The Impact of Behavioral and Economic Drivers on Gig Economy Workers

INFORMS 2018

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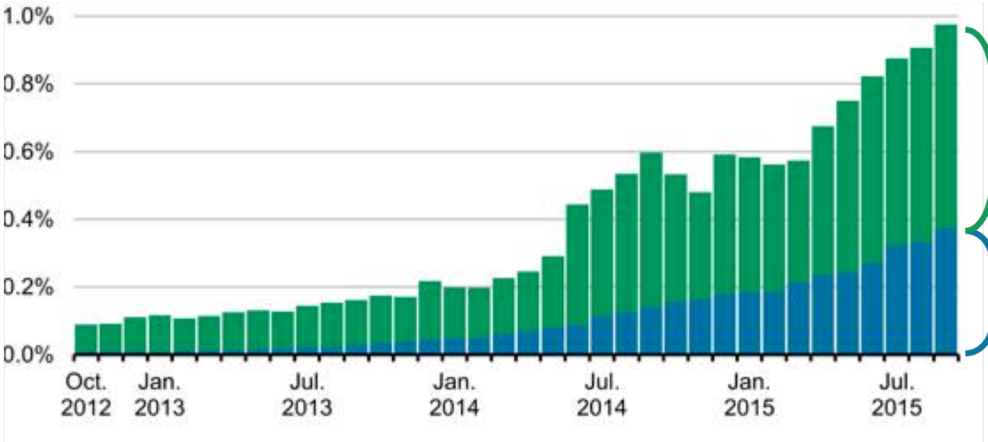
Share of US adults earning income in a given month via online platforms

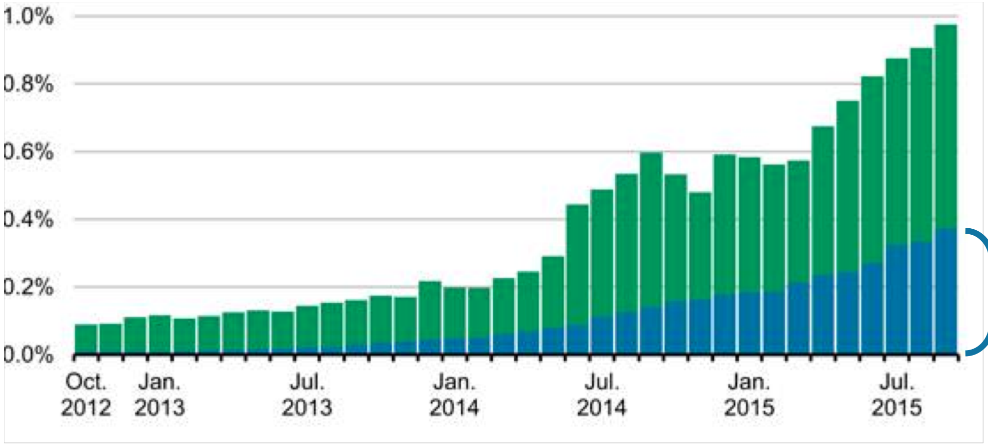


Capital Platforms
AirBnB, eBay, ...

Labor Platforms
Uber, TaskRabbit, ...

Gig Economy

Share of US adults earning income in a given month via online platforms



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Gig Economy

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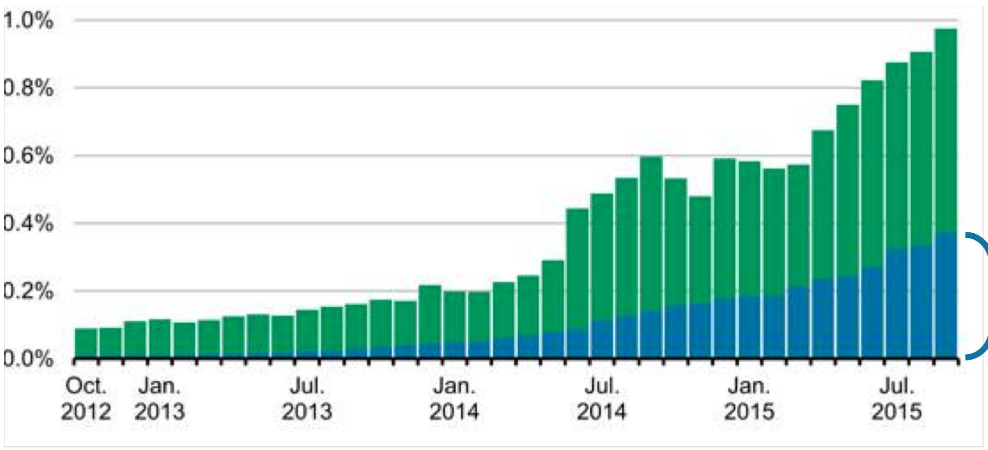


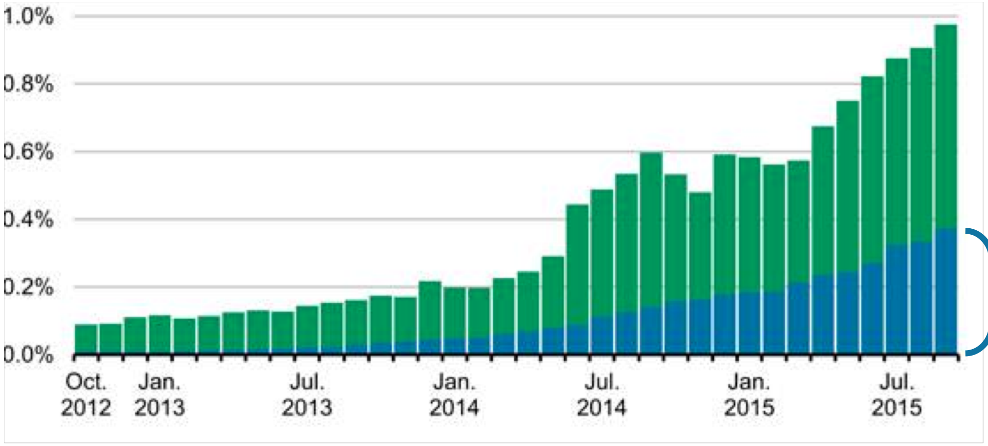
2015

44M people

in the US took on gig work (34%)

Gig Economy

Share of US adults earning income in a given month via online platforms



2015

44M people

in the US took on gig work (34%)

2027

Boost global GDP by $2.7 trillion

Gig work will become workforce majority

Who are Gig Workers?

70% by choice

44% primary income

~50% millennials

2016 McKinsey Global Institute

Who are Gig Workers?

70% by choice

44% primary income

~50% millennials

when to work?

how long?

which platforms?

Who are Gig Workers?

70% by choice

44% primary income

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when to work?

how long?

which platforms?

Workers decide work schedules

Gig Company

Supply $\xleftrightarrow[\text{real-time}]{\text{match}}$ Demand

independent/flexible
on-demand

Gig Company

Supply ⟷ Demand

match

real-time

independent/flexible

on-demand

Workforce planning is challenging

Research Questions

How do gig economy workers make labor decisions?

Research Questions

How do gig economy workers make labor decisions?

How can the platform influence their decisions?

Outline

- What has been done?

  Practice / labor economics / OM

- Data and empirical strategy

  Dealing with endogeneity and selection bias

- Results

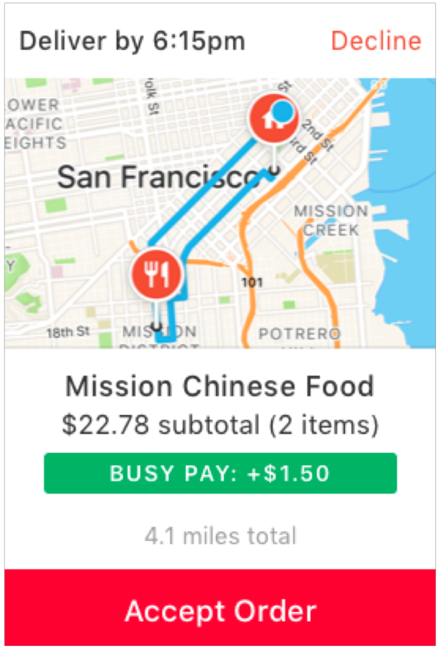
  Impact of incentive and behavioral elements on labor decisions

- Implications

  Simulation of optimal incentive re-allocation

In Practice

Real-time "surge pricing"

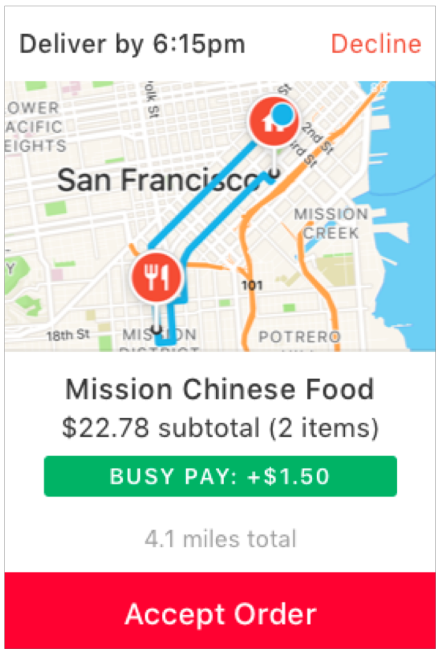


DOORDASH

https://dasherhelp.doordash.com/busy-pay

In Practice

Real-time “surge pricing”



DOORDASH

Pre-announced bonus

5:00 PM–6:00 PM
+10% (5:00pm - 5:30pm)
+30% (5:30pm - 6:00pm)

6:00 PM–7:00 PM
+30% (6:00pm - 6:30pm)
+40% (6:30pm - 7:00pm)

caviar

https://dasherhelp.doordash.com/busy-pay
https://courierhelp.trycaviar.com/customer/en/portal/articles/2821000-peak-hour-pay?b_id=9619/

In Practice

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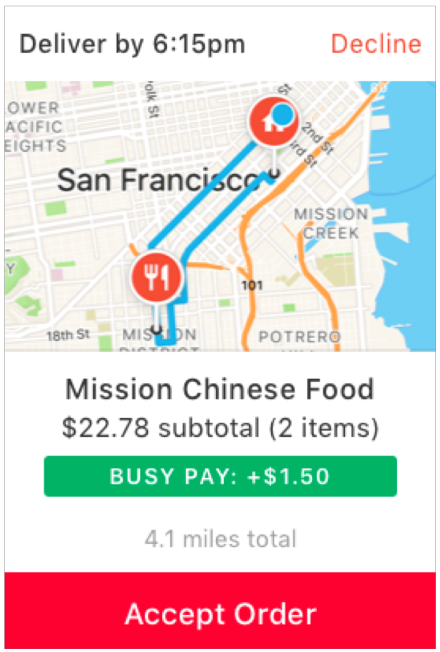

