Surge Pricing and Labor Supply in the Ride-Sourcing Market

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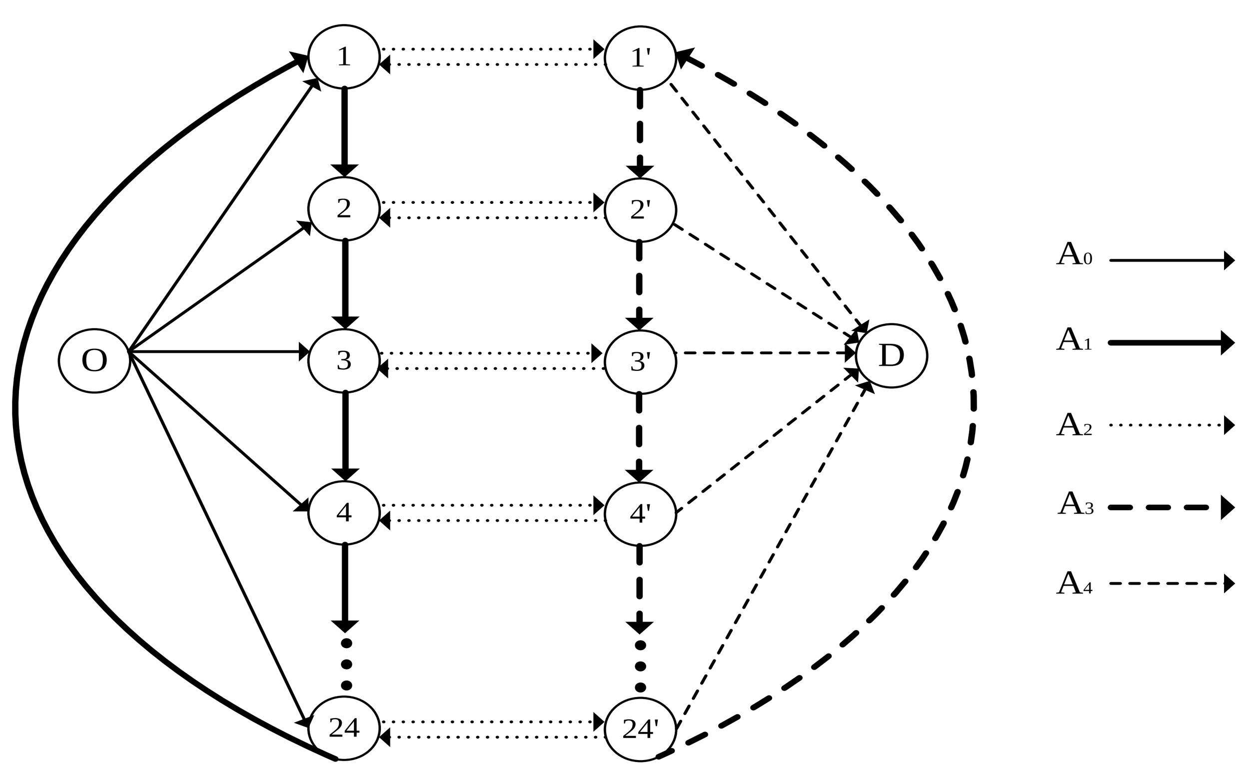
1. INTRODUCTION

This study proposes equilibrium models under different behavioral assumptions of labor supply in the ride-sourcing market and then investigates the performance of surge pricing.

Compared to static pricing, the platform and drivers in general enjoy higher revenue while customers may be made worse off during highly surged periods. A simple regulation scheme to reduce market power is discussed.

