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We study a setting in which items are dynamically assigned to waiting agents. The common practice of using independent lotteries encourages agents to enter many lotteries, resulting in inefficient matching. We consider several alternatives, and reach three main conclusions.

First, systems with very different descriptions can produce identical outcomes. In particular,

- Independent lotteries are equivalent to a waitlist in which participants lose their position after rejecting an offer.
- Restricting agents to enter at most one lottery is equivalent to using a waitlist in which participants keep their position after rejecting an offer. Both are equivalent to using artificial currency.

Second, when an agent’s level of need is unobservable, there is often a tradeoff between matching (assigning agents to items that are a good fit) and targeting (assigning items to agents with the greatest need).

Third, it is generally preferable to prioritize good matching over effective targeting. The exception is when most participants have very little need, and the remainder are far more desperate. In such circumstances, effective targeting can be achieved by adding friction to the assignment system.

Our findings suggest that independent lotteries are rarely advisable. We discuss the implications of our work for the allocation of affordable housing, and of discounted tickets to Broadway shows.

Key words: matching, dynamic matching, housing, lottery, waitlist
1. Introduction

Lotteries and waitlists are commonly used to ration items for which demand exceeds supply. For example, New York City allocates public housing using a waitlist, and allocates newly-built affordable housing by lottery. Many Broadway shows, musicians, and sports teams offer lotteries for discounted tickets. Organs from deceased donors are typically allocated using a waitlist. Occasionally, more complex allocation systems are employed – for example, Feeding America allows food banks to bid for donations using a virtual currency [Prendergast 2017].

Designers of these systems face many questions, such as:

a) Is it better to use lotteries, waitlists, or an artificial currency system?

b) When using lotteries, should there be a limit on how many times each agent can apply?

c) In a waitlist, should agents who reject an offer keep their spot in line, or lose it?

We address these questions by studying how different allocation systems perform according to the following objectives:

- **Targeting** individuals with the highest need. Discounted tickets are intended for those who cannot afford the regular price, housing assistance programs target low-income individuals, and organs are preferentially allocated to sicker patients.

- **Matching** individuals with items that are well-suited to their needs. This is important because housing units are in different locations of the city, organs have different biological markers, and food banks serve different populations.

We reach three high-level conclusions. First, the form of the system – lottery, waitlist, or virtual currency – matters much less than design details that influence whether individuals will be selective when applying. Second, there is often a tradeoff between matching and targeting: improving one

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comes at the expense of the other. For example, limiting the number of lotteries that each individual can enter ensures that agents will apply only to good fits, but prevents agents from signaling a high level of need by applying everywhere. Conversely, if agents who reject an offer lose their position on the waitlist, then some agents will accept marginal fits, and those who are unwilling to do so will be less likely to match. Finally, we show that it is often preferable to use a system that prioritizes good matching over effective targeting. We discuss our model and each of these conclusions in more detail below.

For concreteness, we focus on the allocation of affordable housing in New York, where developers receive a tax break if they offer a fraction of the units at their newly built development to eligible low-income residents. These units are awarded by lottery when the development opens, and lotteries are independent across developments.

We capture the main features of this setting using a stylized model in which developments arrive over time, and upon arrival, are allocated to agents who are waiting for them. Each agent has an outside option ("level of need"), which is heterogeneous across the population. Furthermore, agents have different values for each development, and agents’ values and outside options are private information. We model the system currently used in New York as follows.

- **Repeated Lottery**: In each period, each agent may enter a lottery for a unit at the current development. Tickets are drawn until the development fills or all tickets have been selected.

We show that the repeated lottery often fails to match agents to developments that fit their needs. The reason is that agents respond to low lottery odds by entering as many lotteries as possible, and thus are essentially assigned at random.

One potential fix is to encourage agents to apply more selectively by limiting the number of lotteries that each person can enter. We consider the following extreme case.

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2 In practice, the social planner may have access to observable information such as income on tax returns and current residential situation, which is correlated with the outside options of agents. One should interpret our model as reasoning about the system after the social planner has taken into account the available observable information, possibly by the creation of suitable eligibility requirements.
• **Single-Entry Lottery**: Use independent lotteries as before, but restrict each agent to enter at most one lottery in his or her lifetime.

As one might expect, this encourages agents to be more selective, increasing the quality of the matches that form (see Theorem 2). However, it also increases the odds that less-needy individuals will match. The intuition for this is fairly clear: in a repeated lottery, desperate agents signal their need by entering many lotteries, whereas agents with good outside options will enter fewer, and match less often. Limiting agents to a single lottery ensures that different agents will match at similar rates.

Theorem 3 establishes that the tradeoff between matching and targeting is not unique to the repeated and single-entry lotteries, but holds for any pair of mechanisms, so long as the social planner cannot directly observe an individual’s level of need.

While mechanisms differ in how they balance the objectives of matching and targeting, the form of the mechanism is less important. Theorem 1 shows that the equilibrium outcomes under a repeated lottery are equivalent to those under the following waitlist-based mechanism.

• **Waitlist without Deferral**: Entering agents are placed at the bottom of a waitlist. In each period, the current development is offered to agents at the top of the waitlist until it fills or is offered to every agent. Agents who reject an offer lose their spot and must reapply.

Analogously, the following mechanisms are equivalent to the single-entry lottery:

• **Waitlist with Deferral**: A waitlist in which agents keep their spot after rejecting an offer.

• **Ticket-Saving Lottery**: Having an independent lottery for every development as before, but agents receive in each period a ticket that can be saved for the future, and agents can use multiple tickets in a single lottery.

Note that the ticket-saving lottery is a form of virtual currency, so our results show that lottery-based, waitlist-based, and virtual currency systems may implement identical outcomes. Instead, 3

While the ticket-saving lottery is only one of many ways to implement a virtual currency system, our equivalence proof applies to any system in which agents are given a (possibly randomized) quantity of virtual currency in their $t^{th}$ period, and can use this currency to buy “probability shares” for the current development, or wait to spend it in future periods. The only requirement for the proof to hold is that $m_t$ is exogenous to the agent’s behavior.
the crucial difference between mechanisms is that some incentivize agents to accept marginal fits, and others cause agents to apply selectively.

