A simple model

- Continuous time, stationary and non-atomic supply and demand
- Destinations: \( D = \{1, 2, \ldots, D\} \)
- Arrival rate of riders to destination \( i \in D \)
- Riders’ patience level: \( P > 0 \), a rider will cancel trip request after \( P \) driver declines
- Arrival rate of drivers: \( \lambda \), Opportunity cost of driver’s time: \( c \)
- Net earnings from a trip to location \( i \in D \): Assume \( w_1 > w_2 > \cdots > w_{D} > 0 \)

**EQUILIBRIUM OUTCOME UNDER STRICT FIFO**

- Driver at the head of the queue: accept only trips to location 1 (i.e. highest earning trips). First position in the queue willing to accept location 1 trips: \( N_1 = 0 \).
- In comparison to location 2, a driver is willing to wait for an additional \( r_{21} \) periods for a trip to location 1. We know \( w_1 - r_{21} c = w_2 \Rightarrow r_{21} = (w_1 - w_2)/c \).
- Little’s Law: first position willing to accept location 2 trips \( N_2 = \lambda/\mu \).
- Can similarly find the first position \( N_i \) where driver is willing to go to location \( i \geq 3 \).
- With rider patience level \( P \), a location 3 trip (offered to drivers starting from the head of the queue under strict FIFO) is canceled by the rider after \( P \) declines.
- All trips to location \( i \) with \( N_i > P \) are unfulfilled—poor revenue and throughput.

**THE DIRECT FIFO MECHANISM**

Direct FIFO. Dispatch location \( i \) trips starting from the \( N_i^{th} \) position in the queue.

**Theorem.** It is a subgame-perfect equilibrium (SPE) for drivers to accept all dispatches from direct FIFO. The equilibrium outcome is ex-post envy-free.

**Discussion.** The option to skip the rest of the line incentivizes drivers further from the head of the queue to accept lower earning trips.

**THE RANDOMIZED FIFO MECHANISM**

A randomized FIFO mechanism is specified by \( P \) ‘bins’. A trip is first dispatched to a driver in the first bin \( [b_0, b_1) \) uniformly at random. If declined for \( b_{k-1} \rightarrow b_k \), then for the \( b_k \) time a trip request is dispatched, select a random driver from \( [b_k, b_{k+1}) \).

**Theorem.** Randomized FIFO achieves the second best in Nash equilibrium.

**Discussion.** When drivers are straightforward, drivers closer to the head of the queue are prioritized for trips to any destination—fair, and robust to idiosyncratic preferences.

- Randomization increases the waiting times for the next dispatch (vs. the driver at the head of the queue under direct FIFO), raising the costs of cherry-picking.
- Drivers who have waited longer in the queue (i.e. earlier bins) will accept higher earning trips → small variance/uncertainty in drivers’ net payoffs.

**SIMULATION RESULTS**

- Data from the City of Chicago
- Ridesharing trips originating from Chicago O’Hare, Nov. 2018 - Mar. 2020
- A total of around 800 destinations (census tracts in Chicago)

**The first best.** Drivers are dispatched upon arrival to locations in dec. order of \( w_i \).

**Varying arrival rate of drivers \( \lambda \)**

Total rider arrival rate: 12 per min; Assuming rider patience \( P = 12 \)

**Varying rider patience level \( P \)**

Fixing rider arrival rate at 12 per min, and driver arrival rate at 10 per min

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**HETEROGENEOUS EARNINGS & IMPATIENT RIDERS**

- Loss of reliability, revenue and trip throughput under FIFO dispatching
- Heterogeneity in earnings by destination: long trips pay substantially more
- Drivers who have waited longer in the queue (i.e. in earlier bins) will accept higher earning trips
- Some trips are necessarily more lucrative than the others
- Difficult to reduce earnings from long trips due to minimum time/distance rates
- Suboptimal to increase fares of short trips to match the earnings from long trips

This work: align incentives and reduce earning inequity using *waiting times*, when we do not have the power to tell drivers what to do, or the full flexibility to set prices.