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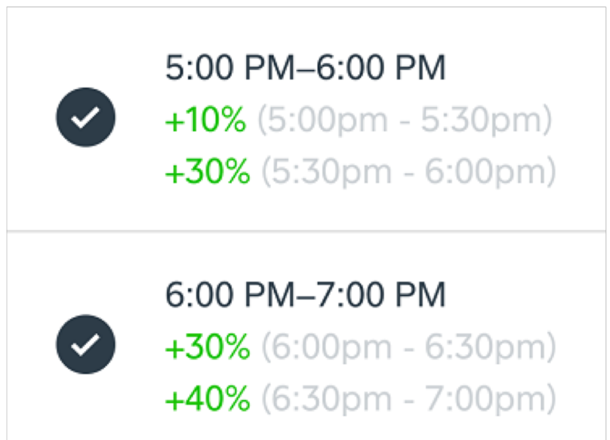
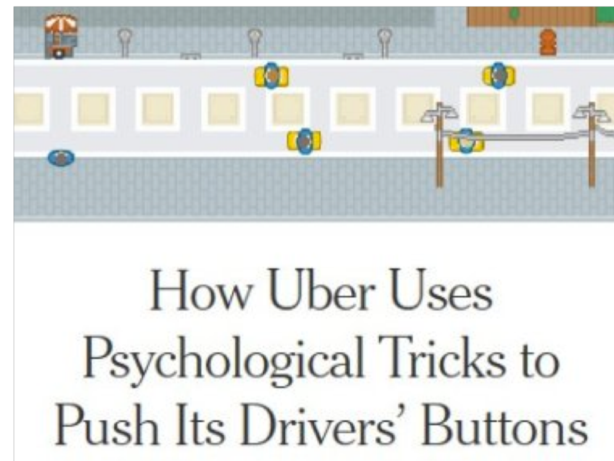


caviar

"You're so close to your precious target"



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https://nytimes.com/interactive/2017/04/02/technology/uber-drivers-psychological-tricks.html

Theories of Labor Supply

Neoclassical

- Maximize lifetime utility

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Neoclassical

- Maximize lifetime utility
- **Positive** income elasticities

Wage ↑

Work more

Theories of Labor Supply

Neoclassical

- Maximize lifetime utility
- **Positive** income elasticities

Carrington (1996)

Oettinger (1999)

Wage ↑
Work more

Stafford (2013)

Chen/Sheldon (2016)
Sheldon (2016)

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Carrington (1996)

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Stafford (2013)

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Behavioral

- Reference-dependence, targets

Theories of Labor Supply

Neoclassical

- Maximize lifetime utility
- **Positive** income elasticities

Behavioral

- Reference-dependence, targets
- **Negative** income elasticities

Carrington (1996)

Oettinger (1999)

Wage ↑
Work more

Stafford (2013)

Chen/Sheldon (2016)
Sheldon (2016)

Wage ↑
Work less

Theories of Labor Supply

Neoclassical

- Maximize lifetime utility
- **Positive** income elasticities

Behavioral

- Reference-dependence, targets
- **Negative** income elasticities

Carrington (1996)

Camerer et al. (1997)

Oettinger (1999)

Farber (2005)

Fehr/Goette (2007)

Farber (2008)

Stafford (2013)

Farber (2015)

Chen/Sheldon (2016)

Sheldon (2016)

Thakral/To (2017)

Wage ↑
Work more

Wage ↑
Work less

Recent work in OM

Theoretical

Dong & Ibrahim (2018)
Taylor (2017)
Cachon, Daniels & Lobel (2017)
Hu & Zhou (2017)
Ibrahim (2017)
Bimpikis, Candogan & Saban (2017)
Gurvich, Lariviere & Moreno (2016)
Tang et al. (2016)
Banerjee, Riquelme & Johari (2016)
Benjaafar et al. (2015)
...

Empirical

Kabra, Belavina & Girotra (2017)
Karacaoglu, Moreno & Ozkan (2017)
Chen, Chevalier, Rossi & Oehlsen (2017)
Cui, Li & Zhang (2017)
Li, Moreno & Zhang (2016)
...

Our Paper

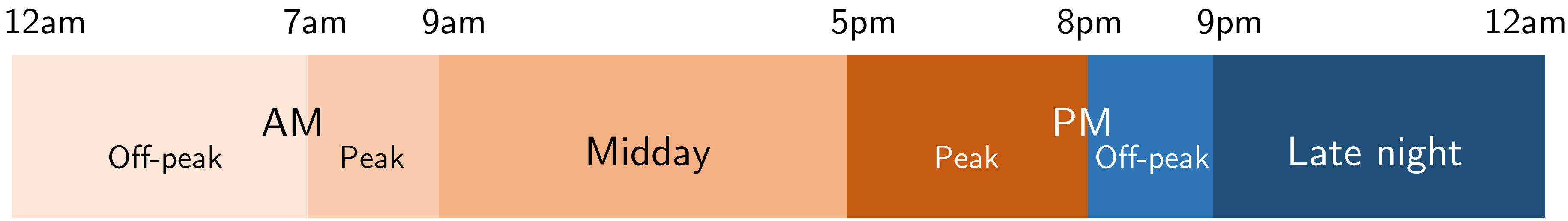
- Behavioral drivers of decisions
- Rich data with complete description of the supply side
- Connect to system-wide decisions

Data US ride-hailing firm

Drivers are guaranteed an hourly base rate.

Data US ride-hailing firm

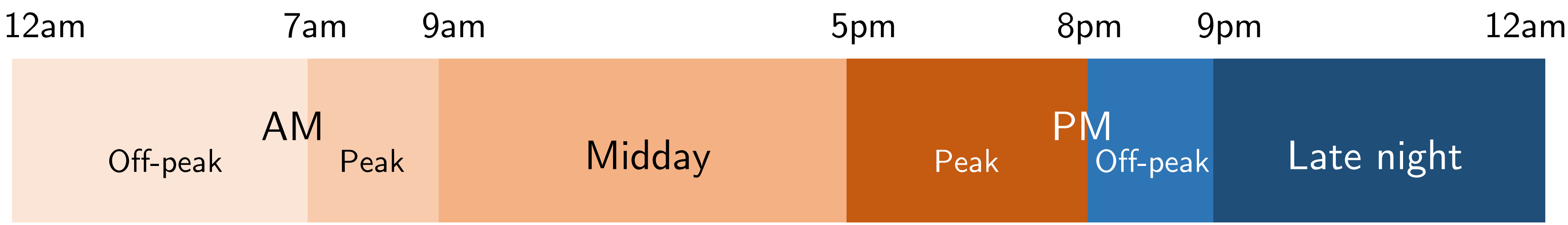
Drivers are guaranteed an hourly base rate.



Shift-level financial incentives and driving activity *for all*

Data US ride-hailing firm

Drivers are guaranteed an hourly base rate.



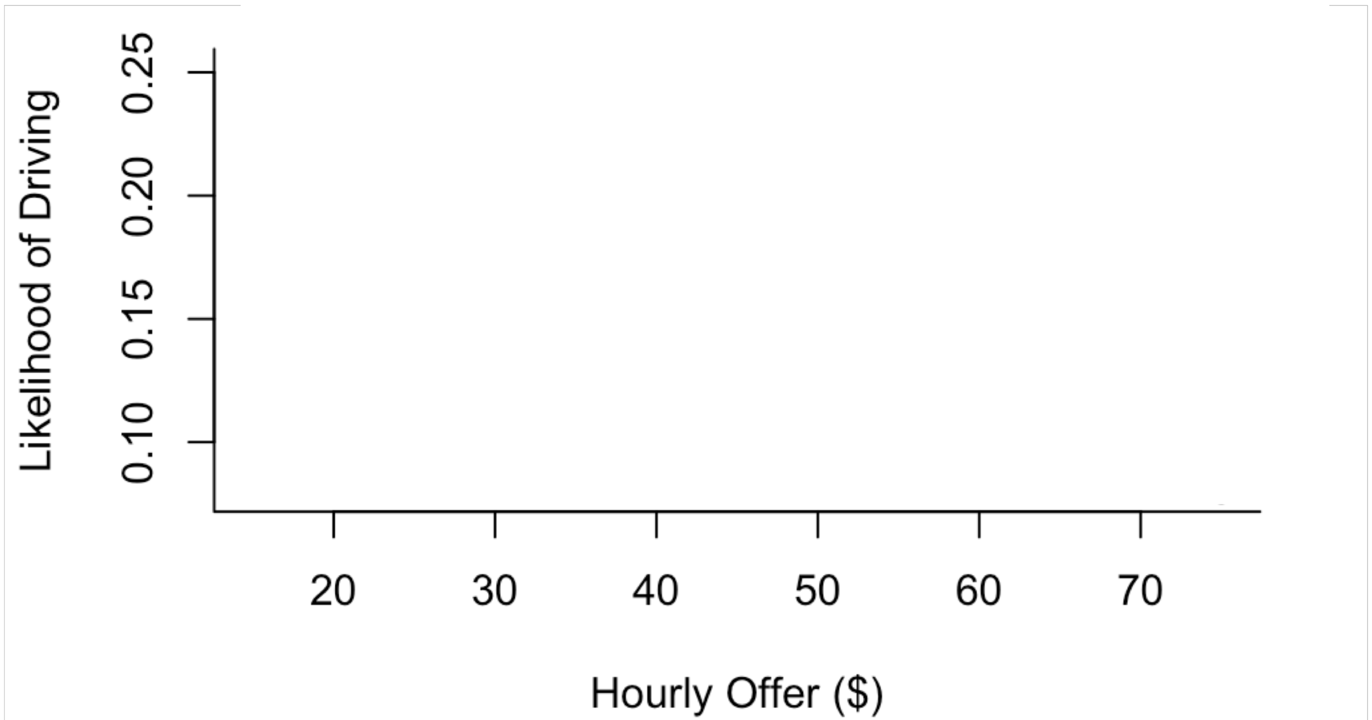
Shift-level financial incentives and driving activity *for all*