2. BASIC MODEL

2.1 Time-Expanded Network



1. A path between the hypothetic O-D pair corresponds to a work schedule for a ride-sourcing driver.
2. A driver is free to work, take a rest or end her daily schedule.
3. Demand is only generated on working links (A_1). When a driver is taking a rest (A_3), she is not able to be matched to a customer.
4. Sample schedule: O→1→ 2→ 2'→ 3'→3→4→5→6→7→7'→D

2.2 Definitional Equations

Hourly demand is a decreasing function of trip fare $\gamma_b F_b$ and average waiting time w_b^c :

$$Q_b = q_b\left(\gamma_b F_b, w_b^c\right),\ \forall b \in A_1$$

where γ_b is the surge multiplier during hour b; $w_b^c \propto 1\Big/\sqrt{N_b^v/S}$ is induced from a closest vehicle matching process; N_b^v is the vacant vehicle hours.

From vehicle conservation during hour b

$$N_b^v + N_b^o = u_b,\ \forall b \in A_1$$

where N_b^o is the occupied vehicle hours; u_b is the total vehicle hours.

Average hourly revenue (gross hourly wage rate):

$$R_b = \frac{(1-\eta)\bar{F}_b Q_b}{u_b},\ \forall b \in A_1$$

where $R_b'(u_b) < 0$; $\eta = 0.2$ is the commission ratio charged by the platform.

Pay-off for drivers of class m in choosing path p:

$$U^{pm} = \begin{cases} \left(1+\rho^m\right)\left(R^p - I^m\right) - \bar{C}^{pm} + U_0, & R^{pm} < I^m \\ \left(1-\rho^m\right)\left(R^p - I^m\right) - \bar{C}^{pm} + U_0, & R^{pm} \geq I^m \end{cases},\ \forall p \in P,\ m \in M$$

where I^m, U_0 are the pre-determined income target and reservation utility levels, respectively; $\bar{C}^{pm}$ is the total cost associated with the chosen schedule; ρ^m controls the degree of loss aversion.

$0 < \rho^m < 1$: Income-targeting $\qquad \rho^m = 0$: Neoclassical

2.3 Market equilibrium

$$\left(U^m - U^{pm}\right) f^{pm} = 0,\ \forall m \in M,\ p \in P$$

$$U^m - U^{pm} \geq 0,\ \forall m \in M,\ p \in P$$

$$\sum_{p \in P} f^{pm} = N^m,\ \forall m \in M$$

$$f^{pm} \geq 0, \forall m \in M, \forall p \in P$$

where $U^m = \max_{p \in P}\left(U^{pm}\right) > 0$; f^{pm} is the number of drivers of class m choosing path p; N^m is the total number of drivers of class m.

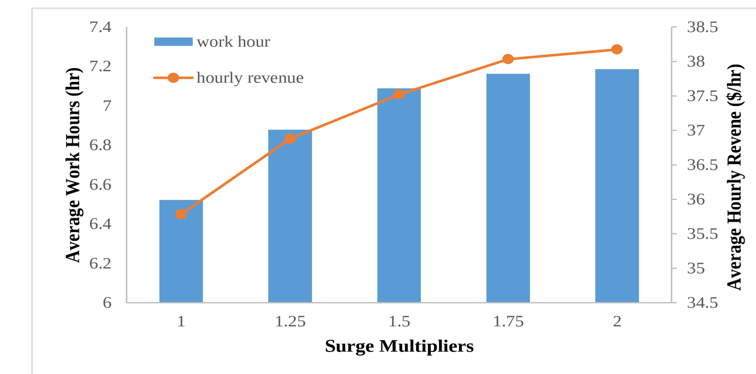
Equilibrium with neo-classical labor supply

Start time	End time	Work hours (hr)	Rest hours (hr)	Revenue ($)	Cost ($)	Profit ($)	Path flow(veh)
Class 1							
15	1	9	1	317.7	210.3	107.4	1182
1	9	8	0	286.5	179.1	107.4	818
Class 2							
1	7	6	0	214.4	149.1	65.3	49
7	12	5	0	176.4	111.1	65.3	546
10	22	5	7	183.8	118.5	65.3	380
10	20	5	5	181.8	116.5	65.3	337
6	12	5	1	177.6	112.3	65.3	125
10	22	5	7	183.8	118.5	65.3	66
7	15	5	3	179.6	114.3	65.3	497
Class 3							
7	17	9	1	317.7	210.3	107.4	268
9	19	9	1	317.7	210.3	107.4	248
1	9	8	0	286.5	179.1	107.4	266
8	18	9	1	317.7	210.3	107.4	289
7	20	6	7	218.7	111.3	107.4	930
Class 4							
7	12	5	0	176.4	102.1	74.3	345
7	14	5	2	178.6	104.3	74.3	755
6	11	5	0	177.0	102.7	74.3	110
9	22	5	8	184.8	110.5	74.3	302
10	22	5	7	183.6	109.3	74.3	488