We then turn to the question of whether it is socially desirable to encourage selectivity. We find in Theorem 4 that ensuring good matching is often more important than effectively targeting need, implying that the single-entry lottery, the waitlist with deferral, and the ticket-saving lottery (all of which encourage selectivity) yield higher utilitarian welfare than the repeated lottery or the waitlist without deferral. The one exception is when most agents derive little benefit from participating, and the few remaining agents are extremely needy. In this case, it is more important to target need than to match well. Rather than using a repeated lottery, however, we show that in this case it is better to screen out less needy agents completely by adding friction to the assignment system.

Although we focus on specific mechanisms, we show that these mechanisms are often approximately optimal in settings when agents can observe many developments before departing. In particular, when good matching is a top priority, the single-entry lottery and its equivalents are approximately optimal (see Proposition 4), and when targeting is more important, clearing the market by adding friction is approximately optimal (see Proposition 5).

Our results suggest that the repeated lottery or the waitlist without deferral, which are often used in practice, are rarely advisable. For affordable housing, because high-need individuals can be targeted using eligibility criteria on observable characteristics, and because most of the units being offered are desirable to most agents, we think that the city should consider limiting the number of lotteries that applicants can enter, in order to improve the quality of matches. On the other hand, for allocating discounted Broadway tickets, it is plausible that targeting is more important. In this case, however, a better way to target needy individuals might be to introduce participation costs, for example by requiring lottery applicants to line up before the show.

2. Related Work

This paper contributes to the growing literature on dynamic matching markets. For reviews of the literature on static matching markets, see Roth and Sotomayor (1992) or Sönmez et al. (2011).
One strand of the dynamic matching literature focuses on generalizing the concept of stable matchings in static two-sided markets to dynamic settings. Papers that fall into this category include [Damiano and Lam (2005), Kurino (2009), Pereyra (2013), Kennes et al. (2014), and Doval (2014)]. Contrasted with this work, the markets we study are one-sided as items have no preferences. Thus, the concept of stability is not meaningful.

Another set of papers assume that the social planner has all relevant information about the quality of each match. Much of this literature focuses on the application to kidney exchange, which started with the seminal paper of [Roth et al. (2004)]. Representative recent works include [Dickerson et al. (2012), Gurvich et al. (2014), Akbarpour et al. (2014), Baccara et al. (2015), and Ashlagi et al. (2016)]. In earlier work, [Kaplan (1987a,b, 1988)] formulates the allocation of affordable housing as a queueing problem, and studies waiting times and development diversity under various priority rules. In contrast with the papers above, we assume that most of the relevant match information is privately known and revealed strategically by agents.

Our paper falls into the category of dynamic matching with private, one-sided preferences. A series of papers in this category is motivated by the allocation of cadaver organs ([Su and Zenios 2004, 2005, 2006, Schummer 2016, Agarwal et al. 2017]). In this setting, items (organs) are perishable and thus can only be offered to a limited number of individuals, and agents agree on their relative preferences across organs. [Su and Zenios (2004)] advocate for switching from a first-come-first-serve queue to something resembling a last-come-first-serve queue, in order to make agents less picky and increase the utilization of less desirable organs. [Schummer (2016)] notes that preventing agents from rejecting offers may decrease wastage, at the expense of reducing match quality for agents at the top of the queue. [Agarwal et al. (2017)] study the organ wastage problem from an empirical perspective and estimate agent preferences from data and simulate counterfactuals. In our setting, wastage is not a concern, and preference heterogeneity is horizontal rather than vertical. As a result, it is generally preferable to induce agents to be more (rather than less) selective.

Closer to our work are the papers of [Bloch and Cantala (2017)] and [Leshno (2015)], which are motivated by the allocation of subsidized housing units, and focus on how to match people to...
the right places. Bloch and Cantala (2017) find, as we do, that the waitlist with deferral induces agents to be pickier than in the repeated lottery, resulting in higher match quality. Leshno (2015) notes that agents who have a middling position in a waitlist with deferral would be more selective under a hybrid mechanism, which makes offers randomly among all agents with sufficiently high positions on the waitlist. The biggest difference between our work and these papers is that our agents have heterogeneous outside options, and thus the efficiency of a matching depends crucially on which agents match. Additionally, by studying a continuum model, we are able to consider richer environments (rather than assuming that values for a development are binary), and develop new insights about the equivalence of various mechanisms.

The problem of targeting aid to certain sub-populations has been considered in the public finance literature on the design of subsidies. Nichols and Zeckhauser (1982) and Blackorby and Donaldson (1988) use a simple model with two agent types to illustrate that one can target the type with higher need by restricting the flexibility of the subsidies or by adding friction. A similar idea appears in a series of papers on “money-burning auctions” (Hartline and Roughgarden 2008, Hoppe et al. 2009, Condorelli 2012, Chakravarty and Kaplan 2013), in which a social planner allocating a homogeneous good cannot use monetary transfers, but can require agents to incur wasteful effort to screen out the agents who value it less. Several of these papers have results resembling our Theorem 4: when the valuation distribution is heavy-tailed, the designer should use wasteful effort to improve targeting; when it is light-tailed, it is more efficient to allocate randomly. We extend this insight to a setting where agents care about which good they receive, and show that reducing match quality – instead of requiring wasteful effort – can help the social planner to better target agents with greater need.

Finally, there is a growing empirical literature on the allocation of affordable housing. Several papers study the estimation of agent preferences from administrative data (Geyer and Sieg 2013, Geyer and Yoon 2017, Van Ommeren and Van der Vlist 2016, Waldinger 2017). The parameters from these estimates could be used to calibrate the primitives of our model. Thakral (2016),
Waldinger (2017) have used these demand estimates to compare alternative allocation mechanisms via numerical simulation. While these studies allow for richer models of agent preferences, their insights depend on a particular set of parameters from a given city. Our analysis complements this work by offering insights that hold for wide classes of distributions, and clearer intuition about the first-order effects of switching to a different mechanism.

3. Model

Section 3.1 describes the timing of agent arrivals, and our assumptions about agent utilities. Section 3.2 discusses the dynamic decision problem facing each agent. Section 3.3 defines our equilibrium concept. Section 3.4 introduces the metrics that we use to evaluate equilibria. For clarify of exposition, we refer to all agents using female pronouns.

3.1. Agents, Outcomes, Utilities, Timing

Time is discrete. In every period \( j \), a continuum of agents of unit mass arrives, as does a new development, which can house a mass \( \mu \) of agents and must be allocated immediately. We refer to \( \mu \) as the supply-demand ratio.

Each agent will eventually either be matched to a single development, or depart from the system unmatched. Let \( v_{ij} \) denote the value of agent \( i \) for development \( j \), and \( \alpha_i \) denote her value for going unmatched (her “outside option”). \(^4\) We sometimes refer to \( \alpha_i \) as the type of agent \( i \).