5.5M
Observations

358
Days
Oct 2016 – Sep 2017

7,826
Unique drivers
SUV/Sedan/Van

Empirical Strategy Challenges



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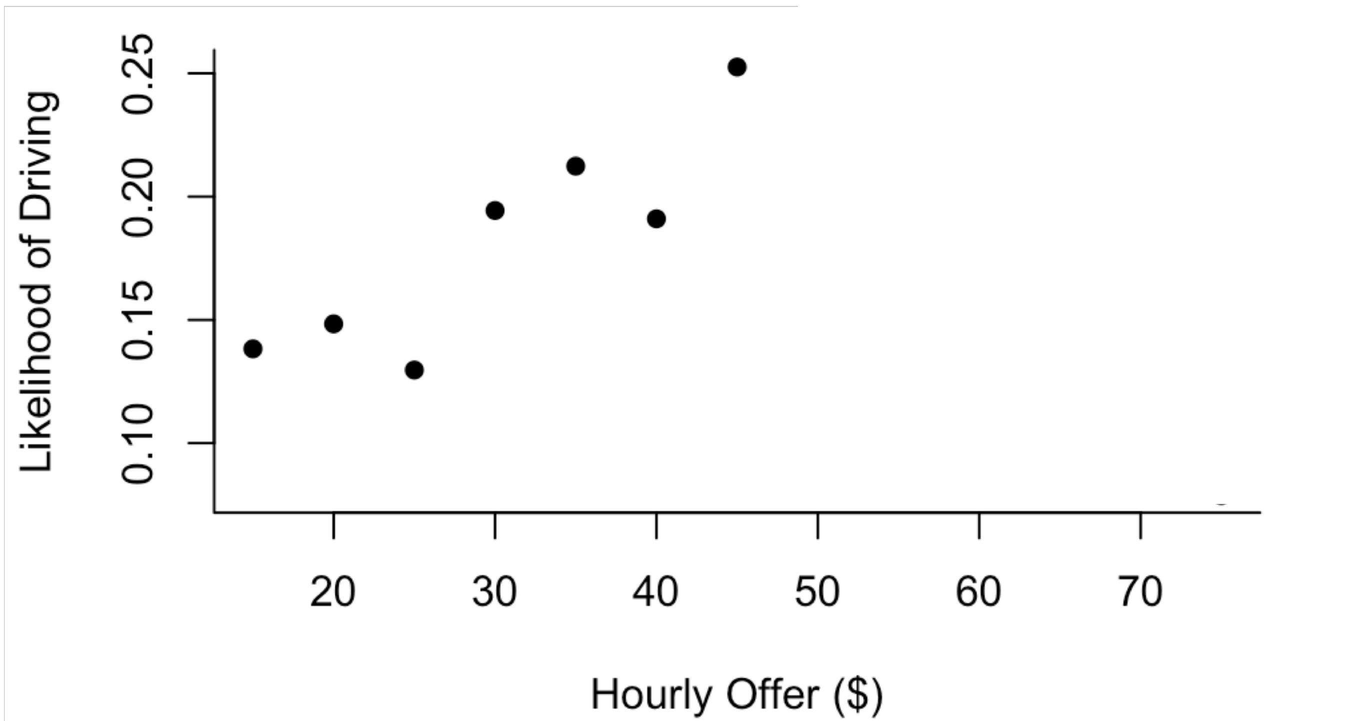

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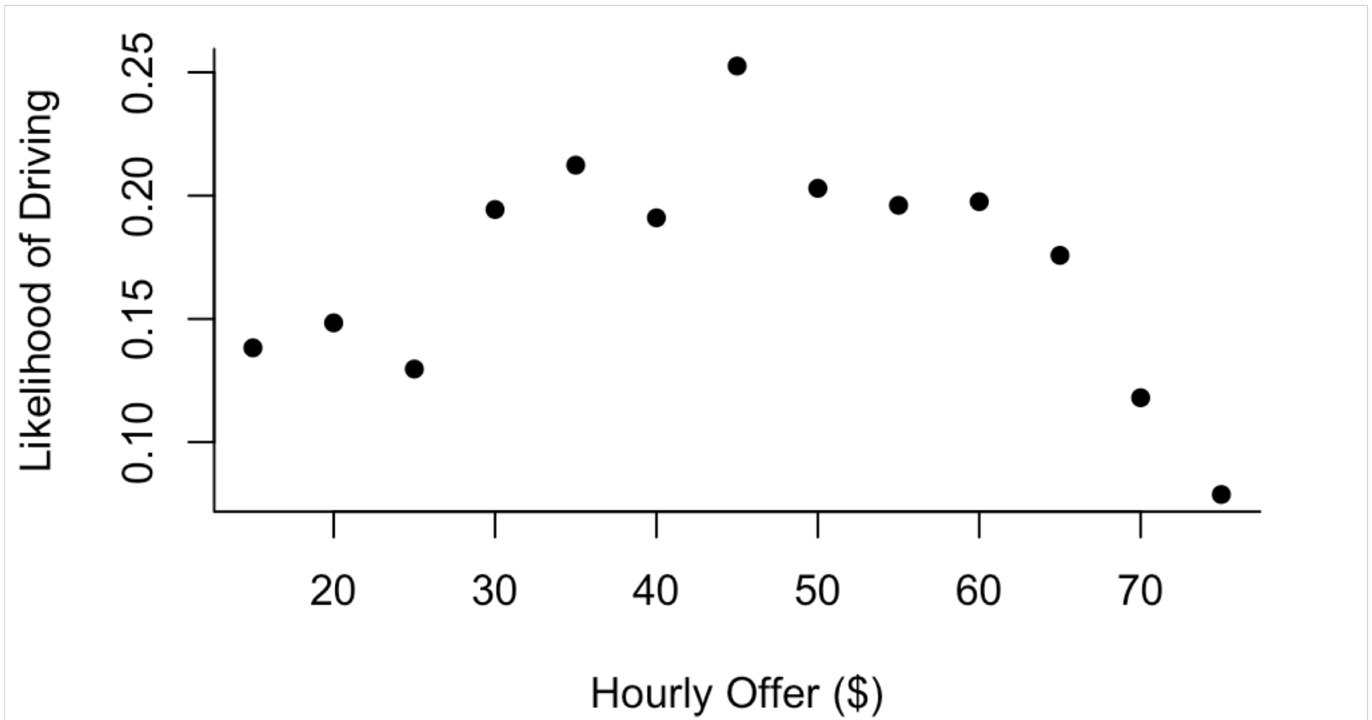
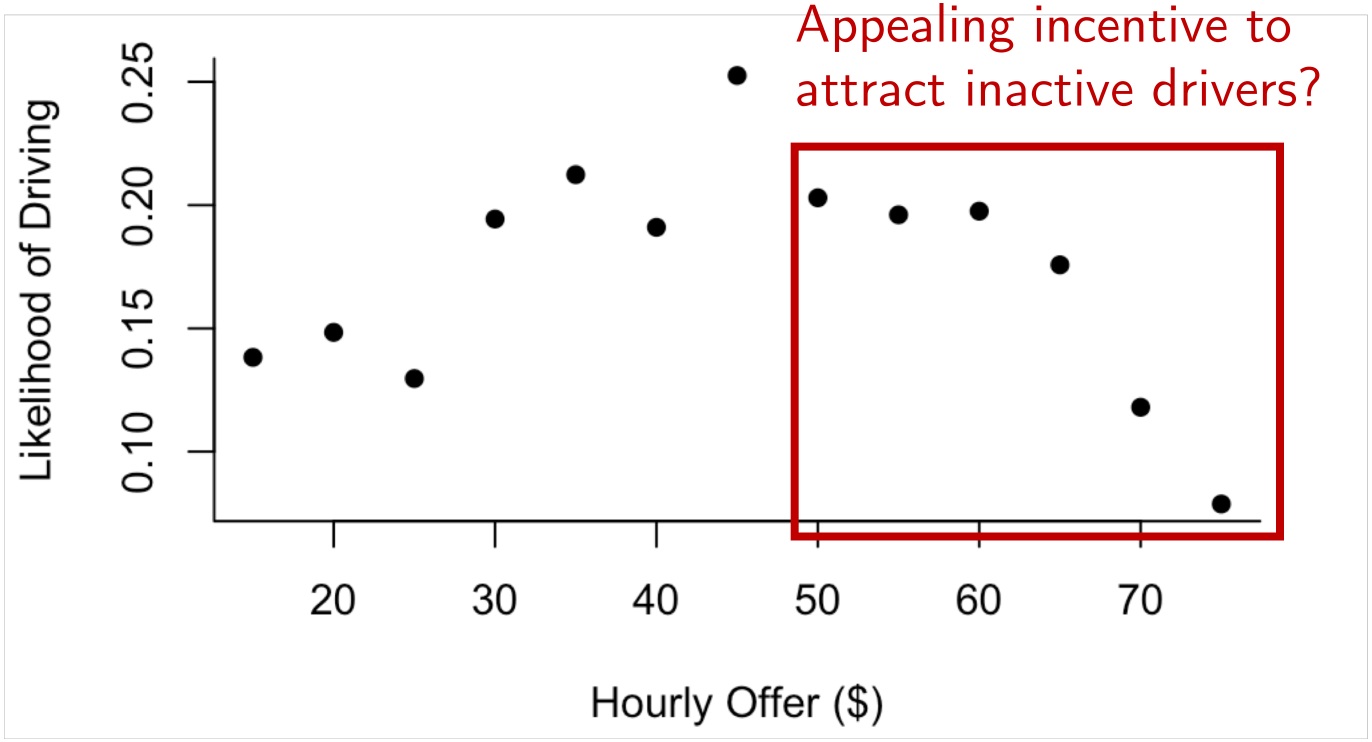


Empirical Strategy Challenges

Higher wage, less likely to drive?

Appealing incentive to attract inactive drivers?

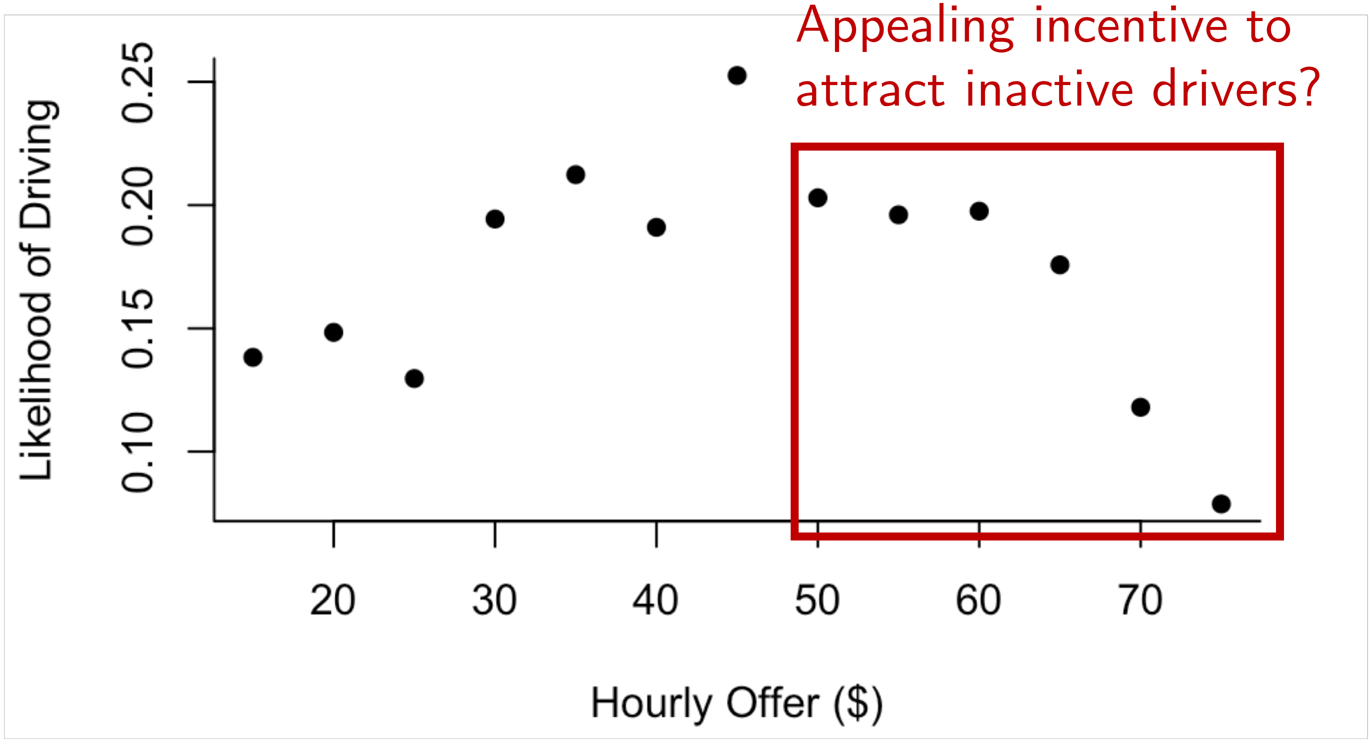


Empirical Strategy Challenges

Simultaneity

Higher wage, less likely to drive?

