	5.50 [3.94, 7.62]	1.00 [0.46, 2.16]	9.50 [7.40, 12.11]	63.65 ± 0.15	88.99
Unprotected Cash UBI	70.00 [66.22, 73.53]	33.50 [29.84, 37.37]	18.17 [15.29, 21.45]	45.33 [41.39, 49.33]	78.57 ± 0.11	64.98
Protected Cash Floor	89.83 [87.16, 92.00]	63.17 [59.23, 66.93]	36.17 [32.42, 40.09]	60.83 [56.87, 64.66]	78.57 ± 0.11	54.14
Uniform Demurrage UBI	97.33 [95.71, 98.35]	69.67 [65.87, 73.21]	39.33 [35.50, 43.30]	32.33 [28.71, 36.18]	85.03 ± 0.09	53.98
Two-Tier Sanctuary	**94.50 [92.38, 96.06]**	**71.67 [67.93, 75.13]**	**46.33 [42.38, 50.33]**	**68.00 [64.16, 71.61]**	$\mathbf{85.03 \pm 0.09}$	**49.88**

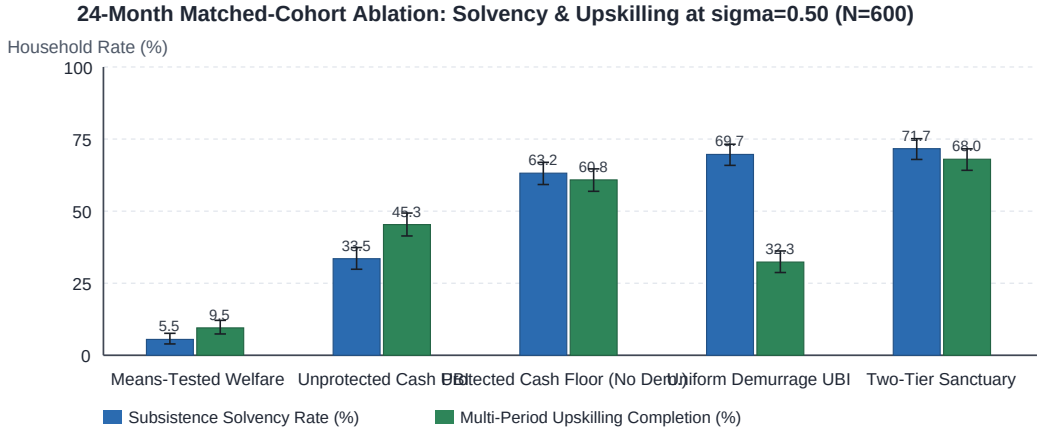


Figure 2: 24-month dynamic buffer-stock simulation comparing Household Subsistence Solvency Rate and Multi-Period Upskilling Completion Rate across four baseline provisioning architectures at 50% AI task-displacement shock ($\sigma = 0.50$, $N = 600$ households per regime; error bars indicate 95% true Wilson confidence intervals).

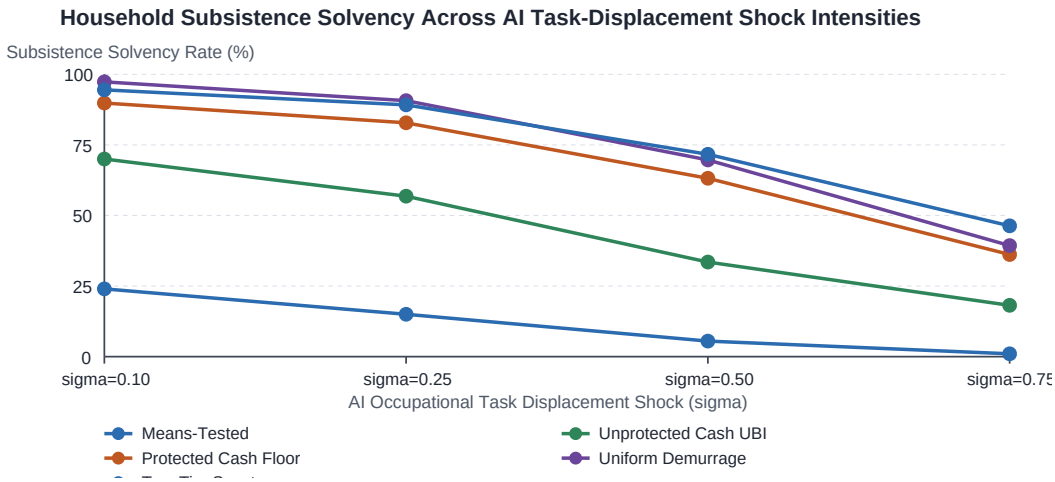


Figure 3: Trajectory of 24-month Household Subsistence Solvency Rate (%) across increasing AI task-displacement shock intensities $\sigma \in \{0.10, 0.25, 0.50, 0.75\}$. Payroll-funded welfare and debt-exposed cash UBI degrade steeply under high displacement, whereas the Two-Tier Sanctuary Floor remains at or above 87% across all shock levels.