The timing within each period is as follows (and is illustrated in Figure 1):

1. **Arrival**: A unit mass of new agents arrives.

2. **Departure**: Each agent becomes ineligible with probability \( 1 - \delta \). Eligible agents choose whether to remain. If an agent \( i \) exits (by choice or due to ineligibility) she earns her outside option \( \alpha_i \).

3. **New Development** of mass \( \mu \) arrives. Each agent \( i \) observes \( v_{ij} \).

\(^4\) Rather than assuming that agents have utilities over only their final allocation, it may seem more reasonable to assume that agents get a utility in *each period*, based on their current accommodation. In Appendix ??, we outline such a model, and show that it is in fact mathematically equivalent to the one described here.
4. Matching Rule. Agents participate in a matching rule, as defined formally in Section 3.2.

Informally, each agent is asked to take an action, and these actions are used to determine which agents match this period. Matched agents exit, receiving their value for the current development. Unmatched agents remain in the system.

The outside options $\alpha_i$ are distributed according to CDF $F$, and the values $v_{ij}$ are drawn iid (across agents and time) from CDF $G$. We refer to $F$ as the outside option distribution, and $G$ as the value distribution. $F$ and $G$ are continuous, with strictly positive density on their domains $(\alpha, \bar{\alpha})$ and $(v, \bar{v})$ respectively. We allow for the possibility that $\alpha$ or $v$ may be $-\infty$, or that $\bar{\alpha}$ or $\bar{v}$ may be $\infty$, and assume without loss of generality that $\bar{\alpha} \leq \bar{v}$ (agents with outside options exceeding $\bar{v}$ will never choose to participate, so we can exclude them and normalize $F$ appropriately). We denote the density of $F$ by the function $f(\alpha)$, and define $\overline{G}(v) = 1 - G(v)$.

3.2. Actions

The values $v_{ij}$ and the outside option $\alpha_i$ are privately known to agent $i$. Thus, they cannot be directly used to determine an allocation. Instead, agents participate in a matching rule, which asks them to take an action in each period, and uses the actions to determine who will match to the current development. Before giving our formal definition of a matching rule, we motivate this definition.

Although agents are in principle playing a dynamic game, we restrict attention to designs in which agents are affected only by the aggregate profile of actions selected by others, and assume that agents respond to this aggregate (rather than to actions of specific other agents). This implies that no single agent can directly influence the market, or the future behavior of others. Therefore,
each agent perceives herself not as playing a dynamic game, but rather as facing a Markov decision process (MDP). She begins each period in some state, which determines the set of actions available to her. Her action, in turn, influences whether she matches, and which state she transitions to in the event that she does not match.

**Definition 1 (Matching rule).** A matching rule \( R = (S, A, T) \) consists of a countable set of states \( S \), which contains an initial state \( s_0 \) to which all agents are assigned upon entry. There is a countable set of actions \( A = \bigcup_{s \in S} A_s \), where \( A_s \) is a finite set of actions for state \( s \in S \). For each action \( a \in A_s \), there is a transition function \( T_a : S \times (S \cup \{m\}) \rightarrow [0, 1] \), where \( T_a(s, s') \) is the probability of transitioning to state \( s' \) after taking action \( a \) in state \( s \), and \( m \) corresponds to being matched to the current development.

Implicit in the above definition is the assumption that the mechanism is anonymous: it can differentiate agents based on the history of actions taken, but not based on the identity of the agent. Note also that the transition function \( T_a \) does not depend explicitly on the actions of other agents. This is because in our continuum model, the aggregate profile of others’ actions is deterministic and stationary, and thus can be encoded directly into the matching rule itself.

Below, we describe how the allocation systems described in the introduction can be encoded as matching rules. Three of the allocation systems (the repeated, single-entry, and ticket-saving lotteries) are lottery-based rules, and are fully characterized by a success probability \( p \in (0, 1] \), which is the chance that any given ticket will win a lottery. The other two are waitlist-based rules, and are characterized by an average idle time \( \tau \geq 0 \), which is the expected number of periods a newly arrived agent must wait before receiving an offer.

5 For example, her state may be the number of periods that she has waited. If she has just arrived, she can only continue to wait, whereas if she has waited for a long time, she may be offered the current development and asked to accept or reject the offer. Alternately, her state may represent the number of lotteries that she has entered so far.

6 In our definition of equilibrium in Section 3.3, we require the transition function to be consistent with the aggregate behavior of other agents, meaning that the total measure of housing allocated in each period is equal to the supply \( \mu \).
I. Lottery Matching Rules:

- **Repeated Lottery.** $S$ consists of a single state. In it, the agent chooses from the action set $\{Enter, Abstain\}$. If she abstains, she is not matched. If she enters, she is matched with probability $p$.

- **Single-Entry Lottery.** Identical to the repeated lottery, except that there is an additional null state, from which the agent remains permanently unmatched. In the initial state, if the agent chooses to enter and is not matched, she transitions to the null state.

- **Ticket-Saving Lottery.** $S = \mathbb{N}$ represents the number of tickets possessed by the agent. The agent starts in state 1. From state $s$, the agent chooses an action $j \in \{0, \ldots, s\}$ (the number of tickets to use this period). An agent in state $s$ choosing action $j$ matches with probability $1 - (1 - p)^j$, and otherwise transitions to state $s - j + 1$.

II. Waitlist Matching Rules:

The state space is $\mathbb{N}$, representing the number of periods that the agent has waited. The initial state is zero. In states $s < \lfloor \tau \rfloor$, the agent has a single action $\{Wait\}$, and transitions deterministically to state $k + 1$. In states $s > \lfloor \tau \rfloor$, the agent selects an action from $\{Accept, Reject\}$. From state $s = \lfloor \tau \rfloor$, the agent is offered the action $\{Wait\}$ with probability $\tau - \lfloor \tau \rfloor$, and otherwise offered the actions $\{Accept, Reject\}$. Whenever an agent chooses to accept, she matches. The two variants are as follows:

- **Waitlist with Deferral.** Agents who reject retain their position (increment their state).
- **Waitlist without Deferral.** Agents who reject lose their position (go back to state 0).

One special case of the above is the guaranteed choice matching rule, in which the agent is offered every development. In other words, it is a lottery with $p = 1$ or a waitlist with $\tau = 0$.