Appealing incentive to attract inactive drivers?



Simultaneity

Solution: Instrumental Variables

- **Offer:** Average of other drivers' offers (Hausman 1996, Sheldon 2016, Xu et al 2017)

Empirical Strategy Challenges

Simultaneity

Solution: Instrumental Variables

- **Offer:** Average of other drivers' offers (Hausman 1996, Sheldon 2016, Xu et al 2017)
- **Promo** (binary): Lagged value from the same shift in the previous week
  (Villas-Boas & Winer 1999, Yang et al 2003, Archak et al 2011, Ghose et al 2012)

Empirical Strategy Challenges

Simultaneity

Solution: Instrumental Variables

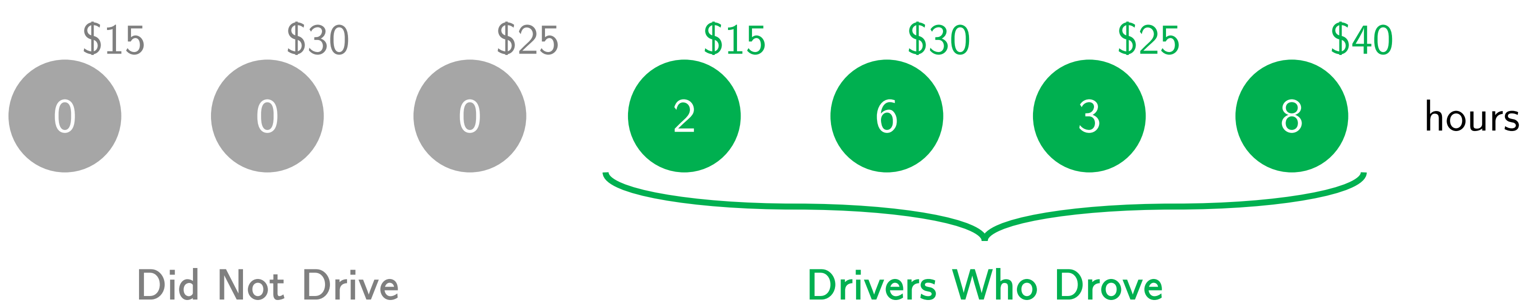
Hours ~ Wage?

Empirical Strategy Challenges

Simultaneity

Solution: Instrumental Variables

Hours ~ Wage?



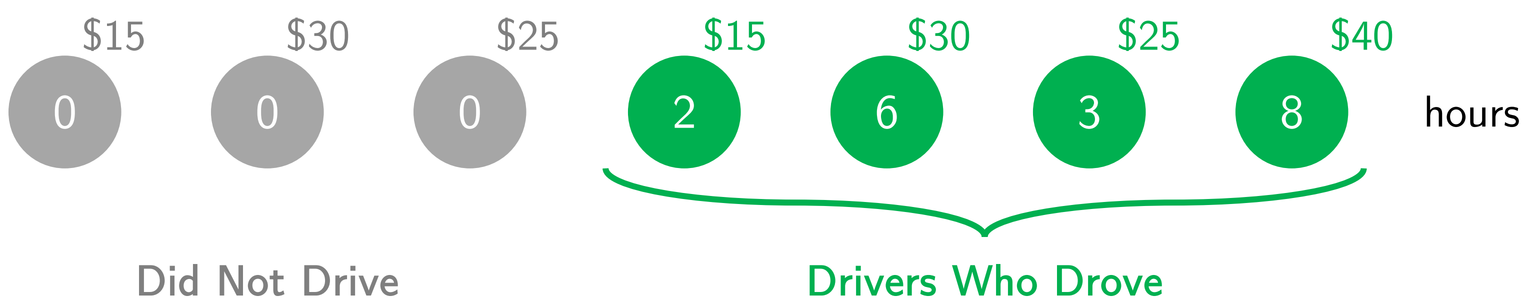
Empirical Strategy Challenges

Simultaneity

Solution: Instrumental Variables

Decision to work is **not random**

Hours ~ Wage?



Empirical Strategy Challenges

Simultaneity

Solution: Instrumental Variables

Selection Bias

Hours ~ Wage

\$15	\$30	\$25	\$15	\$30	\$25	\$40	
0	0	0	2	6	3	8	hours

Did Not Drive

Drivers Who Drove

Empirical Strategy Challenges

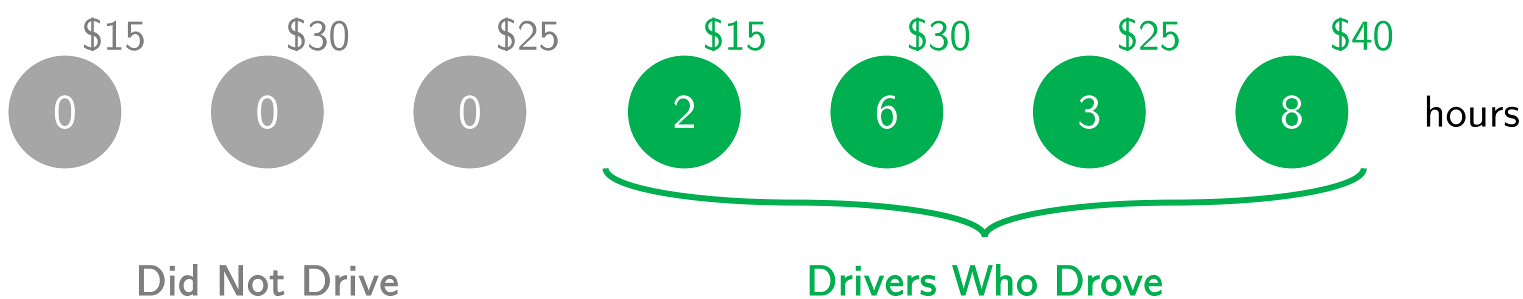
Simultaneity

Solution: Instrumental Variables

Selection Bias

Solution: Heckman Two-Stage Method
("Heckit" - Heckman 1979)

Hours ~ Wage



Empirical Strategy Heckman + IV

1 **Work or not?**

Control Function Probit:

P(drive) on ***Offer*** + ***Promo***

Empirical Strategy Heckman + IV

1 **Work or not?**

Control Function Probit:

P(drive) on ***Offer*** + ***Promo*** + Controls

Hourly Weather Humidity, Temp, Precipitation
Holiday, Day of Week
Month-Year FE
Past Work Habits
Total last week, same day last week, same shift last week
Driver's Experience New?
Driver's FE

Empirical Strategy Heckman + IV

1 Work or not?

Control Function Probit:

P(drive) on ***Offer*** + ***Promo*** + Controls

Demand
- Hourly Weather Humidity, Temp, Precipitation
- Holiday, Day of Week
- Month-Year FE

Short-term Habits
- Past Work Habits
  Total last week, same day last week, same shift last week

Long-term Habits
- Driver's Experience New?
- Driver's FE

Empirical Strategy Heckman + IV

1 **Work or not?**

Control Function Probit:

P(drive) on ***Offer*** + ***Promo*** + ISF + Controls

Income So Far

= accumulated income since beginning of day

Empirical Strategy Heckman + IV

1 **Work or not?**

Control Function Probit:

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Income So Far
= intensity of work

Empirical Strategy Heckman + IV

1 **Work or not?**

Control Function Probit:

P(drive) on ***Offer*** + ***Promo*** + ISF + HSF + Controls

Income So Far
= intensity of work

Hours So Far
= accumulated time
logged in since beginning of day

Empirical Strategy Heckman + IV

1 **Work or not?**

Control Function Probit:

P(drive) on ***Offer*** + ***Promo*** + ISF + HSF + Controls

Income So Far
= intensity of work

Hours So Far
= amount of active time

Empirical Strategy Heckman + IV

1 **Work or not?**

Control Function Probit:

P(drive) on ***Offer*** + ***Promo*** + ISF + HSF + Controls

Income So Far
= intensity of work

Hours So Far
= amount of active time

Conditional
on working

2 **How long to work?**

2SLS with Fixed Effects

\# Hours on ***Earning*** + ISF + HSF + Controls

Empirical Strategy Heckman + IV

1 Work or not?

Control Function Probit:

P(drive) on ***Offer*** + ***Promo*** + ISF + HSF + Controls

Income So Far
= intensity of work

Hours So Far
= amount of active time

Conditional on working

2 How long to work?

2SLS with Fixed Effects

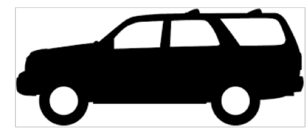
Hours on ***Earning*** + ISF + HSF + IMR + Controls

Inverse Mills Ratio
= correct for selection bias

Results

Financial Offer ISF HSF

1 **Work or not?** 2 **# Hours**



Within-Day

Midday

↓

Late Night

Across-Days

Tuesday

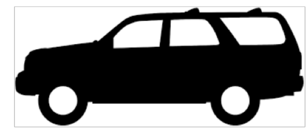
↓

Sunday

Results

Financial Offer ISF HSF

1 **Work or not?** 2 **# Hours**



Within-Day

Midday

↓

Late Night

Across-Days

Tuesday

↓

Sunday

Late Night

1

	Work or not?	
	Base	**+ Targets**
Hourly offer/ earnings		
Promo		
Income so far		
Hours so far		
AIC	95,856.010	72,887.620

N = 166,766

Late Night

1

	Work or not?	
	Base	+ Targets
Hourly offer/ earnings	0.008*** (0.001)	0.012*** (0.001)
Promo	0.229*** (0.038)	0.285*** (0.046)
Income so far		
Hours so far		
AIC	95,856.010	72,887.620

N = 166,766

Financial incentives and getting a "deal" encourage working

Late Night

1

	Work or not?	
	Base	+ Targets
Hourly offer/ earnings	0.008*** (0.001)	0.012*** (0.001)
Promo	0.229*** (0.038)	0.285*** (0.046)
Income so far		-0.002*** (0.0002)
Hours so far		
AIC	95,856.010	72,887.620

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Late Night

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	Work or not?	
	Base	+ Targets
Hourly offer/ earnings	0.008*** (0.001)	0.012*** (0.001)
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Income so far	Income Target	-0.002*** (0.0002)
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The more you've earned, the less likely you're going to continue working.

Late Night

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Hours so far		
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For average driver,
$100 additional income so far,
P(drive) decreases by 2.5%

The more you've earned, the less likely you're going to continue working.

