Peeking Beneath the Hood of Uber
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Northeastern University
What is Uber?

• Select a pickup location
• Choose type of car
  • UberX: cheap sedan
  • UberSUV: cheap SUV or van
  • UberBlack: fancy sedan
  • UberXL: fancy SUV
  • UberPool: car pool with some randos
  • Etc...
• Request and ride away
Simple and Convenient, Except...
Marketplaces

Transparent
- Suppliers set their own prices
- Customers may observe all products and their prices

Opaque
- Supply and demand are hidden from customers
- Suppliers do not choose their own prices
- Prices are set by an algorithm
Is Uber Surge Pricing Fair?

How to never get slammed with Uber surge pricing again

Detest Uber’s surge pricing? Some drivers don't like it either

The practice of tripling, quadrupling and quintupling ride fares in times of high demand may face limits from New York City officials. Many drivers might be OK with that.

Uber's surge pricing is good for you, Uber study says

by Kia Kokalitcheva @imklialthecar SEPTEMBER 17, 2015, 8:58 PM EDT
Goals

• Determine how the surge pricing algorithm works
  • Does it work the way Uber claims?
  • Is it responsive to changes in supply and demand?

• Can surges be predicted and/or avoided?

• Impact of surges on drivers and passengers
Data Collection
Measuring Surges
Avoiding Surges
Impact of Surges
Conclusions
Data Collection

• Uber’s official surge pricing patent says the calculation is based on supply, demand, and other factors

• How can we collect this data?
  1. Uber API
     • Pros: easy to use, includes surge multipliers and Estimated Wait Times (EWT)
     • Cons: no cars, demand, or supply information
  2. Uber Rider App
Uber App

- Pings Uber’s servers every 5 seconds
- 8 nearest cars
- Estimated Wait Time (EWT)
- Surge multiplier
Limitations

• Measuring supply is straightforward
  • Supply = observed cars on the road

• Measuring demand is tricky
  • Cars may get booked...
  • Or just go offline...
  • Or drive out of the area

• We can only estimate demand
  • Fulfilled demand = number of cars that go offline
    • Upper bound on true fulfilled demand
Limited Visibility

Recall: the Uber app only sees the 8 closest cars

3pm on Sunday
Limited Visibility

How far apart should we place our measurements points?

5pm on Monday
Radius Measurements

Cars observed by all apps:
Final Data Collection

- Collected four months of data from Midtown Manhattan and San Francisco
  - 2 months from each city, 43 measurement points
  - 2\textsuperscript{nd} and 3\textsuperscript{rd} largest Uber markets
  - Very different public transport options

- Radius experiments
  - 247 meters in Midtown Manhattan
  - 387 meters in downtown San Francisco

- Validated methodology using ground-truth data from NYC taxis
  - Built an “Uber simulator” and used our methods to measure the taxis
  - Observed 97% of supply and 95% of demand
Example Measurement Grid

- 43 measurement points
- Collected 2 months of data in Midtown
Ethics

• We did not collect any personal information about Uber drivers or passengers

• We never booked any rides

• We did not induce any surges
  • We placed 40 “users” in random locations with no surge, in the middle of the night
  • Did not observe surges for one hour
  • Repeated 100 times at different locations and hours
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Research Questions

• How much and how often does it surge?
• How long do surges last?
• How do surge prices vary by location?
• What features does Uber use to calculate surge prices?
How much does it surge?

- 14% of the time it is surging in Manhattan
- 57% of the time in SF
- Surge multipliers tend to be higher in SF
How long do surges last?

- Noisiness: 70% of surges last <=10 minutes
- Staircase: surges last multiples of 5 minutes
How does surge vary by location?
How is surge calculated?

- Many possible variables
  - Supply, demand, EWT, etc.
- Use cross-correlation to perform time-series analysis

![Diagram showing match and no match with surge and supply over time]

- High correlation at -10 minutes
Cross-correlation

(Supply – Demand) vs. Surge

- Moderately strong correlations when time difference is zero
  - Suggests Uber uses data from the last 5 minute window when calculating surge

- Zero correlation in other time windows
  - Surge pricing algorithm is responsive but noisy

EWT vs. Surge
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Can we predict surges?