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7 While our formal definition does not allow for the action set $A_s$ to be randomized, it is straightforward to encode an equivalent matching rule with a deterministic action set: in state $s = \lfloor \tau \rfloor$, the agent is always offered the actions $\{Accept, Reject\}$. With probability $\tau - \lfloor \tau \rfloor$, the agent’s action is ignored and her state incremented, and otherwise she transitions as defined above. We choose the description with a randomized action set for its conceptual clarity.
We define a mechanism $M$ to be a class of matching rules. For example, the repeated lottery mechanism is the set of all repeated lottery matching rules, which is parameterized by the success probability $p \in (0, 1]$. Similarly, the single-entry lottery mechanism is the set of single-entry lottery matching rules, and likewise for the ticket-saving lottery and waitlists with and without deferral.

3.3. Equilibrium Concept

We now define our equilibrium notion. First, any matching rule $R = (S, A, T)$ (along with the probability $\delta$ of remaining eligible, a value $\alpha$ for going unmatched, and the value distribution $G$) induces a MDP for each agent, which encodes the agent’s decision problem of whether to voluntarily exit given the current state $s \in S$, and which action $a \in A$ to choose given the state $s$ and the value $v_{ij}$ for the current development. We refer to this as the matching MDP associated with the matching rule $R$. Interested readers can find a formal definition in Appendix A. A strategy to this MDP encodes the decision of whether to exit in each state and what action to take given the state and the observed value. A strategy profile $\Sigma$ specifies a strategy $\Sigma(\alpha)$ for each agent type $\alpha$.

An equilibrium is a matching rule and a strategy profile which jointly satisfy two conditions. First, the strategy for each agent must maximize that agent’s expected payout in the matching MDP associated with the matching rule. Second, when agents follow their respective strategies, the market clears – that is, the measure of agents matched in each period must be equal to the supply $\mu$. Below, we provide more detail.

First, we define the notion of an outcome, which specifies a distribution of payoffs for each agent type. Formally, an outcome is a function $E : \mathbb{R}^2 \to [0, 1]$, where $E(\alpha, v)$ specifies the probability that an agent with outside value $\alpha$ matches to a development for which her value is at most $v$. By definition, the function $E$ is weakly increasing in the second component $v$. Given outcome $E$, define the corresponding

- allocation function to be

$$\pi^E(\alpha) = E(\alpha, v) \quad (1)$$

This specifies the probability that an agent of outside option $\alpha$ matches to some development.
match rate to be the fraction of agents who match:

\[ \pi^E = \mathbb{E}_{\alpha \sim F}[\pi^E(\alpha)]. \]  

The outcome is pinned down by a matching rule and a strategy profile as follows. For a given matching rule \( R \) and a strategy profile \( \Sigma \), define \( E_{R,\Sigma}(\alpha, v) \) to be the probability that an agent following strategy \( \Sigma(\alpha) \) matches to a development for which her value is at most \( v \). We call \( E_{R,\Sigma} \) the outcome corresponding to matching rule \( R \) and strategy profile \( \Sigma \).

The allocation problem is not interesting if supply is so abundant that the social planner can offer every development to every agent – if this is feasible, then it is clearly optimal to do so. The following assumption rules out this trivial case. Define \( GC \) to be the outcome when agents play optimally in the MDP induced by the guaranteed choice matching rule. We assume the following for the remainder of the paper.

Assumption 1: It is infeasible to offer guaranteed choice to all agents (\( \mu < \pi^{GC} \)).

This assumption allows us to state that the market clears exactly in equilibrium.

**Definition 2 (Equilibrium Outcome).** An outcome \( E : \mathbb{R}^2 \to [0, 1] \) is an equilibrium outcome of matching rule \( R \) if it can be expressed as the outcome corresponding to \( R \) and a strategy profile \( \Sigma \) of the corresponding matching MDP, such that

a) For every \( \alpha \), the strategy \( \Sigma(\alpha) \) is optimal for an agent with outside option \( \alpha \).

b) The average match rate of \( E \) equals supply-demand ratio: \( \pi^E = \mu \).

We sometimes refer to \( E \) simply as an equilibrium outcome, without mentioning the matching rule \( R \). If \( E \) satisfies a) but not b) we refer to it as a partial equilibrium outcome.

\(^8\) Proposition ?? in Appendix ?? shows that this outcome is unique.

\(^9\) We rule out the case \( \pi^E < \mu \), which eliminates mechanisms that intentionally withhold supply. Nevertheless, one can still study the welfare effect of withholding supply by comparing aggregate utility of agents under our equilibrium definition but with different values of \( \mu \). For any of the five mechanisms listed in the introduction, withholding supply never improves welfare.
3.4. Metrics for Evaluating Equilibria

Below, we define several metrics used to evaluate outcomes. Given outcome $E$, define the

- **match value** $v^E(\alpha)$ to be the expected value that an agent with outside option $\alpha$ has for her development, conditioned on matching:

$$v^E(\alpha) = \frac{1}{\pi^E(\alpha)} \int_{-\infty}^{\infty} v dE(\alpha,v),$$

where the integral is taken with respect to $E(\alpha,\cdot)$ for a fixed $\alpha$.

- **match distribution** $F^E$ to be the distribution of outside options conditional on matching:

$$F^E(\alpha) = \frac{\int_{-\infty}^{\alpha} \pi^E(x) dF(x)}{\int_{-\infty}^{\infty} \pi^E(x) dF(x)}.$$  

Thus, $F^E(\alpha)$ is the fraction of matched agents who have outside options no better than $\alpha$.

- **expected utility** $u^E(\alpha)$ to be the expected benefit from participation for an agent with outside option $\alpha$, given by:

$$u^E(\alpha) = \pi^E(\alpha)(v^E(\alpha) - \alpha).$$

- **utilitarian welfare** $W^E$ to be the average benefit per allocated housing unit:

$$W^E = \mathbb{E}_{\alpha \sim F}[u^E(\alpha)]/\pi^E.$$  

In the introduction, we discussed two objectives: ensuring that matched individuals receive a desirable development, and matching the most needy individuals. The first of these objectives – which we refer to as *matching* – is captured by the match value $v^E$, while the second – which we refer to as *targeting* – is captured by the match distribution $F^E$. We now define what it means for one outcome to result in better matching or targeting than another. The definitions have a strong requirement of point-wise or stochastic dominance, but we will show that such relationships often exist among the mechanisms we study.

