Intertemporal Resource Exchange: How Local Storage Shapes Decentralized Sharing Markets

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1. Motivation

- Baseline model assumes agents must share generated resources immediately.
- **Real systems often allow delay**: batteries store energy, caches hold data, and queues postpone computation.
- Storage changes the decision problem: **agents now choose not only who to share with, but also when to share.**

How does local storage affect strategic decision-making, equilibrium, and efficiency in a decentralized money-free exchange economy?

2. Storage-Enabled Equlibrium

- In a traditional competitive market, equilibrium is usually described by three conditions: market clearance, budget feasibility, and utility maximization.
- In reciprocal exchange, agents do not use money. They trade directly using their own generated resources. Therefore, budget feasibility and market clearance collapse into one market clearence condition
- **Storage-enabled feasibility** $$D_i(t) + S_i(t-1) = \sum_{j \in \mathcal{N}_i} x_{ij}(t) + S_i(t)$$

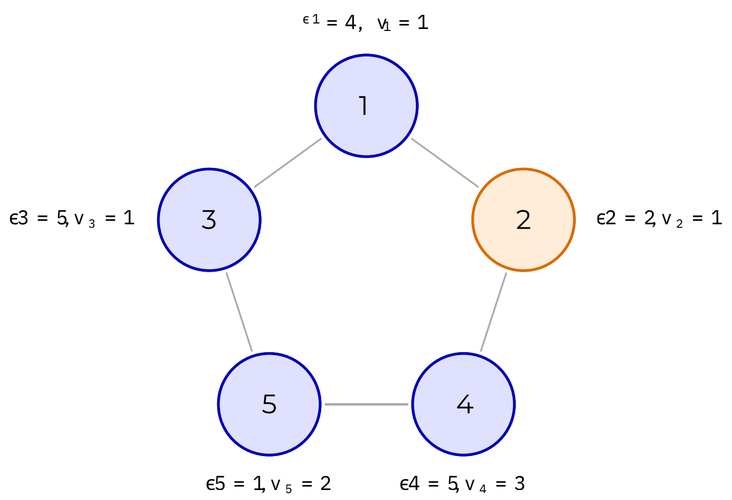
Each unit of available resource is either shared with a neighbour or carried forward in local storage.

- **Intertemporal market clearance** $$\lim_{T \to \infty} \frac{1}{T} \sum_{t=1}^{T} \sum_{j \in \mathcal{N}_i} x_{ij}(t) = \epsilon_i.$$

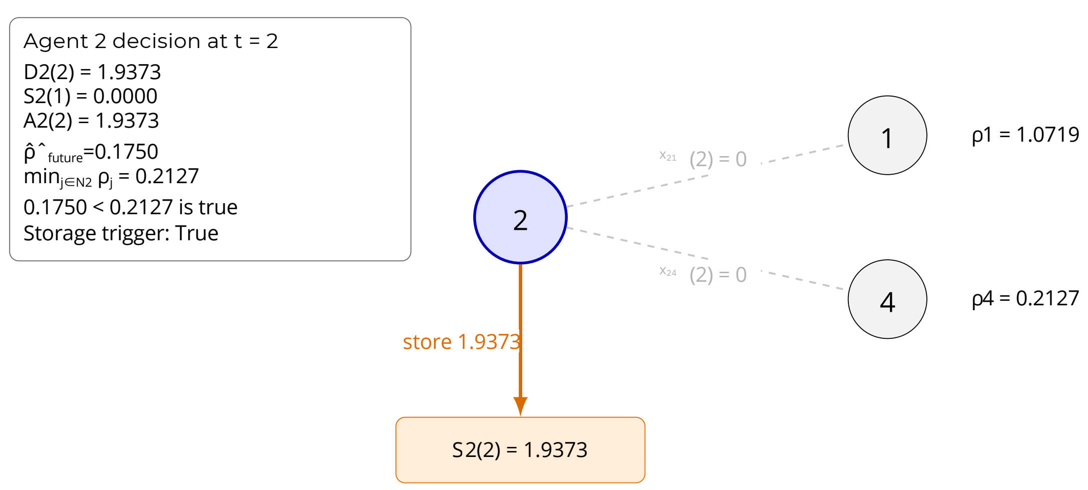
Because storage is bounded and lossless, it can delay exchange, but it cannot permanently remove resources from the market.

- The utility-maximization benchmark remains the same as in the baseline model. Storage changes when resources are exchanged, not how utility is defined.