Late Night

1

	Work or not?	
	Base	+ Targets
Hourly offer/ earnings	0.008*** (0.001)	0.012*** (0.001)
Promo	0.229*** (0.038)	0.285*** (0.046)
Income so far	Income Target	-0.002*** (0.0002)
Hours so far		0.361*** (0.007)
AIC	95,856.010	72,887.620

N = 166,766

Late Night

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	Work or not?	
	Base	+ Targets
Hourly offer/ earnings	0.008*** (0.001)	0.012*** (0.001)
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Hours so far	Inertia	0.361*** (0.007)
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The longer you've been active, the more likely you'll continue working

Late Night

1

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	Base	+ Targets
Hourly offer/ earnings	0.008*** (0.001)	0.012*** (0.001)
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Income so far	Income Target	-0.002*** (0.0002)
Hours so far	Inertia	0.361*** (0.007)
AIC	95,856.010	72,887.620

N = 166,766

For average driver,
1 additional hour so far,
P(drive) increases by 4.1%

The longer you've been active, the more likely you'll continue working

Late Night

	Work or not? 1		# Hours 2		
	Base	+ Targets	Naive	Base	+ Targets
Hourly offer/ earnings	0.008*** (0.001)	0.012*** (0.001)			
Promo	0.229*** (0.038)	0.285*** (0.046)			
Income so far	Income Target	-0.002*** (0.0002)			
Hours so far	Inertia	0.361*** (0.007)			
IMR					
AIC/R^2	95,856.010	72,887.620			

N = 166,766

Late Night

	1		2		
	Work or not?		# Hours		
	Base	+ Targets	Naive	Base	+ Targets
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Income so far	Income Target	-0.002*** (0.0002)			
Hours so far	Inertia	0.361*** (0.007)			
IMR				***	***
AIC/R^2	95,856.010	72,887.620	0.313	0.324	0.957
	N = 166,766		N = 18,941		

Late Night

	Work or not? (1)		# Hours (2)		
	Base	+ Targets	Naive	Base	+ Targets
Hourly offer/ earnings	0.008*** (0.001)	0.012*** (0.001)	-0.010*** (0.001)	-0.001 (0.001)	0.001*** (0.0002)
Promo	0.229*** (0.038)	0.285*** (0.046)			
Income so far	Income Target	-0.002*** (0.0002)			-0.0002*** (0.00002)
Hours so far	Inertia	0.361*** (0.007)			0.187*** (0.001)
IMR				***	***
AIC/R^2	95,856.010	72,887.620	0.313	0.324	0.957

N = 166,766

N = 18,941

Late Night

	1			2	
	Work or not?		**# Hours**		
	Base	+ Targets	Naive	Base	+ Targets
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Hours so far	Inertia	0.361*** (0.007)		Inertia	0.187*** (0.001)
IMR					
AIC/R^2	95,856.010	72,887.620	0.313	0.324	0.957
	N = 166,766			N = 18,941	

The more you've earned, you'll drive shorter hours.

The longer you've been active, you'll drive longer hours.

Late Night

	Work or not? (1)		# Hours (2)		
	Base	+ Targets	Naive	Base	+ Targets
Hourly offer/ earnings	0.008*** (0.001)	0.012*** (0.001)	-0.010*** (0.001)	-0.001 (0.001)	0.001*** (0.0002)
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Late Night

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Hours so far		0.361*** (0.007)			0.187*** (0.001)

Work or not?

	Offer	ISF	HSF
Late night	+	-	+

Late Night

	Work or not? (1)		# Hours (2)		
	Base	+ Targets	Naive	Base	+ Targets
Hourly offer/ earnings	0.008*** (0.001)	0.012*** (0.001)	-0.010*** (0.001)	-0.001 (0.001)	0.001*** (0.0002)
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Income so far		-0.002*** (0.0002)			-0.0002*** (0.00002)
Hours so far		0.361*** (0.007)			0.187*** (0.001)

	Work or not?			# Hours		
	Offer	ISF	HSF	Earning	ISF	HSF
Late night	+	-	+	+	-	+

Results Within Day

1

Work or not?

	Offer
Midday	+
PM peak	+
PM off	+
Late night	+

Financial incentives have a **consistently positive** impact.

Results Within Day

1

Work or not?

	Offer	ISF
Midday	+	+
PM peak	+	-
PM off	+	-
Late night	+	-

Income Target

Income Target:
The more you earned, the less likely you'll work a new shift.

The negative impact of **income target kicks in later in the day**.

Results Within Day

1

Work or not?

	Offer	ISF	HSF
Midday	+	+	+
PM peak	+	-	+
PM off	+	-	+
Late night	+	-	+
		Income Target	Inertia

Inertia: The longer you've been active, the more likely you'll work another shift.

Inertia has a **consistently positive** impact.

Results Within Day

	1			2		
	Work or not?			# Hours		
	Offer	ISF	HSF	Earning	ISF	HSF
Midday	+	+	+	-	+	+
PM peak	+	-	+	+	-	+
PM off	+	-	+	+	-	+
Late night	+	-	+	+	-	+
		Income Target	Inertia		Income Target	Inertia

The negative impact of income target kicks in later in the day for both stages.

Results Across Days

	1 Work or not?			2 # Hours		
	Offer	ISF	HSF	Earning	ISF	HSF
Tuesday	+	+	+	+	+	+
Wednesday	+	+	+	+	-	+
Thursday	+	-	+	+	-	+
Friday	+	-	+	+	-	+
Saturday	+	-	+	+	-	+
Sunday	+	-	+	+	-	+
		Income Target	Inertia		Income Target	Inertia

The results are consistent across days as well.

Results Summary

As day/week proceeds...

Neoclassical
Financial Incentive | encourages working

Results Summary

As day/week proceeds...

Neoclassical
Financial Incentive — encourages working

Behavioral
Income Target — discourages working later on

Results Summary

	As day/week proceeds...
Neoclassical Financial Incentive	encourages working
Behavioral Income Target	discourages working later on
New Inertia	encourages working