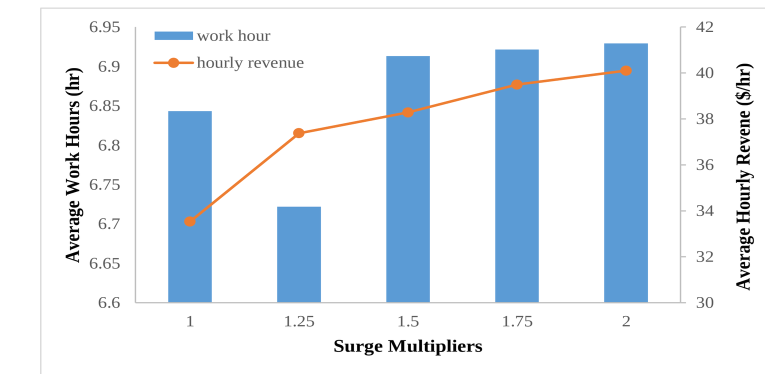
Equilibrium with income-targeting labor supply

Start time	End time	Work hours (hr)	Rest hours (hr)	Revenue ($)	Cost ($)	Utility ($)	Path flow(veh)
Class 1							
15	1	9	1	293.0	210.3	281.3	1294
1	9	8	0	267.0	179.1	281.3	706
Class 2							
8	20	5	7	174.3	118.3	350.9	1482
7	12	5	0	168.3	111.1	350.9	518
Class 3							
7	17	9	1	293.0	210.3	281.3	840
1	9	8	0	267.0	179.1	281.3	547
8	17	9	1	293.0	210.3	281.3	613
Class 4							
8	20	5	7	174.3	109.3	359.9	210
7	22	5	10	177.0	112.5	359.9	381
6	22	5	11	178.1	113.9	359.9	41
7	15	5	3	171.1	105.5	359.9	488
7	22	5	10	177.0	112.5	359.9	631
7	22	5	10	177.0	112.5	359.9	249

2.4 Labor supply elasticity



Neoclassical



Income-targeting

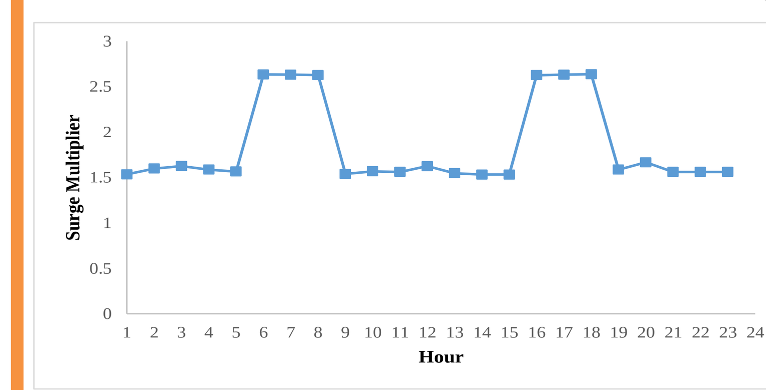
3. SURGE PRICING

To facilitate the presentation, we assume the neo-classical labor supply.