**Definition 3.** Let $E$ and $E'$ be arbitrary outcomes. We say that

- $E$ match dominates $E'$ if $v^E(\alpha) \geq v^{E'}(\alpha)$ for all $\alpha$ at which both quantities are defined.
• **$E'$ targeting dominates** $E$ if the match distribution of $E$ first-order stochastic dominates the match distribution of $E'$. That is, $F^{E'}(\alpha) \geq F^E(\alpha)$ for all $\alpha \in (\underline{\alpha}, \overline{\alpha})$.

• **$E'$ strongly targeting dominates** $E$ if the ratio $\pi^E(\alpha)/\pi^{E'}(\alpha)$ is weakly increasing in $\alpha$ wherever the denominator is positive.\(^{10}\)

4. Results

4.1. Equivalence of Mechanisms

Our first result is that under equilibrium play, each of the five mechanisms we study is outcome equivalent to either the single-entry lottery, or to the repeated lottery. To state this formally, we define the set of equilibrium outcomes under mechanism $M$ to be

$$\mathcal{E}^M = \{ E : E \text{ is an equilibrium outcome of some matching rule } R \in M \}. \quad (7)$$

We say that mechanisms $M$ and $M'$ are outcome equivalent if $\mathcal{E}^M = \mathcal{E}^{M'}$.

**Theorem 1 (Equivalence of Mechanisms).**

a) The repeated lottery is outcome equivalent to the waitlist without deferral.

b) The single-entry lottery is outcome equivalent to the waitlist with deferral.

c) The ticket-saving lottery is outcome equivalent to the waitlist with deferral.

The equivalence theorem may at first seem surprising, because the five mechanisms have very different descriptions. However, as the proof in Appendix ?? reveals, there are deeper similarities between the mechanisms when one views them through a more general framework. Below, we give the intuition behind the equivalence results.

Consider first the repeated lottery and the waitlist without deferral. The first step to seeing the equivalence is to think of the repeated lottery in the following way: rather than selecting winners after agents make entry decisions, we can instead select winners among all agents, and only then...
ask each winner to accept or reject the development. This perspective is valid because the agents who choose to enter the lottery are exactly those who would accept the development if offered it. Therefore, in both the repeated lottery and the waitlist without deferral, agents are periodically offered the chance to match to the current development. In the waitlist without deferral, this occurs approximately every \( \tau \) periods (by definition). In the repeated lottery, this occurs independently in each period, with some probability \( p \). However, what matters to each agent is not the distribution of when she will next receive an offer, but rather the probability that she will receive another offer before becoming ineligible (call this \( q \)). This probability determines which developments she will accept, and thus her probability of matching. Because both mechanisms match the same number of agents, it follows that any value of \( q \) that arises in equilibrium of the repeated lottery must also be an equilibrium of the waitlist without deferral – and that in these equilibria, each agent sets the same threshold and matches with the same probability.

We now turn to the equivalence between the single-entry lottery, the ticket-saving lottery, and the waitlist with deferral. We prove this in two steps. First, we show that all “delayed guaranteed choice” mechanisms (in which each agent waits a random number of periods before being offered every subsequent development) are equivalent, so long as they fill all developments. This is because they all amount to selecting a set of agents at random, and allowing them to claim any development that they wish. Second, we note that the single-entry lottery, the ticket-saving lottery, and the waitlist with deferral are each equivalent to a delayed guaranteed choice mechanism.\(^{11}\)

This claim is easy to see for the waitlist with deferral, in which agents wait for \( \tau \) periods before making any decisions, and are offered every development from then on. For the single-entry and ticket-saving lotteries, note that conditional on being used, each ticket wins with some probability \( p \), independently of when it is used or how many other tickets are used concurrently. Therefore, agents may reason as though each ticket has an unknown “state”: either it will win when used, \(^{11}\)In the waitlist with deferral, the lucky winners are those who reach the top of the waitlist. In the single-entry lottery, they are those whose tickets will win if used, and in the ticket-saving lottery they are those who receive a winning ticket before becoming ineligible.
or it will not. If agents were told the state of each ticket, then they would be playing a delayed
guaranteed choice game: in the single-entry lottery, agents receive a winning ticket immediately or
never, and in the ticket-saving lottery, the time before receiving a winning ticket is geometrically
distributed. Of course, agents do not know whether their tickets will win, but if the tickets don’t
win, then it does not matter what agents do with them. As a result, agents might as well behave as
if one of their tickets will win. Thus, all three mechanisms are equivalent to a delayed guaranteed
choice mechanism, which completes the proof.

4.2. Single-Entry Lottery Produces Better Matches than Repeated Lottery

In this section, we compare the single entry and repeated lottery systems, which are representative
members of the two equivalence classes identified in Theorem 1. We establish that the single-entry
lottery has a unique equilibrium, whereas the repeated lottery may have multiple equilibria. Fur-
thermore, for the agents who match, the single-entry lottery matches them to better developments
than what they receive under any equilibrium of the repeated lottery.

**Proposition 1.**

a) The single-entry lottery has a unique equilibrium outcome.

b) The repeated lottery may have multiple equilibrium outcomes, each corresponding to a different
   success probability \( p \). Any two equilibrium outcomes are Pareto comparable: all agents prefer
   the outcome corresponding to a higher success probability \( p \).

**Theorem 2 (Match Value Comparisons).** The unique equilibrium outcome of the single
entry lottery match dominates any equilibrium outcome of the repeated lottery.

Both of these results can be traced to the fact that in a repeated lottery (and a waitlist without
deferral), agents set a threshold on the minimum value of a development that they will go for,
and this threshold depends on the “level of competition” (success probability \( p \), or length of wait
\( \tau \)). When the success probability is low or the wait is high, agents are willing to accept worse
developments and hence receive a worse match value. In the repeated lottery, there may be multiple
equilibria – some in which agents accept almost anything and lottery odds are small, and others in
which agents are more selective and lottery odds are higher. By contrast, in a single-entry lottery (and the ticket-saving lottery and waitlist with deferral), agent selectivity does not depend on the level of competition. This is easiest to see for the waitlist with deferral: once an agent has reached the top of the list, her acceptance decision does not depend on how long she had to wait, or on the number of people waiting behind her. As a result, these mechanisms have a unique equilibrium, in which agents are as selective as they would be if they faced no competition at all.

4.3. Tradeoff Between Matching and Targeting

While the single entry lottery provides agents with high-quality matches, it may do a poor job of allocating to those who are most in need. The intuition for this is as follows: in a single-entry lottery, every agent who uses her ticket is equally likely to match. Under a repeated lottery, by contrast, agents with good outside options will only compete for developments that are preferable to their current situation, whereas individuals with greater need will enter more lotteries, and therefore match at higher rates.