Outline

- What has been done

  Practice / labor economics / OM

- Data and empirical strategy

  Dealing with endogeneity and selection bias

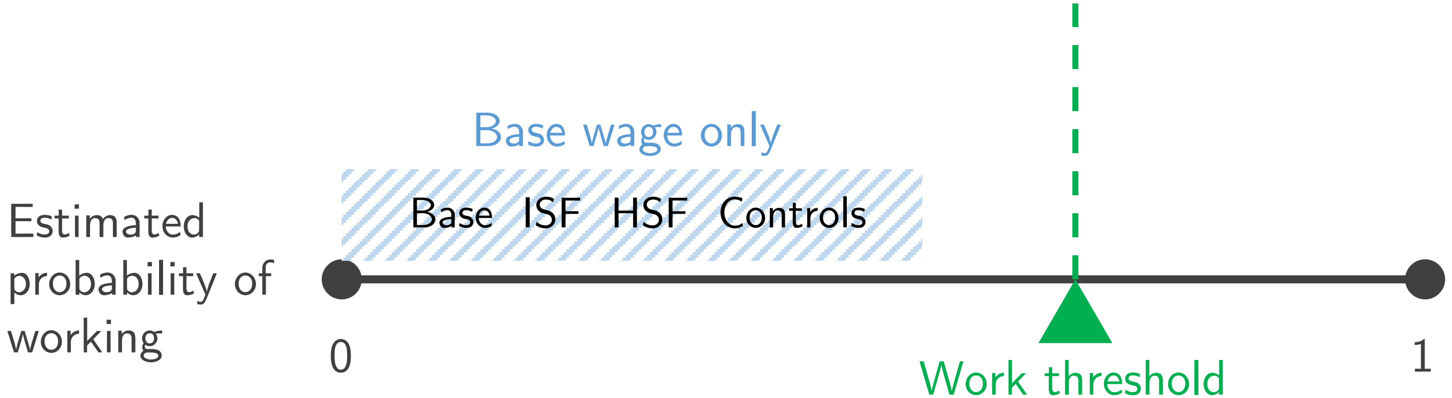
- Results

  Impact of incentive and behavioral elements on labor decisions

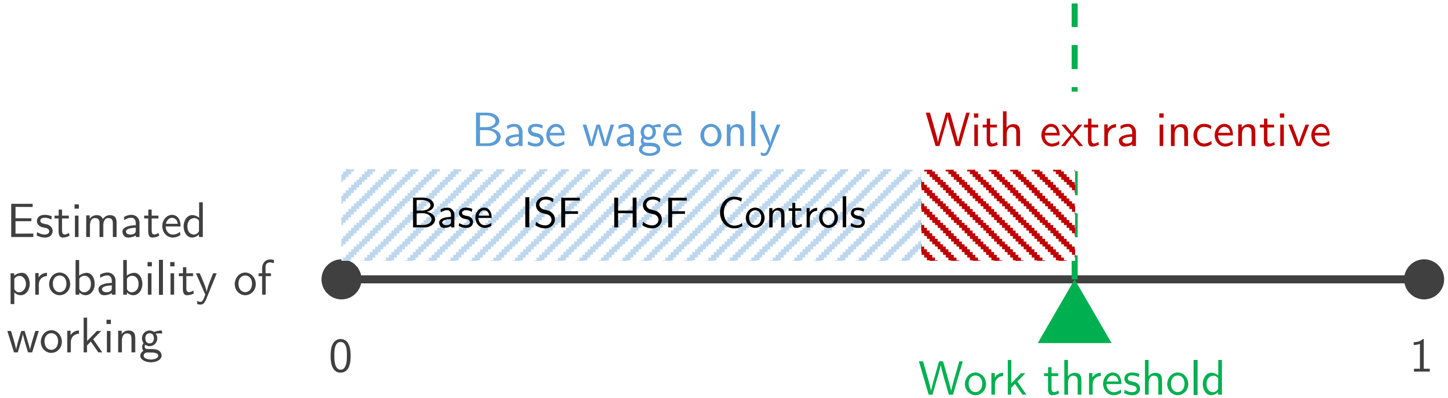
- Implications

  Simulation of optimal incentive re-allocation

Optimal Targeted Incentive



Optimal Targeted Incentive

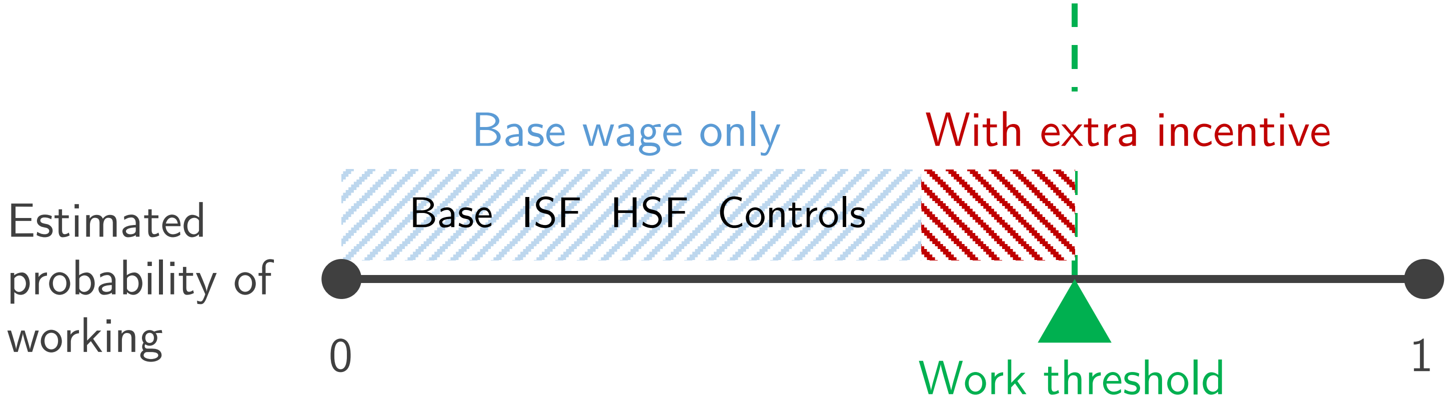


Optimal Targeted Incentive

Ranking each driver by her

minimum work-inducing incentive

= how much to trigger working decision



Reallocating Incentives

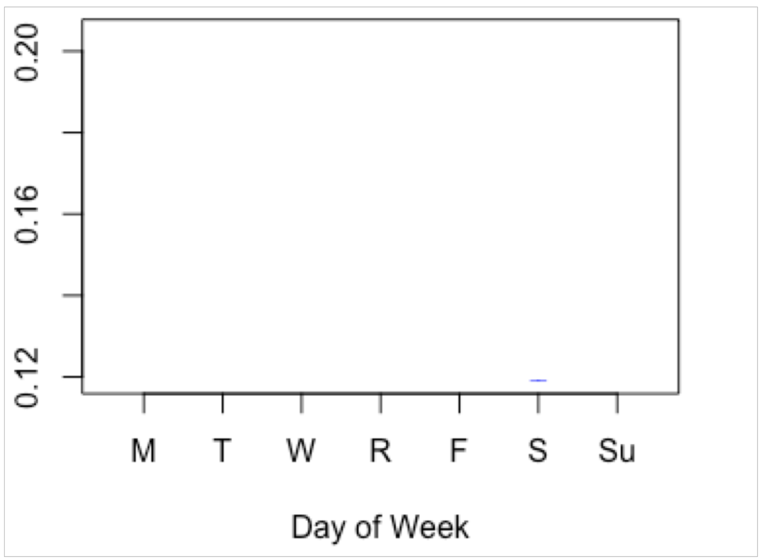
Compared to current practice from Jan to Sep 2017 out-of-sample

Reallocating Incentives

Compared to current practice from Jan to Sep 2017 out-of-sample

Given the same budget

Extra
drivers

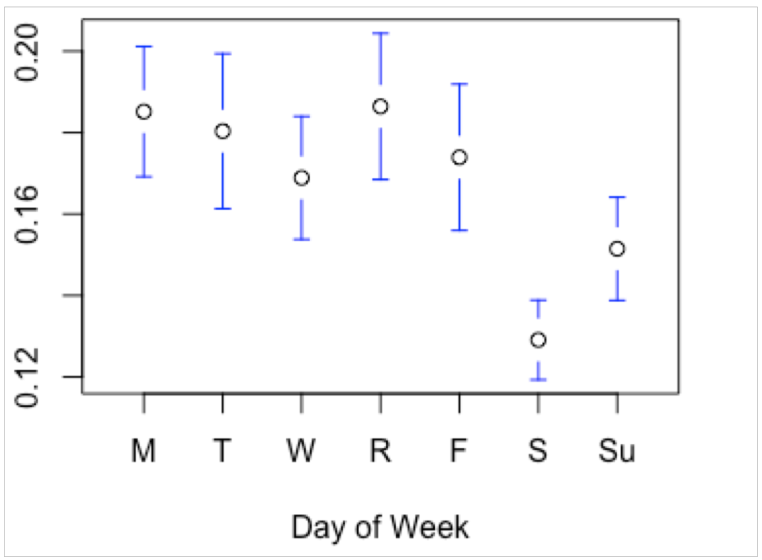


Reallocating Incentives

Compared to current practice from Jan to Sep 2017 out-of-sample

Given the same budget

Extra drivers



Can recruit **17% more drivers**

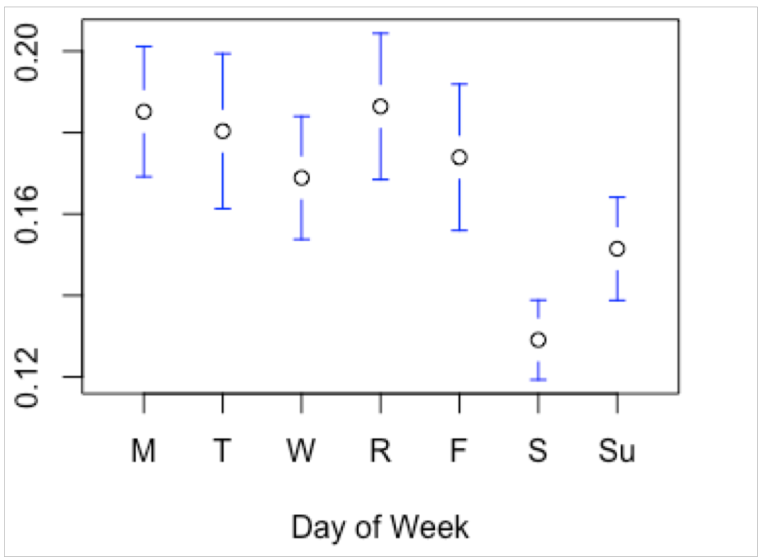
Average promo: 1.61x

Reallocating Incentives

Compared to current practice from Jan to Sep 2017 out-of-sample

Given the same budget

Extra drivers

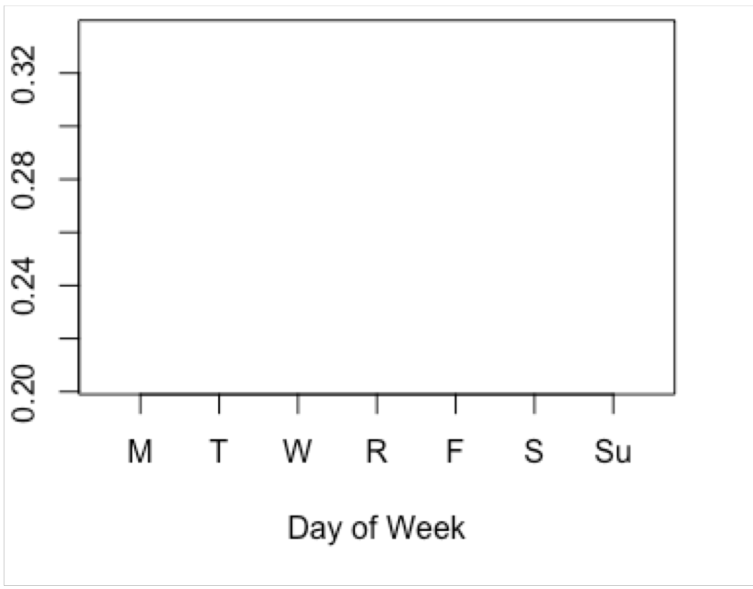


Can recruit **17% more drivers**

Average promo: 1.61x

Given the same capacity

Cost saved

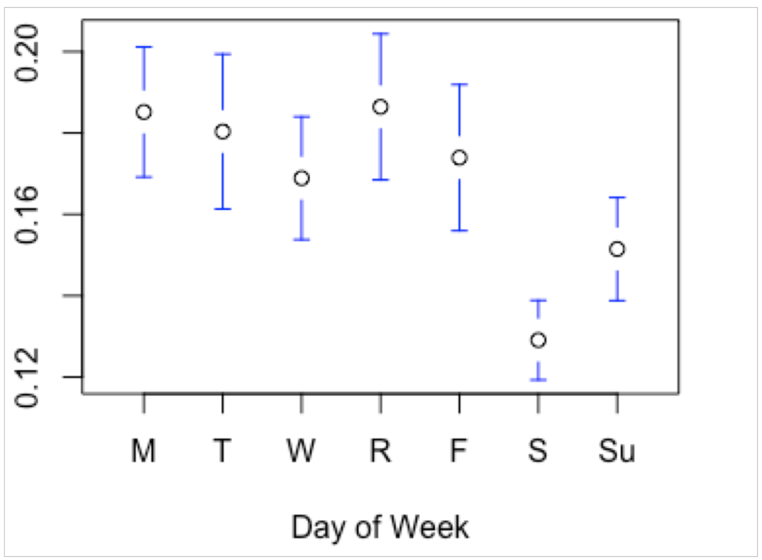


Reallocating Incentives

Compared to current practice from Jan to Sep 2017 out-of-sample

Given the same budget

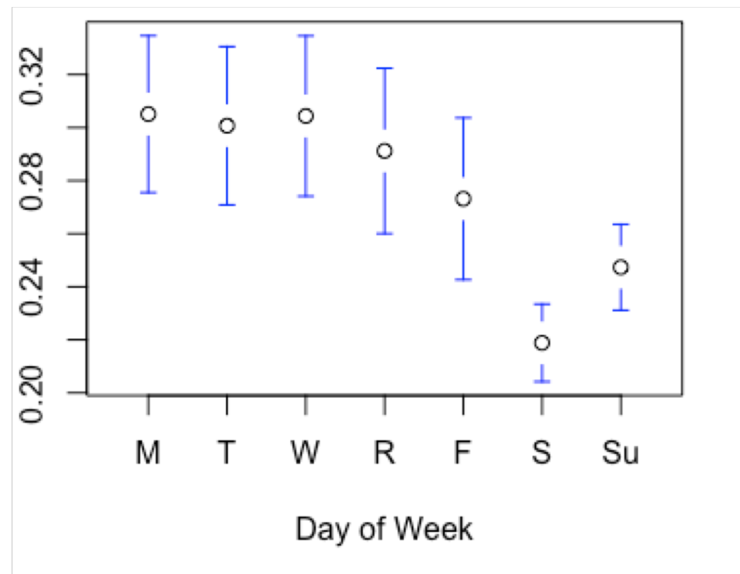
Extra drivers



Can recruit **17% more drivers**
Average promo: 1.61x

Given the same capacity

Cost saved



Costs 28% less to maintain capacity

Summary

How do gig economy workers make labor decisions?