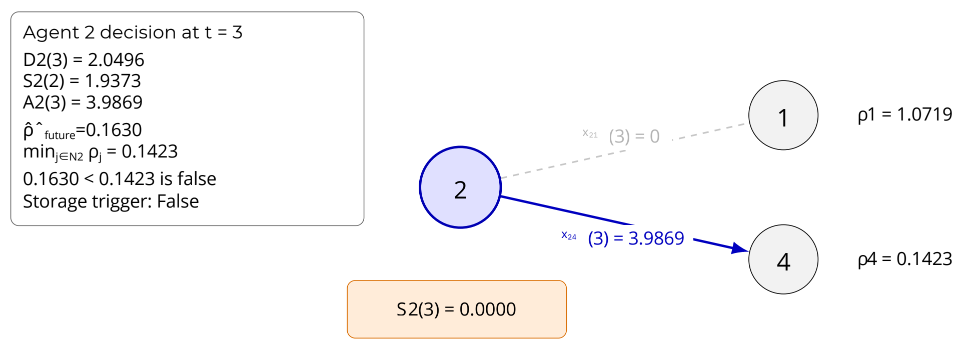
3. Greedy



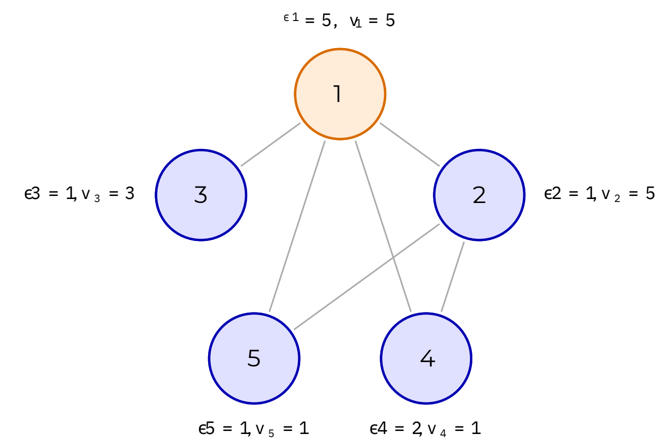
Pure greedy decision: t = 1 → t = 2



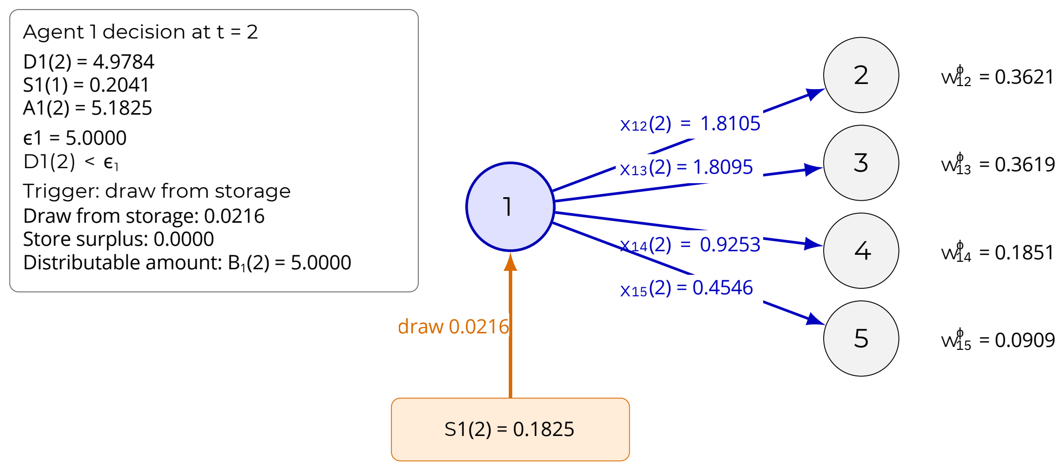
Pure greedy decision: t = 2 → t = 3



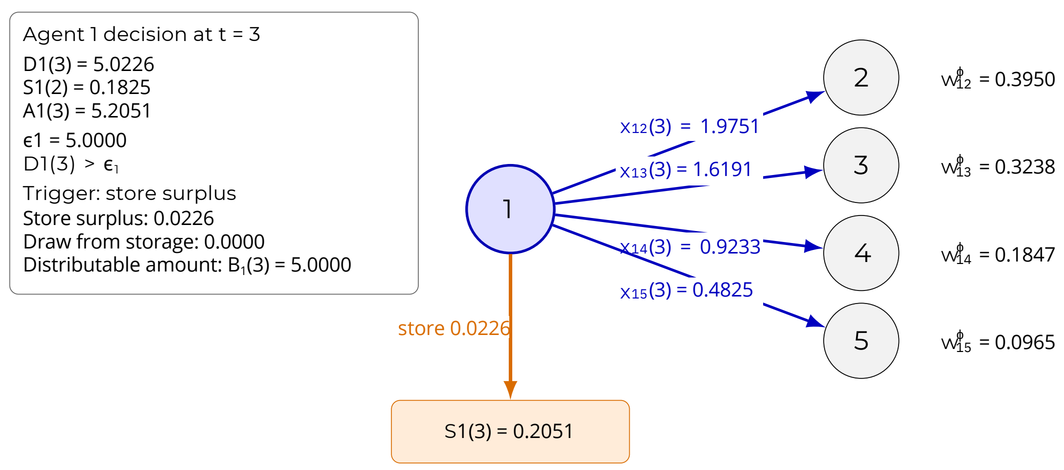
4. Proportional



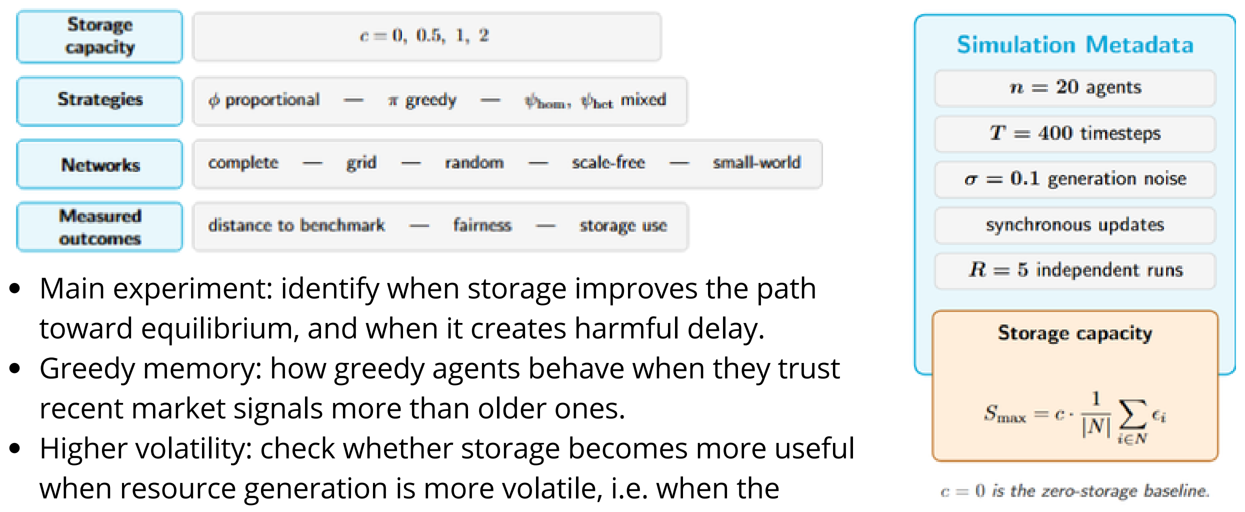
Pure proportional decision: t = 1 → t = 2



Pure proportional decision: t = 2 → t = 3



5. Simulation Setup



- Main experiment: identify when storage improves the path toward equilibrium, and when it creates harmful delay.
- Greedy memory: how greedy agents behave when they trust recent market signals more than older ones.
- Higher volatility: check whether storage becomes more useful when resource generation is more volatile, i.e. when the standard deviation is higher.

6. Discussion

- **Storage capacity is not always an improvement**
  - More storage gives agents more freedom to delay exchange, but delay is only useful if it leads to better future allocations.
  - In many cases, extra capacity just changes the timing without improving the final market state.
- **Greedy storage can hurt, but not in every market instance.**
  - Greedy agents store when the future looks better than the current best neighbour.
  - This can work well in specific situations where waiting really does create a better exchange opportunity.
  - However, on average, the same behaviour mostly hurts.
- **Recency changes storage usage, not outcomes.**
  - When greedy agents trust recent observations more, they store less and share sooner, but final loss and fairness do not change much.