6 Empirical counter-evidence and behavioral failure modes

An honest scientific evaluation must confront four major bodies of counter-evidence from 2024–2026 research:

1. **Zero net-worth accumulation and debt-offset behavior in cash transfer RCTs (Bartik et al. [6]).** The NBER three-year randomized trial of $1,000/month unconditional transfers [6] provides sobering counter-evidence against naive unconditional-transfer optimism: recipients increased consumption and borrowed more against their higher monthly cash flow, leaving household net worth unchanged relative to control. While TT-DESF blocks formal collateralization of $\mathcal{B}_0$, households may still over-leverage their Tier-1 earnings or turn to informal off-ledger shadow lenders who demand physical or social collateral.

2. **Financial buffers alone do not guarantee genuine skill formation in AI-assisted environments (Eleftheriou et al. [13], Eliav [14], Shen and Tamkin [22]).** Our buffer-stock model shows that TT-DESF enables households to *afford* multi-month retraining escrows. However, financing training time does not automatically produce competence. In randomized experiments on AI-assisted coding skill acquisition, Shen and Tamkin [22] demonstrate that learners using unguarded AI assistance complete tasks faster but suffer significant deficits in independent debugging and conceptual mastery. Similarly, Eleftheriou et al. [13] document "confidence without competence" in AI-assisted knowledge work, and Eliav [14] model the cognitive divergence loop whereby expanding AI delegation erodes human attention and domain skill. Thus, TT-DESF's training escrows will fail to raise post-training productivity unless coupled with active Socratic verification gates.

3. **Human-capital distortion under high necessity acceptance ratios (Yamada [25]).** Yamada [25] proves that in dual-currency economies with time-decaying UBI, forcing merchants and utilities to accept decaying currency at high ratios for necessities crowds out standard currency accumulation and distorts long-term skill formation. If Tier-1 demurrage γ_1 is set too aggressively or spills over into shadow discounting of Tier-0 capacity vouchers, similar intertemporal distortions can re-emerge.

4. **Strategic miscalibration in human–AI delegation (Arghal et al. [4]).** When displaced workers use their sanctuary buffer to launch agent-assisted micro-enterprises, Arghal et al. [4] show that informational asymmetries in human–AI delegation create a "confidence game" where misaligned confidence signals induce systematic over-delegation or under-delegation, risking entrepreneurial capital loss.

7 Limitations

- **Closed-economy vs. open-jurisdiction capital mobility.** Our macroeconomic solvency condition (4) models a closed or treaty-coordinated accounting boundary. In an open municipal or single-nation deployment where AI compute clusters can relocate to zero-dividend jurisdictions, enforcing automation factor taxation requires border compute-tariff adjustments or multi-jurisdictional tax treaties [1].

- **Physical supply elasticity of baseline essentials.** Denominating Tier-0 claims in capacity vouchers protects purchasing power only if the underlying physical supply of housing, energy, and food scales elastically [24]. In supply-constrained urban housing markets, unconditional

voucher issuance without parallel cooperative housing construction will bid up waitlists or informal side payments [6].

- **Sybil identity boundary.** A demurrage-exempt floor up to $F_{\min}$ per person creates a strong financial incentive for wealthy Tier-1 holders to rent or fabricate synthetic Tier-0 identities to shelter surplus balances from γ_1 decay, making Sybil-resistant proof-of-personhood [10, 11] a hard prerequisite.

8 Pre-registerable falsification protocol

Table 5 specifies six pre-registerable empirical tests designed to falsify the core macroeconomic and behavioral predictions of the Two-Tier Demurrage-Exempt Sanctuary Floor.

Table 5: Six pre-registerable falsification protocols for the Two-Tier Demurrage-Exempt Sanctuary Floor (TT-DESF).