Approach

- Shift-level data from ride-hailing company
- Modified Heckman estimation w/ IVs and fixed effects

Findings

		As day/week proceeds...
Neoclassical	Financial Incentive	encourages working
Behavioral	Income Target	discourages working later on
New phenomenon	Inertia	encourages working

Implications

- Compared to current practice, our approach can improve service capacity without incurring extra cost or maintain the same capacity at a lower cost

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swich@wharton.upenn.edu / wichinpong.com / @wichinpong

Structural Estimation

- Goals

  Uncover the inertia behavior
  Confirm income targeting behavior
  Quantify the value of guaranteed pay

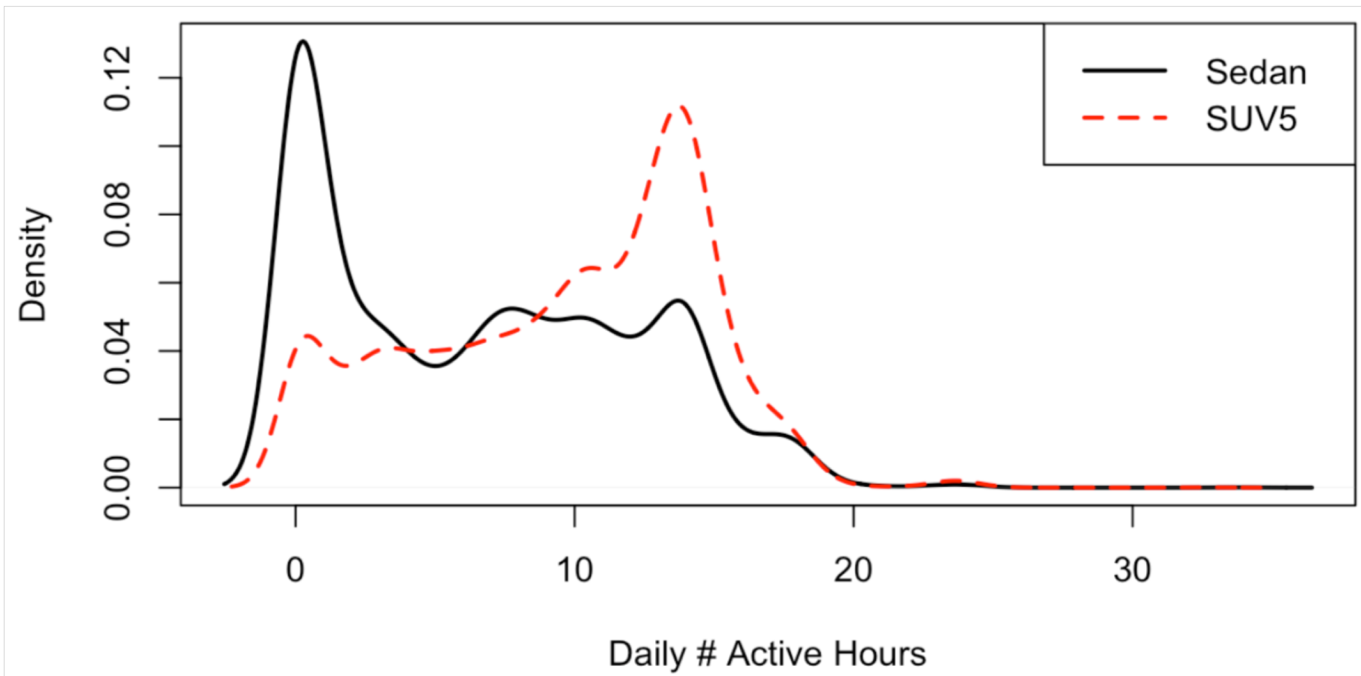
- Data

  Trip-level data for sedan and SUV drivers
  TLC data of trips by all ride-hailing platforms

- Model

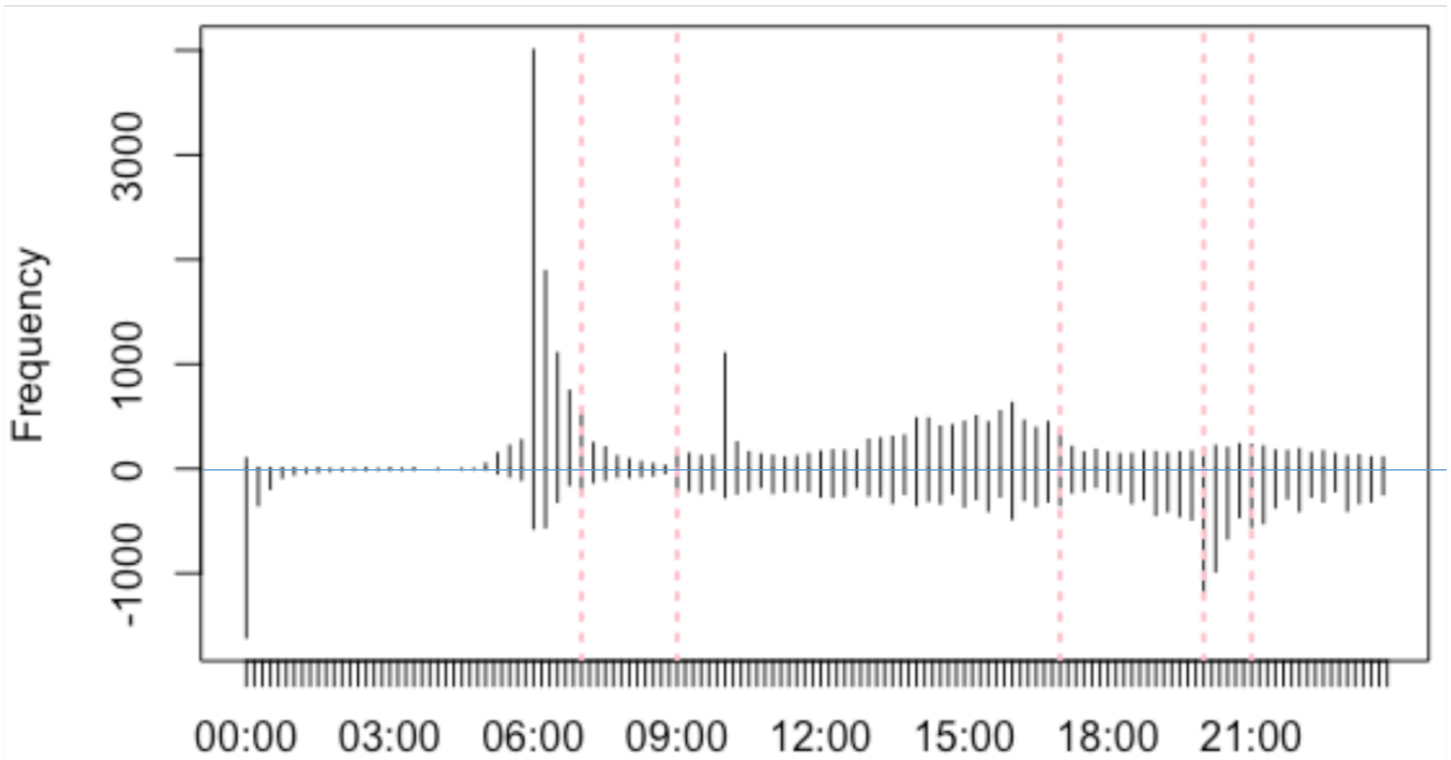
Trip-Level Data

- Log on and off times of each driver



Trip-Level Data

- Log on and off times of each driver



Trip-Level Data

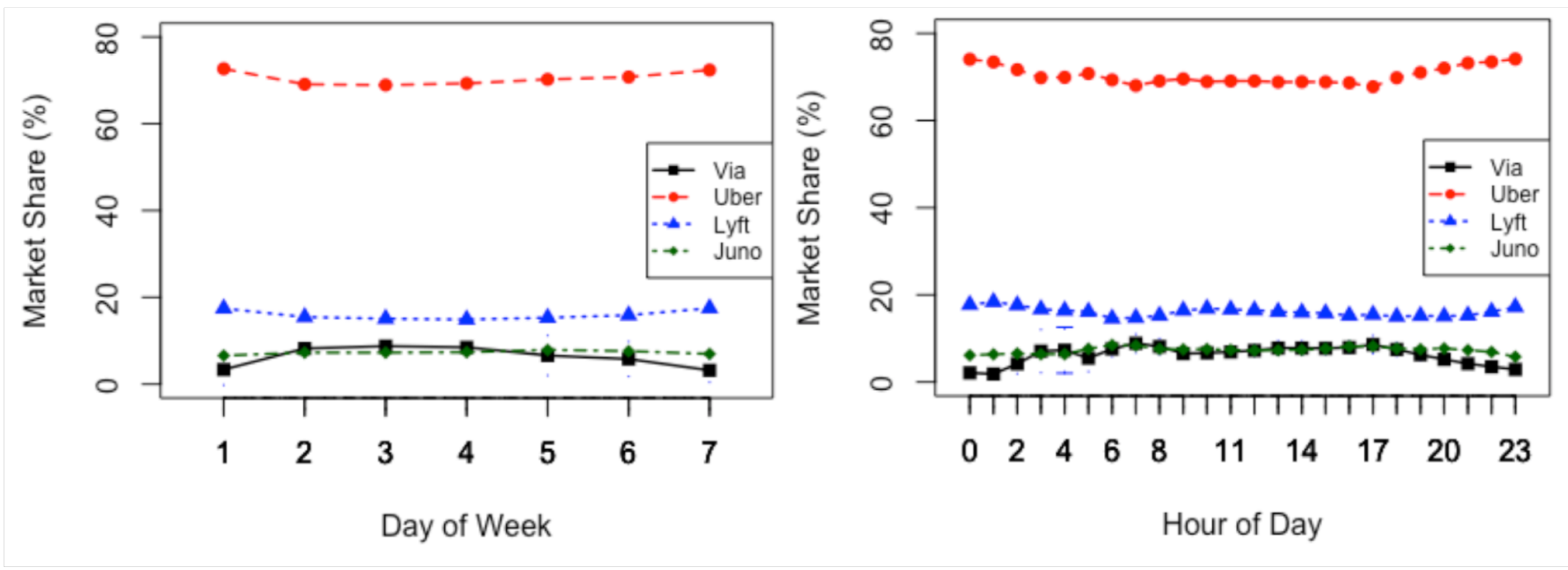
- Longer previous active sessions, longer new session

	(1) OLS	(2) Fixed Effects	(3) Fixed Effects
prevdur	**0.506*** (0.005)**	**0.150*** (0.006)**	**0.133*** (0.006)**
Constant	8,739.000*** (142.300)		
Control	-	-	Shift, Day of Week
Observations	24,632	24,632	24,632
R2	0.256	0.023	0.138
Adjusted R2	0.256	0.009	0.126
Note:			*p<0.1; **p<0.05; ***p<0.01

- Also, longer break, shorter next session

TLC Data

- Pickup/drop-off locations and timestamps of each trips by all the ride-hailing platforms



Model

- Assume finite horizon, $t = 1, 2, ..., T$. Each period has length ΔT.
- The driver knows exactly his base rate and real-time promotion information $\rightarrow w_{i,t}$ wage per period.
- Consider 3 decisions that can be made: $d_{i,t}$
  1. Work for this focal company
  2. Work for the competitor
  3. Not work at all/rest
- Assume that there is a cap of number of drivers for the focal company. Moving from competitor or not working at all to working for this company has a risk of full capacity.

Model

Working for the focal company

Utility function of working for period t:

$$U_{i,t}^{d=1} = \beta_w w_{i,t} - \beta_T \left(\frac{(\Delta T)^{1+\nu}}{1+\nu} \right) + f_I(I_{i,t} + w_{i,t}) + f_H(H_{i,t} + \Delta T) + \epsilon_{i,t} \tag{1}$$

The cost or disutility of working for the period of length ΔT is $(\Delta T)^{1+\nu}/(1+\nu)$ following the labor economics literature. $I_{i,t}$ is the accumulated income up until period t. $H_{i,t}$ is the accumulated time worked so far up until period t.

Model

Working for the competitor

Here, we assume that the driver does not know exactly the wage rate of the competitor, but he forms belief based on observed demand.