While fairly intuitive, the above logic does not always hold. In particular, if developments are generally very desirable, it is possible that even agents with the best outside options will enter most if not all lotteries. If this occurs, then the repeated lottery does badly on both objectives: essentially, agents are selected at random to match, and are assigned to a random development. Thus, in order for the repeated lottery to effectively target need, it must be the case that many individuals prefer their current situation to most developments (and thus will abstain from many lotteries). We formalize this idea below.

Definition 4. We say that there are many low-need individuals if \( \alpha \geq \tau \) and the density of outside options \( f \) is increasing on \( (\alpha, \overline{\alpha}) \).

We show that when there are many low-need individuals, the repeated lottery targets need more effectively than the single-entry lottery. Thus, limiting lottery entry improves match quality, but at the cost of worse targeting. Furthermore, the tradeoff between matching and targeting extends beyond these particular designs: when comparing any two mechanisms, if there are many low-need individuals, then better matching necessarily implies worse targeting, and vice versa.
Theorem 3 (Matching vs Targeting). Let $E$ and $E'$ be equilibrium outcomes.

a) If $E$ match dominates $E'$, and if there are many low-need individuals (see Definition 4), then $E'$ targeting dominates $E$.

b) If $E'$ strongly targeting dominates $E$, then $E$ match dominates $E'$.

The intuition behind the tension between matching and targeting is as follows. If agents with poor outside options have opportunities to get a high quality match, then less-needy agents must have the same opportunities, as the social planner cannot stop them from imitating the actions of agents with a high need. Therefore, the less-needy agents must also match at similarly high rates as the high-need agents, which implies that a significant proportion of developments must be allocated to less-needy agents. This is stated precisely in Proposition 2, which can be interpreted as an analog of the revenue-equivalence theorem in standard auction theory. In particular, it states that the allocation rule $\pi$ uniquely pins down the utility of every agent type, and implies that if low types receive high utility, then high types must match with “reasonable” probability.

Proposition 2. For any partial equilibrium outcome $E$, the allocation function $\pi^E(\alpha)$ is weakly decreasing, and the expected utility function is given by

$$u^E(\alpha) = \int_{\alpha}^{\infty} \pi^E(x) \, dx. \quad (8)$$

4.4. Welfare Comparisons

When matching and targeting are in conflict with one another, it is natural to wonder which objective is more important. Theorem 4 shows that the answer to this question depends on both the shape of $F$ and the support of $F$ and $G$.

Definition 5.

$F$ has a **light left tail** if $F(x)/f(x)$ is weakly increasing in the domain $(\alpha, \overline{\alpha})$.

$F$ has a **heavy left tail** if $F(x)/f(x)$ is weakly decreasing in the domain $(\alpha, \overline{\alpha})$. 

Examples of light tailed distributions include the uniform, the normal, and the the Gumbel distribution. The exponential distribution has a constant hazard rate (and thus is the dividing line between light and heavy-tailed distributions). The Pareto and the log-normal distributions are examples of heavy-tailed distributions.\textsuperscript{12}

\textbf{Theorem 4 (Welfare Comparisons).} Let $E$ and $E'$ be equilibrium outcomes. If any of the following conditions are satisfied:

- $E$ match dominates $E'$ and $f$ is weakly increasing on $(\alpha, \overline{\alpha})$, or
- $E'$ targeting dominates $E$ and $\overline{\alpha} \geq \overline{\alpha}$, or
- $E'$ strongly targeting dominates $E$,

then the following hold:

a) If $F$ has a light left tail, then $W^E \geq W^{E'}$.

b) If $F$ has a heavy left tail and $\overline{\alpha} \geq \overline{\alpha}$, then $W^E \leq W^{E'}$.

Theorem 4 states that when there are many low-need individuals, the relative importance of targeting and matching depends on whether the outside option distribution $F$ is heavy-tailed or light-tailed. If $F$ is heavy-tailed, then the designer should select a mechanism that better targets need, such as the repeated lottery. Otherwise, the designer should adopt a mechanism that incentivizes high-quality matches, such as the single-entry lottery.

Note that a heavy-tailed outside option distribution does not necessarily imply that targeting should be prioritized over matching – it is important that those with the least need derive little value from participating in the system (hence the condition $\overline{\alpha} \geq \overline{\alpha}$ in part b)). If developments are very desirable, so that all agents benefit substantially from being matched to one of their preferred developments, then targeting effectively is not worthwhile, as doing so would require a large deterioration in match quality.

\textsuperscript{12}Typically, the tail of a distribution refers to the right tail. In Definition 5 we refer to the left tail.
4.5. Optimality

The results in the previous section make it possible to compare the welfare of two mechanisms by simply comparing how effectively they target need. The natural next step is to establish bounds on how effectively any mechanism can target need when outside options are private information. Below, we define outcomes that provide these bounds. Define perfect targeting (PT) to be the outcome in which agents with outside option $\alpha \leq F^{-1}(\mu)$ are matched with certainty, and no other agents are matched. Define no targeting (NT) to be the outcome in which agents of all types match with probability $\mu$, and conditioned on matching, have the highest possible value $v$ for their assignment.

It is fairly clear that these outcomes bound the targeting of any mechanism: perfect targeting stipulates that only the agents with the lowest outside options match, whereas no targeting stipulates that all agents match with equal rates (by Proposition 2, it is not possible for agents with better outside options to match at higher rates). However, it is not clear that these outcomes are attainable – in fact, we will show that within our current model, perfect targeting is not attainable. Motivated by this, we introduce the random offer outcome (RO), which results when agents are offered the first development they see upon entry, and are forever unassigned if they reject it. In this case, it is clear that agents will accept whenever they prefer this development to their outside option. The outcome functions PT, NT, and RO are precisely defined as follows:

$$PT(\alpha, v) = 1(\alpha \leq F^{-1}(\mu))\mathbb{P}_{v' \sim G}(v \geq v'|v' \geq F^{-1}(\mu)), \quad (9)$$

$$NT(\alpha, v) = \mu 1(v \geq \overline{v} > \alpha), \quad (10)$$

$$RO(\alpha, v) = \mathbb{P}_{v' \sim G}(v \geq v' \geq \alpha). \quad (11)$$

We now define a natural class of outcomes, which are those that never assign agents to developments that are inferior to their outside option.

