Regulating Transportation Network Companies:
Should Uber and Lyft Set Their Own Rules?

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Rise of the TNCs

- **Rapid growth of Transportation Network Companies (TNC)**
  - Uber founded in 2009, San Francisco
  - Estimated value of Uber in 2019: $80B
  - 45,000 TNC drivers in SF, 487,000 SF labor force
  - Competitors: DiDi (China, Latin America), Ola (India), Grab (Singapore) ...

- **TNCs have disrupted urban transportation:**
  - Aug 2018 in NYC, 558K TNC trips vs 275K taxi trips per day [1]
  - 97K registered TNC vehicles vs 16K yellow cabs in NYC [1]
  - 3 million active Uber drivers globally, 750K in US [1]
  - 15M Uber rides daily in 2017 [1]
  - Average NYC business trip cost $24.22 + $4.03 tip
  - Uber generated US consumer surplus estimated at $6.8B in 2015 [2].

Criticisms and Regulation

- **TNC criticisms**
  - Taxi drivers are hurt by TNC competition
  - TNC drivers paid sub-minimum wage:
    - after expenses, drivers earn $14.25/hour in NYC [3] (minimum wage $15/hour) while facing most of the business risk
  - Public transit loses passengers
  - Private car owners are unhappy
    - TNCs caused 50% of increase in congestion in SF during 2010-2016 [4].

- **Cities starting to regulate TNC**
  - In Dec 2018, New York became the first US city to
    - freeze new TNC vehicle registrations for one year
    - set minimum wage for TNC drivers at $17.22/hour
  - London court ruled TNC drivers as employees; under appeal
  - CA supreme court ABC test for gig workers
  - Seattle considering similar rules to raise driver pay

[3] Parrott and Reich, An earning standard for new york city’s app based drivers: economic analysis and policy assessment, 2018
[4] SF transportation authority, TNC&Congestion, 2018
Lyft Financials for 2018

- Bookings = $8.1B, Drivers get $5.9B (72%), Revenues = $2.2B. Driver net wages = 62% of gross = $3.7B
- Total rides in 2018 = 619M

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Per ride</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bookings (Fares collected)</td>
<td>$8.1B</td>
<td>$13.00</td>
</tr>
<tr>
<td>Drivers gross (net)</td>
<td>$5.9B ($3.7B)</td>
<td>$9.50 ($5.90)</td>
</tr>
<tr>
<td>Revenues</td>
<td>$2.2B</td>
<td>$3.50</td>
</tr>
<tr>
<td>Cost of revenues</td>
<td>$1.24B</td>
<td>$2.00</td>
</tr>
<tr>
<td>Loss</td>
<td>$0.91B</td>
<td>$1.47</td>
</tr>
<tr>
<td>Total cost = Rev + Loss</td>
<td>$3.06B</td>
<td>$4.97</td>
</tr>
</tbody>
</table>

Cost of revenue = insurance costs required under TNC and city regulations for ridesharing + payment processing charges, including merchant fees and chargebacks (returns), + hosting and platform related technology costs (AWS). Driver + Cost of revenues = minimum cost of service = 88% of bookings. So gross margin is 12%. To make this 50% need to raise fares by 77%
This talk will:
- explain how regulations affect the TNC marketplace (platforms, drivers, passengers, etc)
  - Earning of drivers
  - Cost to passengers
  - Profit of platform

Focus on three regulations:
- Cap on number of TNC vehicles
- Minimum wage of TNC drivers
- Congestion surcharge on TNC rides
Goal:
- predict the decisions of platform, passengers, drivers
- calculate how decisions are affected by exogenous regulation

Focus:
- platform pricing
- market response
Market Response-Demand Model

- Passenger model:
  - Each passenger faces a trip cost = value of pickup time + trip price \[c = \alpha t + \beta p_1\]
    - \(t\) is pickup waiting time
    - \(p_1\) is the per-mile price
  - Each passenger has a reservation cost
    - captures the cost of alternatives (public transit, walking, etc)
    - CDF function: \(F_p(c)\)

- Demand function:
  \[\text{arrival rate of TNC passengers} = \text{arrival rate of all potential passengers} \times \text{proportion of passengers who take TNC}\]

Market Response-Demand Model

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  - Each passenger has a reservation cost
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- Demand function (new passengers per minute) \( \beta \) includes average trip length:
  \[ \lambda = \lambda_0 \left( 1 - F_p(\alpha t + \beta p_1) \right) \]
Market Response-Supply Model

- Driver model:
  - The hourly earning (wage rate) of each driver is:
    \[ r = \frac{p_2 \lambda}{N} \]
  - \( p_2 \): per-mile payment to drivers
  - \( N \): total number of TNC drivers
  - Each driver has a reservation wage
    - CDF function: \( F_d(r) \)

- Supply function
  \[ N = N_0 F_d \left( \frac{p_2 \lambda}{N} \right) \]