Utility of working for the competitor:

$$U_{i,t}^{d=2} = \beta_w \bar{w}_{i,t} - \beta_T \left(\frac{(\Delta T)^{1+\nu}}{1+\nu} \right) + f_I(I_{i,t} + \bar{w}_{i,t}) + f_H(H_{i,t} + \Delta T) + \eta_{i,t} \quad (2)$$

- $\bar{w}_{i,t}$ is a random variable that can be interpreted as the expected number of trips multiplied by the expected average earning per trip on the competitor's platform. It should be a function of current observed demand D_t.
- The expected value of $\bar{w}_{i,t}$ should be strictly greater than $w_{i,t}$, the guaranteed wage for the first option. But it is the variance of $\bar{w}_{i,t}$ that makes this option uncertain.

Not working/rest

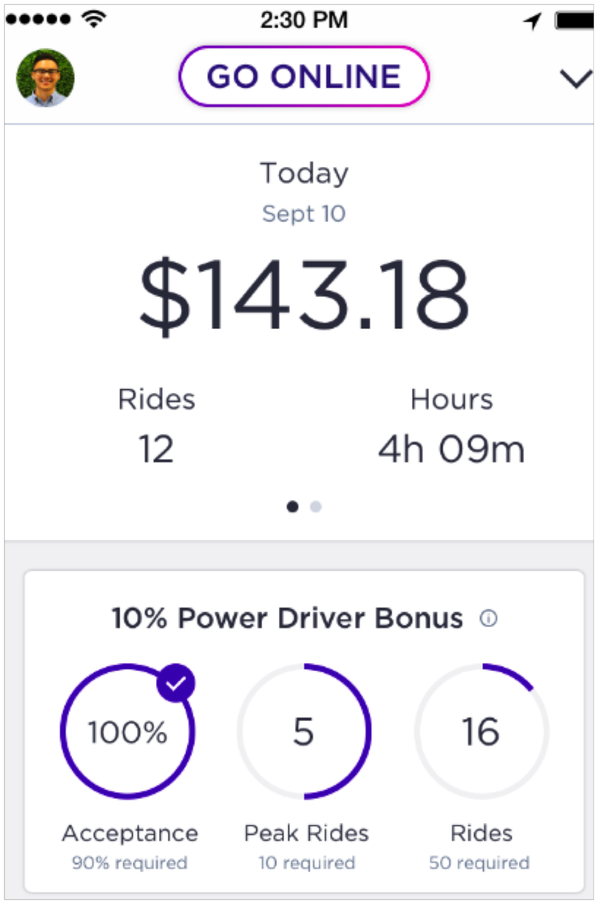
Utility of not working:

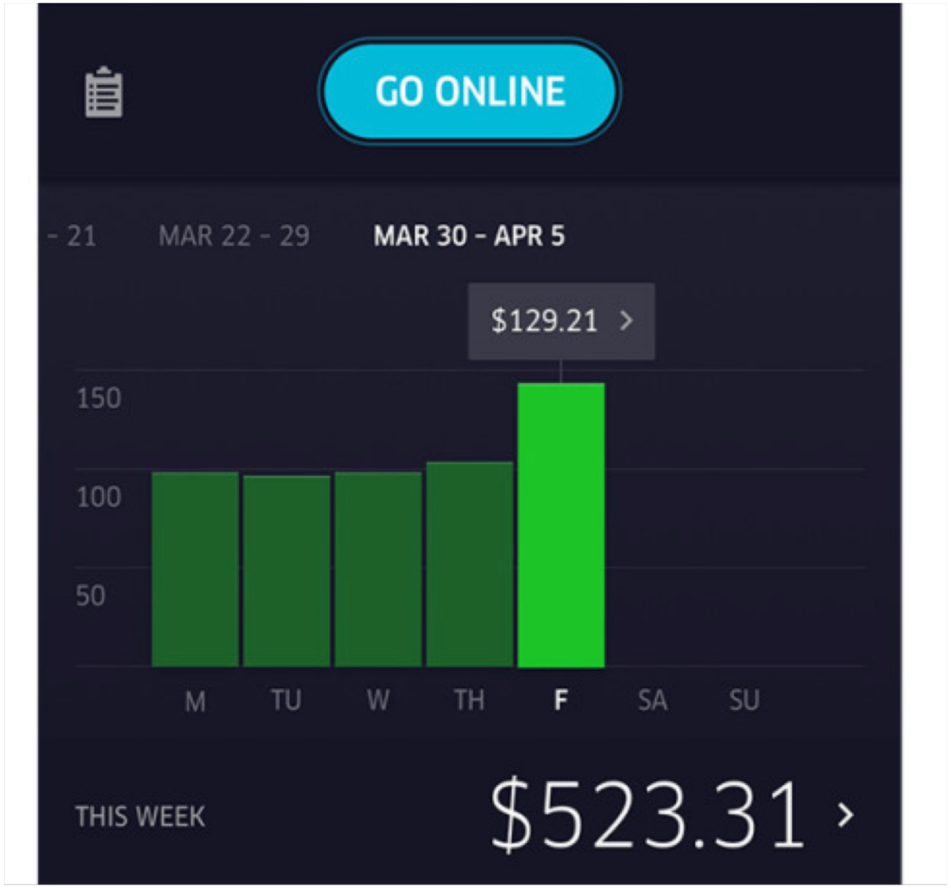
$$U_{i,t}^{d=3} = \alpha \cdot \Delta T + f_I(I_{i,t}) + f_H(H_{i,t}) + \zeta_{i,t} \quad (3)$$

α is the marginal benefit of having a time-off.

Appendix

Salience of ISF/HSF

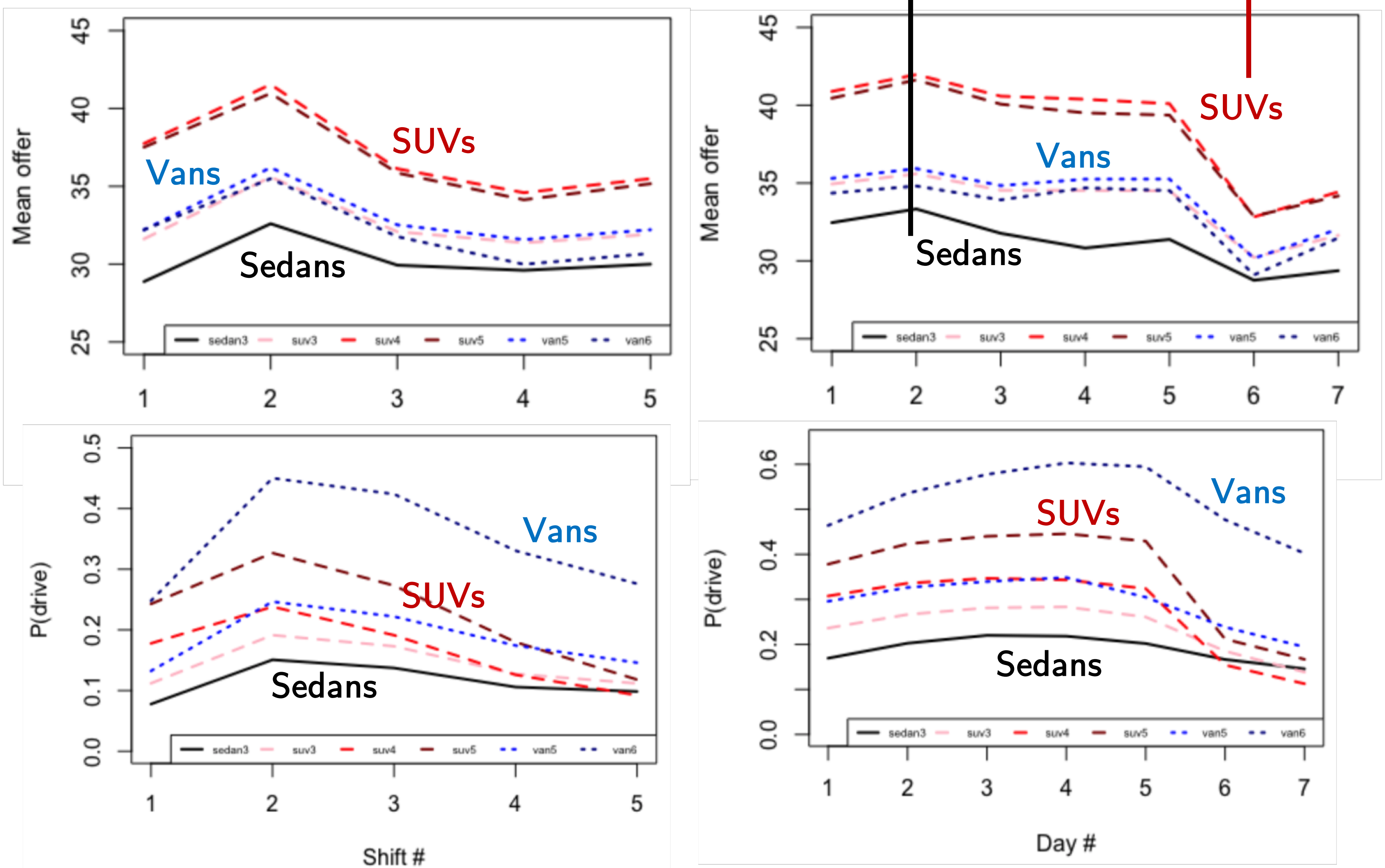




Drivers

5.33 hrs/day, 12.65 hrs/wk

4.86 hrs/day, 5.86 hrs/wk



Gig Economy x Retail

Baker Retailing Center

- **Retail candidates value flexible shift patterns** and shorter work weeks over compensation and benefits.
- Benefits of adopting flexible workforce: Seasonality, resolving high turnover, matching consumer trend, high quality/fresh perspective
- Many have already adopted/worked closely with gig companies
  - Delivery business: Walmart x Uber/Lyft, GM x Lyft, Apple x Didi
  - Flexible staffing: IKEA x TaskRabbit, Samsung x Upwork

snag.work on-demand

Wonolo

coople

(allwork)

Heckit with IVs

1. Choice Equation "Drive or not?"

CF: Regress **hourly offer/promo** on IVs. Keep **residuals**

Probit: Estimate **P(drive)**

$$P(Drive_{i,t}=1|\boldsymbol{X_{i,t}})=\Phi(\alpha_{0,t}+\alpha_w w_{i,t}+\alpha_\psi \psi_{i,t}+\boldsymbol{\alpha X_{i,t}}+\alpha_e \hat{e}_{i,t})$$

C

Inverse Mills Ratio (IMR)

$$\lambda(c_z)=\frac{\phi(c_z)}{1-\Phi(c_z)}$$

Conditional on driving

2. Level Equation "How long?"

IV: Estimate **hourly earning** from IVs

OLS: Estimate **hours**

$$f(Hour_{i,t})=\beta_{0,i}+\beta_\omega \omega_{i,t}+\boldsymbol{\beta Z_{i,t}}+\theta\lambda_{i,t}+u_{i,t}$$

L

X/Z include past work frequency, experience, holiday, temperature, precipitation, humidity