



Robust Pseudo-Markets for Reusable Public Resources

SIDDHARTHA BANERJEE, Cornell University, USA

GIANNIS FIKIORIS, Cornell University, USA

ÉVA TARDOS, Cornell University, USA

We study non-monetary mechanisms for the fair and efficient allocation of *reusable public resources*. We consider settings where a limited resource is repeatedly shared among a set of agents, each of whom may request to use the resource over multiple consecutive rounds, receiving some utility only if they get to use the resource for the full duration of their request. Such settings are of particular significance in scientific research where large-scale instruments such as electron microscopes, particle colliders, or telescopes are shared between multiple research groups; this model also subsumes and extends existing models of repeated non-monetary allocation where the resource is demanded only for a single round.

We focus on a stochastic rewards setting where in every round t , each agent draws demand (V_t, K_t) from some underlying distribution, where K_t is the duration she needs the item for, and V_t is the per-round utility she gets if allocated the item on rounds t to $t + K_t - 1$. Demands are independent across agents, and across rounds. To receive utility from demand in round t , an agent must be allocated the item for the entire K_t rounds.

In the absence of money there is no way to make interpersonal comparisons, and so we need a benchmark that is independent of agents' values. To this end, given an agent's *fair share* $\alpha \in (0, 1)$ – the fraction of rounds she is 'entitled' to win – we define her *ideal utility* as the maximum expected utility she can receive in the absence of competition, but where she can utilize the item on up to an α fraction of rounds. Computing this is challenging as accepting the demand in any given round may block future demands, as well as eat into the agent's utilization budget. We formalize this optimization problem via an infinite-horizon control problem, and show that the optimal policy can be computed in polynomial time via a linear program. Since the ideal utility is defined independently of other agents' behavior, it gives a reasonable measure of how much utility an agent can hope to get, while ensuring her resource utilization does not exceed her fair share.

We next explore a simple pseudo-market mechanism where upfront we endow each agent with some budget of artificial credits, reflecting her fair share. Our mechanism, *First-Price Pseudo-Auction with Multi-Round Reserves*, runs a first-price auction whenever the item is available, using a selective reserve: every agent submits a desired duration and per-round-bid (which must be at least the reserve price if the requested duration lasts multiple rounds); the highest bidder gets to use the item for the desired duration. We prove that using a simple bidding strategy (where an agent bids as per the optimal control policy that realizes her ideal utility), each agent can get at least $1/2$ of her ideal utility in expectation, regardless of how other agents bid.

We note that our guarantee is robust, unlike measures like no-regret which depend on how other agents behave. Moreover, with symmetric agents, our results imply that our mechanism realizes at least half the maximum welfare under *any* equilibrium. Finally, we complement our guarantee by showing that *no* non-monetary mechanism can guarantee every agent an expected utility that is more than $1/2$ their ideal utility.

A full version of our paper can be found at [arXiv:2302.09127](https://arxiv.org/abs/2302.09127).

ACM Reference Format:

Siddhartha Banerjee, Giannis Fikioris, and Éva Tardos. 2023. Robust Pseudo-Markets for Reusable Public Resources. In *Proceedings of the 24th ACM Conference on Economics and Computation (EC '23)*, July 9–12, 2023, London, United Kingdom. ACM, New York, NY, USA, 1 page. <https://doi.org/10.1145/3580507.3597723>

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EC '23, July 9–12, 2023, London, United Kingdom

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ACM ISBN 979-8-4007-0104-7/23/07.

<https://doi.org/10.1145/3580507.3597723>