Fair Dynamic Rationing
(Draft Coming Soon)

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We study the allocative challenges that governmental and nonprofit organizations face when tasked with equitable and efficient rationing of a social good among agents whose needs (demands) realize sequentially and are possibly correlated. As one example, early in the COVID-19 pandemic, the Strategic National Stockpile faced overwhelming, temporally scattered, a priori uncertain, and correlated demands for medical supplies from different states. To achieve their dual aims of equity and efficiency in such contexts, social planners intend to maximize the minimum fill rate across agents, where each agent’s fill rate must be irrevocably decided upon its arrival. For an arbitrarily correlated sequence of demands, we establish upper bounds on both the expected minimum fill rate (ex-post fairness) and the minimum expected fill rate (ex-ante fairness) of any policy. Our bounds are parameterized by the number of agents and the demand-to-supply ratio, and they shed light on the limits of attaining equity in dynamic rationing. Further, we show that for any set of parameters, a simple adaptive policy of projected proportional allocation achieves the best possible fairness guarantee, ex post as well as ex ante. Our policy is transparent and easy to implement, as it does not rely on distributional information beyond the first moment. Despite its simplicity, we demonstrate that this policy provides significant improvement over non-adaptive policies by characterizing the performance of the optimal target-fill-rate policy and its associated adaptivity gap. We obtain the performance guarantees of (i) our proposed adaptive policy by carefully designing lower-bound functions on its minimum-fill-rate-to-go, and (ii) the optimal target-fill-rate policy by establishing a somewhat surprising connection to a monopoly-pricing optimization problem. Further, we extend our results to considering alternative objective functions and to rationing multiple types of resources. We complement our theoretical developments with numerical studies motivated by the rationing of COVID-19 medical supplies based on a projected-demand model used by the White House. In such a setting, our simple adaptive policy significantly outperforms its theoretical guarantee as well as the optimal target-fill-rate policy.

Key words: rationing, fair allocation, social goods, correlated demands, online resource allocation