- Market equilibrium equation
  \[ \lambda = \lambda_0 \left( 1 - F_p(\alpha t + \beta p_1) \right) \]
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- Proposition: the pickup time satisfies
  \[ t = \frac{c}{\sqrt{N - \lambda / u}} \]
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- Proposition: the pickup time satisfies
  \[ t = \frac{c}{\sqrt{N-\lambda/u}} \]
Numerical Solutions

\[
\begin{align*}
\max_{p_1, p_2} & \quad \lambda(p_1 - p_2) \\
\text{s.t.} & \quad \lambda = \lambda_0 \left(1 - F_p \left(\alpha \frac{c}{\sqrt{N-\lambda/u}} + \beta p_1\right)\right) \\
& \quad N = N_0 F_d \left(p_2 \lambda / N\right)
\end{align*}
\]

- solve under different \(\lambda_0\)
- \(F_p\) and \(F_d\) uniform distributions
- Parameters tuned to match realistic data of SF city

Real Data of San Francisco City [1]
- Number of passenger / minute: \(\lambda = 141\)
- Average number of drivers: \(N = 3200\)
- Ride price: 11.4 $/ trip
- Driver pay: 6.9$/ trip
- Driver hourly wage: 18.3$/hour

[1] TNCS today: A profile of San Francisco Transportation Network Company Activities, 2017
Numerical Solutions (unregulated case)

As potential passengers double

- Cost per ride $p_1$ increases by 15% from $9.9$ to $11.4$
- Driver payment $p_2$ increases 13% from $6.1$ to $6.9$ per ride

\[ \max_{p_1, p_2} \lambda (p_1 - p_2) \]
\[ \text{s.t. } \lambda = \lambda_0 \left( 1 - F_p \left( \frac{c}{\sqrt{N - \lambda/u}} + \beta p_1 \right) \right) \]
\[ N = N_0 F_d (p_2 \lambda / N) \]

- solve under different $\lambda_0$
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Graph showing the price per trip ($/trip$) as a function of potential passenger rate (passenger/min) in SF.
Numerical Solutions (unregulated case)

As potential passengers double
- Driver wage increases by 41% from $13.2 to $18.6 per hour
Numerical Solutions (unregulated case)

\[ \max_{p_1,p_2} \lambda (p_1 - p_2) \]

s.t. \( \lambda = \lambda_0 \left( 1 - F_p \left( \alpha \frac{c}{\sqrt{N-\lambda/u}} + \beta p_1 \right) \right) \)

\[ N = N_0 F_d \left( p_2 \lambda / N \right) \]

- solve under different \( \lambda_0 \)
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As potential passengers double
- Occupancy increases 23% from 43% to 53%
TNC scale economies (NYC, unregulated)

- As number of potential passengers doubles from 500 to 1,000 rides per minute, the cost per ride increases by 11 percent from $2.4 to $2.7 per mile, driver payment increases by 6.6 percent from $1.4 to $1.5 per mile, platform share increases 20 percent from $1 to $1.2 per mile.

- Driver wages increase 29 percent from $17 to $24 per hour because driver utilization increases by 25 percent from 0.4 to 0.5.

- By the same token, in the absence of a wage floor, a driver’s hourly wage declines by 29 percent from peak to off-peak hours. Further, platform share increases 20% from $1 to $1.2 per mile.
Profit-Maximizing TNC (Cap Constraint)

- Platform profit:
  \[ R_p = \lambda(p_1 - p_2) \]

- Platform decision:
  - Maximize profit subject to market equilibrium equations and \textit{cap constraint}
    \[ \max_{p_1, p_2} \lambda(p_1 - p_2) \]
    \[ \text{s.t. } \lambda = \lambda_0 \left( 1 - F_p \left( \alpha \frac{c}{\sqrt{N-\lambda/u}} + \beta p_1 \right) \right) \]
    \[ N = N_0 F_d(p_2 \lambda/N) \]
    \[ N \leq \text{Cap} \]

- Theorem:
  - First order condition is sufficient for global optimality.
  - First order conditions admits a unique solution.
Numerical Solutions (Cap Constraint)

- Results under cap constraints

\[
\begin{align*}
\max_{p_1, p_2} \lambda (p_1 - p_2) \\
\text{s.t. } \lambda &= \lambda_0 \left( 1 - F_p \left( \alpha \frac{c}{\sqrt{N - \lambda/u}} + \beta p_1 \right) \right) \\
N &= N_0 F_d (p_2 \lambda/N) \\
N &\leq \text{Cap}
\end{align*}
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- solve under different caps
- \( F_p \) and \( F_d \) uniform distributions
- Parameters tuned to match realistic data of SF city
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### Graphs

- **Number of drivers vs. Cap**
  - Linear relationship
  - \(1000 \leq \text{Cap} \leq 3000\)
  - \(1000 \leq \text{Number of driver} \leq 3000\)

- **Ride Arrival Rate vs. Cap**
  - Linear relationship
  - \(1000 \leq \text{Cap} \leq 3000\)
  - \(50 \leq \text{Ride Arrival Rate} \leq 150\)
Numerical Solutions (Cap Constraint)

- Results under cap constraints

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\max_{p_1, p_2} \lambda(p_1 - p_2)
\]

\[
s.t. \lambda = \lambda_0 \left(1 - F_p \left(\alpha \frac{c}{\sqrt{N-\lambda/u}} + \beta p_1\right)\right)
\]

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N = N_0 F_d \left(p_2 \lambda/N\right)
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N \leq \text{Cap}
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Graphs showing occupancy rate and ride price per mile as functions of cap.
Numerical Solutions (Cap Constraint)

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Graphs showing:
- Driver payment/mile vs. Cap
- Driver Wage/hour vs. Cap
Numerical Solutions (Cap Constraint)

- Results under cap constraints

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Graphs showing:
- Platform revenue against cap, approximately linear
- Social welfare against cap, increasing

Graphs range from 1000 to 3000 on the x-axis, with y-axis values ranging as indicated by the labels.