- **Volatility supports the smoothing-buffer interpretation**
  - When generation becomes noisier, proportional storage becomes more useful because it smooths short-term fluctuations around the long-term endowment.

7. Conclusion

- How can a decentralized sharing problem with local storage be formally modeled? $$D_i(t) + S_i(t-1) = \sum_{j \in \mathcal{N}_i} x_{ij}(t) + S_i(t)$$
- What equilibrium concept is appropriate for a storage-enabled exchange economy? $$\lim_{T \to \infty} \frac{1}{T} \sum_{t=1}^{T} \sum_{j \in \mathcal{N}_i} x_{ij}(t) = \epsilon_i.$$ **The utility-maximization benchmark remains the same as in the baseline model.**
- What is the strategy space of an agent that can choose between sharing resources immediately and storing them for future use? ϕ proportional — π greedy — $\psi_{\text{hom}}, \psi_{\text{het}}$ mixed
- How can the model be simulated to evaluate the effect of storage capacity on efficiency, convergence, and fairness? $$S_{\max} = c \cdot \frac{1}{|N|} \sum_{i \in N} \epsilon_i$$
- How does storage change the path by which decentralized exchange approaches equilibrium?

It depends on the interaction between strategy type and network topology

8. Limitations and Future Work

- The experiments only cover part of the possible storage-enabled market space: fixed market size (n=20), selected strategies, and selected network topologies.
- Storage is idealized as bounded and lossless. Real batteries, caches, or delayed jobs may lose value over time.
- Future work should test larger and more diverse markets and introduce storage decay or degradation to study the trade-off between sharing now and waiting.