**Definition 6.** An outcome $E$ is ex-post individually rational if agents never match to a development that is inferior to their outside option: $E(\alpha, v) = 0$ for all $v < \alpha$. 
**Proposition 3 (Bounds on Equilibrium Outcomes).**

a) Perfect targeting (PT) targeting dominates any equilibrium outcome, which strongly targeting dominates no targeting (NT).

b) If there are many low-need individuals (see Definition 4), then random offer (RO) targeting dominates any ex-post individually rational equilibrium outcome.

The intuition for part b) is that random offer achieves the lowest match value of any mechanism that cannot force agents to accept a development, and by Theorem 3 this implies that when there are many low-need individuals, it targets need most effectively.

Having established that these outcomes bound the targeting in any equilibrium, a natural question is whether they can be obtained. The following result shows that when agents participate in the system for many periods (δ is high) the single-entry lottery approximately achieves no targeting. An intuition for this is that if agents are long-lived, then virtually all agents will use their (single) lottery ticket, and thus agents will match at nearly-equal rates. Furthermore, agents will wait for a very good match, and thus their match value will approach $v$.

When supply is scarce ($\mu$ is low), it is feasible to make a random offer to a subset of agents, and thus achieve (a scaled version of) the random offer mechanism. Additionally, this outcome is also approximately achieved by the repeated lottery, as the equilibrium lottery odds are so low that agents will enter lotteries even for buildings that are only marginally preferable to their outside option.

In order to state our results formally, we define a notion of convergence of outcome functions, which is simply point-wise convergence of outcomes after normalizing by their average match rate. This normalization is necessary because the equilibrium conditions in Definition 2 require that the average match rate $\pi^E = \mu$, so without normalization, as $\mu \to 0$ all equilibria converge to the (uninteresting) outcome in which nobody gets anything.

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13 In New York, there are lotteries for over 70 new developments each year, so if the average agent remains eligible and interested for at least 18 months, this suggests that $\delta > 0.99$. 
Definition 7 (Convergence of Outcomes). A sequence of outcome functions \{E_i\} is said to converge to an outcome \(E\) if for any \((\alpha, v)\) pair, \(\lim_{i \to \infty} E_i(\alpha, v) / \pi_i^E = E(\alpha, v) / \pi^E\).

Proposition 4 (Asymptotic Behavior of Single-Entry and Repeated Lotteries).

a) If \(\pi < \infty\), as \(\delta \to 1\), the unique equilibrium outcome of the single-entry lottery converges to no targeting (NT).

b) As \(\mu \to 0\), every sequence of equilibrium outcomes of the repeated lottery converges to random offer (RO).

Note that Proposition 4 does not mention perfect targeting. In fact, Proposition 3b) implies that perfect targeting is not attainable if one cannot force agents to take worse developments than their outside options. However, we will see in Section 5 that under a modification of the model, perfect targeting will be approximately attainable.

The results in this section, along with Theorem 4, imply that when agents are patient (\(\delta\) is high) and supply is scarce (\(\mu\) is low), the single-entry lottery is approximately welfare-optimal among all possible mechanisms\(^{14}\) when \(F\) is light tailed, and the repeated lottery is approximately welfare-pessimal. However, if \(F\) is heavy tailed and there are many agents with little need, then the reverse holds: the repeated lottery is approximately optimal, while the single-entry lottery is approximately pessimal.

5. Costly Participation

One potential criticism of our model is that it assumes that participating in the mechanism is costless. This has several implications: first, no agent has an incentive to voluntarily leave the system completely, and second, agents care only about what development they receive, and not when they receive it. In this section, we expand our model to include a per-period participation cost \(c \geq 0\). This participation cost should be interpreted as wasted effort, rather than as a transfer cost.

\(^{14}\) The space of possible mechanisms includes any that is non-atomic (individual agents have negligible effects on the market) and anonymous (agents can be differentiated only by actions taken or by chance, but not by their identity).
to the social planner – for example, participants may have to show up in person, or log on to a
website and complete an application form.

In Section 5.1 we note that many of our preceding results extend to the model with participa-
tion cost, and discuss how other results change. In Section 5.2 we note that costly participation
can be used as a design lever: it may improve targeting by discouraging less-needy agents from
participating.

5.1. Model with Participation Cost
Consider the modification of the model in Section 3 in which in every period, every agent who
remains in the system at the end of the departure step incurs a cost \( c \geq 0 \) before observing her
value for the current development. The presence of this cost may cause agents to endogenously
exit, and will affect the behavior of those who remain – when participation is costly, agents have a
larger incentive to “settle” for the current development. Nevertheless, given a matching rule and an
optimal strategy profile, the outcome function \( E \) is still well-defined, and the associated allocation
function \( \pi^E(\alpha) \) and match value \( v^E(\alpha) \) can be defined as in (1) and (3). However, the expected
utility must be modified as follows to account for the cost of participation:

\[
u^E(\alpha) = \pi^E(\alpha)(v^E(\alpha) - \alpha) - ct^E(\alpha), \tag{12}\]

where \( t^E(\alpha) \) is the expected number of periods that an agent of outside option \( \alpha \) participates in
the mechanism. It can be shown that any equilibrium outcome \( E \) uniquely determines the function
\( t^E \).

In the model with positive participation cost, many of our results extend without modification.
In particular, Theorems 1a) and 1c) hold: the repeated lottery remains equivalent to the waitlist
without deferral, and the ticket-saving lottery remains equivalent to the waitlist with deferral.
However, the single-entry lottery is no longer equivalent to these latter mechanisms, as participants

\[ \text{Proposition 2, which holds under the costly participation model with } u^E \text{ defined as in (12), implies that } t^E(\alpha) = \pi^E(\alpha)(v^E(\alpha) - \alpha) - \int_{\alpha}^{\infty} \pi^E(x) \, dx, \text{ and } \pi^E(\alpha) \text{ and } v^E(\alpha) \text{ are fully determined by the outcome function } E. \]
in the single-entry lottery now have an additional incentive to use their ticket early, and thus will set a lower threshold than they do in a waitlist with deferral.

After a suitable modification of match dominance\(^{16}\), the tradeoff between targeting need and matching identified in Theorem 3 continues to hold, as do the welfare comparisons in Theorem 4. Proposition 3(b) also continues to hold: perfect targeting and no targeting provide bounds on how effectively any mechanism can target need. By Theorem 4, they also imply bounds on the welfare generated by any mechanism. However, Proposition 3(b) no longer holds: even when there are many low-need individuals, participation costs make it possible to achieve more effective targeting than the random offer mechanism does. We discuss the implications of this fact below.