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Profit-Maximizing TNC (wage floor)

- Platform profit:
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- Platform decision:
  - Maximize profit subject to market response equations and wage constraint

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\[
N = N_0 F_d(p_2 \lambda/N)
\]
\[
w \leq p_2 \lambda/N
\]
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Numerical Solutions (wage floor)

- Results under wage floor

\[
\max_{p_1, p_2, N} \lambda (p_1 - p_2)
\]

s.t. \( \lambda = \lambda_0 \left( 1 - F_p \left( \alpha \frac{c}{\sqrt{N-u}} + \beta p_1 \right) \right) \)

\[ N \leq N_0 F_d (p_2 \lambda / N) \]

\[ w \leq p_2 \lambda / N \]

- solve under different wage floors
- \( F_p \) and \( F_d \) uniform distributions
- Parameters tuned to match realistic data of SF city

Figure 1

Figure 2
Numerical Solutions (wage floor)

- Results under wage floor

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s.t. \( \lambda = \lambda_0 \left( 1 - F_p \left( \frac{c}{\sqrt{N - \lambda/u}} + \beta p_1 \right) \right) \)

\( N \leq N_0 F_d (p_2 \lambda / N) \)

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Numerical Solutions (wage floor)

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\begin{align*}
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& \quad w \leq p_2 \lambda / N
\end{align*}
\]

- solve under different wage floors
- \( F_p \) and \( F_d \) uniform distributions
- Parameters tuned to match realistic data of SF city
Numerical Solutions (congestion surcharge)

- Results under congestion surcharge

\[
\max_{p_1, p_2, N} \lambda(p_1 - p_2)
\]

s.t. \( \lambda = \lambda_0 \left( 1 - F_p \left( \alpha \frac{c}{\sqrt{N - \lambda/u}} + \beta p_1 + p_3 \right) \right) \)  

\( N = N_0 F_d(p_2 \lambda/N) \)

- Solve this problem for different values of congestion surcharge
- Tune parameter to match SF data

![Graph showing the relationship between tax and number of passengers](image1)

![Graph showing the relationship between tax and number of drivers](image2)
Numerical Solutions (wage floor + surcharge)

- Results under congestion surcharge and wage floor

\[
\max_{p_1, p_2, N} \lambda (p_1 - p_2)
\]

s.t. \( \lambda = \lambda_0 \left( 1 - F_p \left( \alpha \frac{c}{\sqrt{N - \lambda/u}} + \beta p_1 + p_3 \right) \right) \)

\( N \leq N_0 F_d (p_2 \lambda/N) \)

\( w \leq p_2 \lambda/N \)

- Fix wage floor \( w = 17.2 \$/hour \)
- Solve this problem for different values of tax

![Graph showing the relationship between number of drivers, platform revenue, and tax](image)
Numerical Solutions (wage floor + surcharge)

- Results under wage floor and a congestion surcharge

\[
\max_{p_1, p_2, N} \lambda (p_1 - p_2) \\
\text{s.t. } \lambda = \lambda_0 \left(1 - F_p \left(\alpha \frac{c}{\sqrt{N - \lambda / u}} + \beta p_1 + p_3\right)\right) \\
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- Fix wage floor $w = 17.2$/hour
- Solve this problem for different values of tax

\[
\begin{array}{c}
\text{Number of driver} \\
\text{number of passenger}
\end{array}
\]

\[
\begin{array}{c}
\text{Tax ($/trip)} \\
\text{Tax ($/trip)}
\end{array}
\]
Numerical Solutions (wage floor + surcharge)

- With surcharge

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- Without surcharge

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\( w \leq p_2 \lambda / N \)
Extensions of the Model

- **Platform subsidy**
  - Objective is to maximize market share for fixed subsidy or loss, decrease $p_1$ or/and increase $p_2$
  - Subsidize passengers more than drivers

- **Platform competition**
  - More than one platform
  - Need behavior model

- **Autonomous vehicles**
  - Cost of AV today much higher than driver cost
  - AV today not safe enough
Conclusion

- TNC business model requires market power and unorganized driver pool

- Higher minimum wage (up to a limit) increases number of drivers and passengers, and reduces platform rents

- Cap on number of drivers hurts drivers, passengers and platform

- Congestion charge reduces number and wage of drivers

- But with minimum wage congestion charge does not reduce number of drivers
Thank you!