The Cost of Income Guarantees in Centralized Marketplaces

Recent years have witnessed a rise in the use of online platforms serving as an intermediary between consumers and providers. Examples include ride-sharing services such as Uber and Lyft, hospitality services such as Airbnb, mobile food-ordering companies such as Grubhub, and small task platforms such as TaskRabbit, Thumbtack, and Upwork. These platforms connect customers who request a service with providers that provide it. Once the service is completed, the platform charges a particular amount to the customer, which is then split between the service provider and the platform (a revenue-share contract).

When deciding on the allocation of requests to providers, the platform often aims to strike a balance between short-term goals (such as maximizing instantaneous revenue) and additional considerations, which are essential to its long-term sustainability. One such example is maintaining (or increasing) provider retention. Given the relationship between the income and retention of providers, a platform might favor allocations that guarantee a certain level of income to a subset of providers (e.g., new providers), or alternatively, allocations that comply with a notion of fairness and equity in how providers are treated, over allocations that do not comply with such features but generate higher short-term revenue. Therefore, implementing restrictions that account for such long-term considerations may be also associated with short-term revenue-losses for the platform.

In this paper we study the magnitude of the potential revenue losses that are associated with a broad family of allocation restrictions that include income guarantees as well as notions of fairness.
**Model.** We consider a centralized platform that allocates a fixed set of indivisible requests among a fixed number of providers under a revenue sharing contract. We assume that some requests may be mutually incompatible (e.g., in many practical settings, if two requests overlap in time, then these requests cannot be assigned to the same provider), and the only compatibility structure we impose is one of monotonicity with respect to inclusion: If a provider can satisfy a set of requests, then he can also satisfy any subset of these requests. We allow heterogeneity with respect to the revenue share contracts used for different providers, that is, the platform may maintain different revenue portions from different providers.

To study the potential impact of various considerations on the revenue that can be extracted by the platform, we assume that the platform restricts the possible allocations to a set that is closed under pareto-dominance: An allocation that leaves each provider with at least as much revenue as another allocation from the restricted set must be in the restricted set as well. This broad class of restrictions includes many well-studied examples such as max-min fairness, alpha-fairness, and guaranteeing a minimum income threshold to a subset of providers. To study the magnitude of the potential loss associated with a certain set of restrictions we propose a measure that quantifies the relative difference between the maximum revenue that can be captured by an allocation that is limited to the restricted set, and an unrestricted allocation.

**Main Results.** We establish an upper bound on the relative revenue loss that may occur by limiting allocations to a restricted set. This upper bound depends on the number of providers and the extent of heterogeneity across the revenue-sharing contracts. The most important implication of this result is that, under the assumptions of our model, we guarantee a relative
revenue loss that is strictly less than one for any number of providers. In particular, if all providers are offered the same revenue-sharing contract, then we establish that for any restriction set that is closed under pareto-dominance, the relative revenue loss is upper bounded by a half. This finding fundamentally distinguishes our formulation from previous studies that consider communication networks (Tang et al. 2004 and Bertsimas et al. 2011) and air traffic management (Bertsimas et al. 2012), where it has been established, both theoretically and empirically, that such losses can be arbitrarily close to one. Moreover, we show that our upper bounds are tight, by producing instances and restriction sets that achieve them.

In order to understand the magnitude of such revenue loss in practical settings, we perform a numerical study using a data set from the NYC Taxi and Limousine Commission to generate instances of service requests, for which we solve both the short-term revenue maximizing allocation and the restricted revenue maximizing allocation. Both our theoretical and numerical results suggest that platforms can implement income guarantees with limited relative impact on instantaneous revenue.

References.