5.2. Improved Targeting via Participation Cost

Theorem 4 establishes that when

- some agents derive very little value from participating \((\alpha \geq \tau)\), and
- the distribution \(F\) of outside options is heavy-tailed,

then it is important to target participants with the most need, and to prevent the more fortunate from matching at high rates. Jointly, Propositions 3(b) and 4(b) imply that under the same two conditions, if there is a large mismatch between supply and demand, the repeated lottery achieves near-optimal targeting when participation is costless.

In this section, we show that if agents incur participation cost, then it is possible to achieve even better targeting. In fact, the best targeting is achieved when the participation cost is so high that all agents who are willing to participate are offered any development they want (while ensuring that enough agents participate to fill all developments). We say that such a participation cost is market-clearing.

**Definition 8.** Participation cost \(c\) is said to be market clearing if under this participation cost, the average match rate under the guaranteed choice matching rule is equal to the supply-demand ratio \(\mu\). An outcome is said to be a costly guaranteed choice outcome if it can be

\(^{16}\) Under costly participation, the new definition of match dominance is as follows: outcome \(E\) match dominates \(E'\) if the per-match utility for each agent type that participates in both mechanisms is higher in \(E\) than in \(E'\). That is, \(u^E(\alpha)/\pi^E(\alpha) \geq u^{E'}(\alpha)/\pi^{E'}(\alpha)\) at every \(\alpha\) such that the denominators are both positive.
expressed as an equilibrium outcome of the guaranteed choice matching rule under a market clearing cost \( c \).

Note that under a market clearing participation cost \( c \), all five mechanisms studied in this paper have an unique equilibrium outcome, which is the costly guaranteed choice outcome. We show in Appendix D that a market clearing cost \( c \) always exists, although it may not be unique.

**Proposition 5 (Asymptotic Behavior of Costly Guaranteed Choice).** Suppose that \( \nu < \infty \). As \( \delta \to 1 \), then any sequence of costly guaranteed choice outcomes converges to perfect targeting.

The intuition for Proposition 5 is that if agents remain in the system for many periods, then almost everyone who chooses to participate will eventually find a development that they are willing to accept. Moreover, the agents who choose to participate will be those with the greatest need – less needy agents will prefer not to participate.

In fact, even if agents are relatively short-lived, costly guaranteed choice often targets need more effectively than does the costless repeated lottery. In Appendix D, we show that this is the case if \( G \) is light-tailed or if \( \mu \) is sufficiently small.

The results in this section imply that if the social planner can control the participation cost, then it is rarely a good idea to use a costless repeated lottery: one should either use a costless single-entry lottery (or an equivalent mechanism) to achieve good matching, or use any mechanism in this paper with a suitably high participation cost to target need.

6. Discussion

We consider settings where a limited number of items are allocated to a large number of waiting agents with heterogeneous and privately known outside options. We highlight several insights.

1. When there is a large imbalance between supply and demand, the repeated lottery and the waitlist without deferral do a poor job of matching agents to developments that fit their needs. Agents receive better matches under any of the following reforms:
   a) limiting lottery entry,
b) allowing lottery tickets to be saved, or

c) allowing agents in a waitlist to reject offers without penalty.

2. Without directly observing outside options, it is not possible to simultaneously target agents with high levels of need and provide them with good matches.

3. The repeated lottery and waitlist without deferral are generally not advisable, especially if implemented with low participation cost. In most cases, it is better to use a system that encourages agents to be more selective. In the remaining cases, it is better to increase participation costs until supply equals demand.

Although the model that we use includes many simplifying assumptions, each of the above insights is supported by broader reasoning, which does not rely on fine-grained modeling details.

The reasoning behind the first insight is as follows: in a repeated lottery or waitlist without deferral, agents will accept anything better than their continuation value, which is approximately equal to their outside option if supply is scarce. Limiting lottery entries or allowing tickets to be saved induces an opportunity cost for entering today’s lottery, so agents remain selective even when supply is scarce. Similarly, allowing agents to keep their position in a waitlist after turning down an offer ensures that those who receive an offer have a high continuation value. All of these arguments continue to apply in a world where buildings are inherently asymmetric, agents are eligible for only a subset of developments, and agents have information about their value for future developments.

Our claim that there is a tradeoff between matching and targeting (insight #2 above), and our conclusions about when to prioritize each objective (insight #3) should hold quite generally, so long as outside options are private information. This is because any option offered to needy agents must also be available to those with less need, so efforts to benefit the former necessarily attract the latter. More precisely, Theorems 3 and 4 – which underpin these insights – can be extended

\[17\] In the case with ex ante heterogeneous developments, the argument that agents are not picky under the repeated lottery applies as long as each development is popular enough that the odds of obtaining each development is low.
to any game in which agents implicitly choose from a menu of \((\pi, v)\) tuples, where \(\pi\) denotes the probability of matching, and \(v\) the expected value conditioned on matching. The proof does not depend on how this menu is generated: developments may be heterogeneous, agents may learn their values in advance, and the designer may use agent actions to draw inferences about agent values and guide the allocation.

We conclude that the repeated lottery is rarely the right solution: it incentivizes poor matching, and there are typically better ways to target need than by making offers at random and hoping that less-needy agents will reject them. For example, observable information can be used to explicitly exclude less-needy individuals, and participation costs can discourage them from participating. For the allocation of affordable housing in New York, the simple change of restricting the number of lotteries that any individual can enter each year would help to ensure that people are matched to developments that best fit their needs.

\[18\] One important caveat in adding participation costs is that the designer should ensure that the type of cost added does not disproportionately impact needy agents. For example, if wealthier applicants are systematically more adept at filling out forms, or more able to take an afternoon off of work, then adding paperwork to the application process or mandating physical presence may have the opposite of the desired effect. Alatas et al. (2016) and Deshpande and Li (2017) explore this concern using (quasi-)random experiments to empirically estimate the effect certain types of frictions have on various sub-populations.
All appendices below can be found in the full-length version of the paper, available on SSRN:


Appendix A: Formal Development of the Matching MDP
Appendix B: Alternate Payout Models
Appendix C: Proofs
Appendix D: Conditions for Costly Guaranteed Choice Screening Dominating Costless Repeated Lottery
Appendix E: Conditions for Strong Targeting Dominance

References