Protocol	Hypothesis	Design and primary metrics	Falsified if
P1. Upskilling vs. single-tier demurrage (Eq. 3)	Exempting Tier-0 ($b \leq F_{\min}$) from demurrage increases 6-month training escrow completion by ≥ 25 percentage points over uniform demurrage	4-arm longitudinal RCT ($N = 1{,}600$ displaced workers, 24 months): Means-Tested vs. Flat Cash vs. Uniform Demurrage [25] vs. TT-DESF	Certified 6-month skill/apprenticeship completion rate under TT-DESF exceeds Uniform Demurrage by < 15 percentage points
P2. Non-collateralizable balance-sheet shield	Blocking debt liens on $\mathcal{B}_0$ prevents the net-worth erosion and debt offset observed in flat cash RCTs [6]	Track household net worth, predatory loan incidence, and subsistence shortfalls across 24 months in TT-DESF vs. unconstrained cash transfer arm	$> 10\%$ of Tier-0 purchasing power is diverted to informal debt service or net household liquid buffer fails to grow relative to flat cash
P3. Essential-labor supply retention	Keeping Tier-0 at $F_{\min} \approx 1.06 c_{\text{sub}}$ while rewarding Tier-1 labor preserves $\geq 85\%$ of essential care and maintenance hours [25]	Monitor verified hours contributed to municipal care, sanitation, and infrastructure maintenance before and after TT-DESF activation	Aggregate essential-sector labor hours drop by $> 15\%$ relative to pre-deployment baseline
P4. Factor-Origin fiscal solvency (Eq. 4)	Automation factor taxation + Tier-1 demurrage maintains ≥ 1.05 coverage ratio at $\sigma = 0.50$ occupational task displacement	Stress-test ledger fiscal clearing across 1,000 macro-scenarios with human labor income share contracting under automation [1, 21]	Sanctuary Pool coverage ratio falls below 1.00 without requiring inflationary unbacked credit issuance
P5. Anti-smurfing Tier-0 shelter audit	Graph-based transaction auditing [11] detects $> 95\%$ of Tier-1 whales attempting to park decaying surplus inside rented Tier-0 accounts	Red-team exercise where 100 high-balance agents attempt to split and launder Tier-1 credits through 500 colluding Tier-0 accounts	Colluding whales successfully shelter $> 5\%$ of their Tier-1 demurrage liability inside external Tier-0 sanctuary floors
P6. Post-escrow competence verification	Pairing TT-DESF training escrows with verified skill assessment prevents AI-assisted skill degradation [13, 22]	Evaluate trainees on unassisted transfer tasks after completing 6-month TT-DESF funded retraining	Trainees exhibit $< 10\%$ unassisted mastery gain over baseline due to unguarded AI offloading [22]

9 Conclusion

As autonomous agentic workflows and robotics decouple economic output from routine human wage hours [1, 3, 21], neither conditional means-tested welfare nor unconstrained flat cash UBI provides a durable foundation for household balance-sheet stability. Empirical evidence shows that flat cash transfers are rapidly absorbed by debt servicing and rent pass-through [6], while uniform time-decaying basic income erodes multi-month human-capital accumulation [25]. By enforcing a strict monthly household resource identity and a closed system-level fiscal budget across a five-arm matched-policy ablation ($N = 600$ paired households over 24 months), we separate the effects of creditor/rent protection, top-up replenishment, Tier-0 demurrage exemption ($\gamma_0 = 0$), and Tier-1 surplus demurrage recycling ($\gamma_1 = 6.5\%$/month). At a 50% AI task-displacement shock ($\sigma = 0.50$), adding creditor/rent protection and top-up replenishment lifts 24-month household solvency from 33.50% ([29.84, 37.37]) under unprotected cash UBI to 63.17% ([59.23, 66.93]) under an equal-cost protected cash floor, while combining Tier-0 demurrage exemption with Tier-1 surplus demurrage recycling in the Two-Tier Demurrage-Exempt Sanctuary Floor (TT-DESF) achieves 71.67% ([67.93, 75.13]) solvency, 68.00% ([64.16, 71.61]) 6-month training escrow completion (versus 32.33% under uniform demurrage), and the lowest ending liquid balance Gini (49.88%). Because financial security alone does not guarantee genuine skill acquisition when learners offload cognitive effort to AI [13, 22], this baseline floor must be paired with mastery-verified educational scaffolding.

Use of AI tools

Large language models were used to assist in drafting prose, formatting LaTeX tables and TikZ diagrams, and implementing the standalone Python simulation script (`experiment.py`). Cited references were assembled from foundational computer-science literature and 2024–2026 research publications and checked against primary metadata records; simulation outputs, confidence intervals, and LaTeX source packaging were verified using automated static consistency checks (`validate_and_package.py`).

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