• Useful variables
  • Supply, demand, EWT
  • Previous surge multiplier(s)

• Predictive models
  • Linear and non-linear regressions

• Performance
  • $R^2$ ranges from 0.37 – 0.57
  • These results are terrible, i.e. we cannot reliably predict surges

• Missing some key variable(s)
  • Unfulfilled demand: how many people tried to book a ride but couldn’t?
Avoiding Surges

No Surge! EWT = 6 min

No Surge! EWT = 3 min

Surge Pricing:
Demand is off and prices have increased to get more drivers on the road.

1.75x Normal Rate

2.0x Normal Rate
Avoiding Surges

- 10-15% chance you’ll save money
- Savings up to 50% by avoiding surges
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Impact on Supply and Demand

• Why did Uber implement surge pricing?
  • To equalize supply and demand
  • Reduce demand by raising prices
  • Increase supply by incentivizing drivers

• In economic terms, surge pricing is about incentives

• Are the incentives provided by the surge pricing system working?
State Transitions

- If one area is surging, we expect the following five things to happen:
  1. (Supply) **New**: cars should prefer to come online in the surging area
  2. (Supply) **Move-in**: cars should drive into the surging area
  3. (Supply) **Move-out**: few cars should drive out of the surging area
  4. (Demand) **Booked**: fewer cars should get booked in the surging area
  5. (Demand) **Old**: more cars that began in the surge area should remain after 5 minutes
Comparing State Transitions

<table>
<thead>
<tr>
<th>State</th>
<th>Change When Area is Surging</th>
<th>Expected?</th>
</tr>
</thead>
<tbody>
<tr>
<td>New</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Move-in</td>
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*Lee et al.* surveyed Uber drivers and found that experts “do not chase surges”
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Summary

• First systematic audit of Uber’s surge pricing algorithm
  • Prices update every 5 minutes
    • 70% of surges last <= 10 minutes
  • Uber divides cities into surge areas
    • May save significant money by walking into an adjacent area
  • Supply and demand do correlate with surge pricing

• Results call the surge pricing system into question
  • Very effective at suppressing demand
  • Not effective at incentivizing short-term behavior of drivers
From:  
Date:  October 29, 2015 at 9:53:05 PM GMT+9  
To: leonchen@ccs.neu.edu, amislove@ccs.neu.edu, cbw@ccs.neu.edu  
Subject: Uber surge research

Hello, I just read your interesting research on Uber's surge pricing. I agree with your findings. Since I started driving for Uber, I have found its surge pricing the most annoying thing to deal with. It is mostly fake for drivers. If you think that there is a surge in a certain area start driving towards that area, you will just waste time and fuel as it will quickly disappear even if it shows 4 or 5X surge. You may think that there is surge. It usually disappears in a few minutes or even seconds. Uber is scam. They fix everything and have denied us the right to offer our service at a negotiated price. They are the ones who control pricing without the cost of operating vehicles and the risks involved.

Surge pricing is a scam that cheats passengers, mostly when they are drunk, and drivers.

Thank you for the eye opening research. Next time ask the drivers and they will tell you how much they hate it.
The Bug

- In April 2015, Uber users began to receive incorrect surge multipliers at random times.
- Uber confirmed this was a consistency bug in their systems.
- Pricing bug existed for over 6 months, only corrected because of our study.
Growing up, all I knew about my dad’s work was that he “kept the lights on.” It’s probably an apt description for most work: it keeps the lights on. But in my dad’s case, it was the simplest way to explain that he worked on electric power systems, a topic too complex to explain to an eight-year-old.
The Lawsuit

Uber CEO must face price-fixing lawsuit by passengers: U.S. judge

- Both sides have filed briefs that heavily cite our paper
- One side uses our data to claim Uber is fixing prices
- The other uses our results to claim the opposite...
Thanks!

Questions?

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