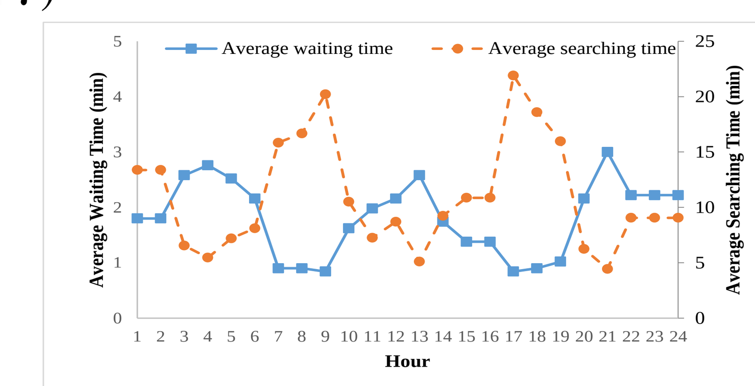
3.1 Equilibrium outcomes

$$\max_{\boldsymbol{\lambda},\mathbf{f},\boldsymbol{\gamma}>\mathbf{0}}\ J = \sum_{b \in A_1} \eta \bar{F}_b Q_b$$

s.t. $\quad G\left(\boldsymbol{\lambda}, \mathbf{f} \mid \boldsymbol{\gamma}\right) = 0$

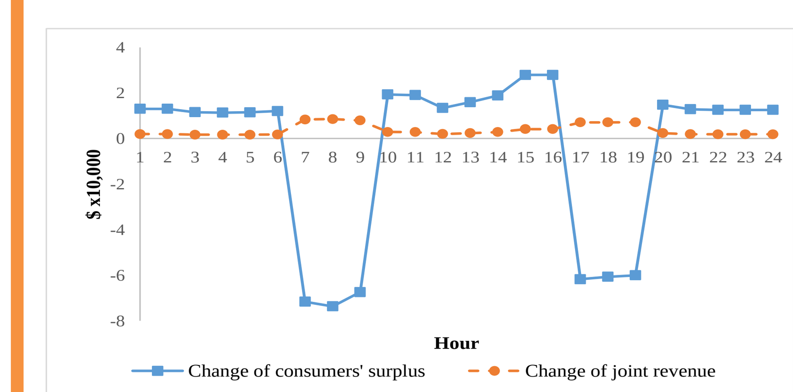


Display of surge multipliers



Display of market frictions

1.Price surges during peak hours;
2.Tendencies of waiting and searching times are opposite each other.



Change of consumers' surplus and joint revenue under surge pricing

1.Surge pricing v.s. optimal static pricing;
2.Platoform and drivers are better-off;
3.Customers are worse-off in highly surged periods.

3.2 Commission cap regulation

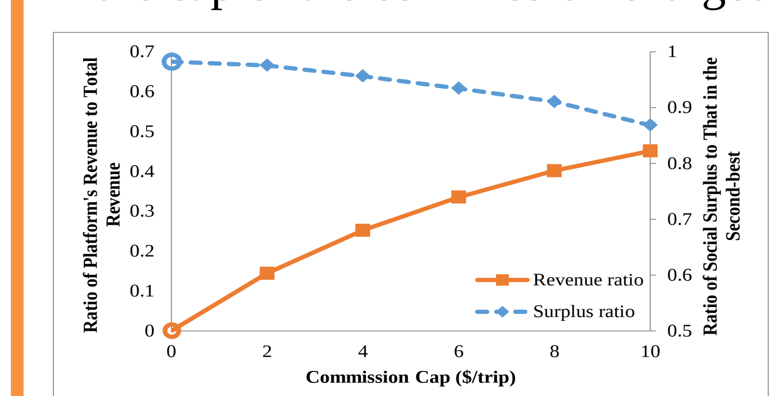
$$\max_{\boldsymbol{\pi},\boldsymbol{\lambda},\mathbf{f},\boldsymbol{\gamma}>\mathbf{0},\hat{\boldsymbol{\eta}}\geq\mathbf{0},\mathbf{N}\geq\mathbf{0}}\ \hat{J} = \sum_{b \in A_1} \hat{\eta}_b Q_b$$

s.t. $\quad G\left(\boldsymbol{\pi}, \boldsymbol{\lambda}, \mathbf{f} \mid \boldsymbol{\gamma}, \hat{\boldsymbol{\eta}}, \mathbf{N}\right) = 0$

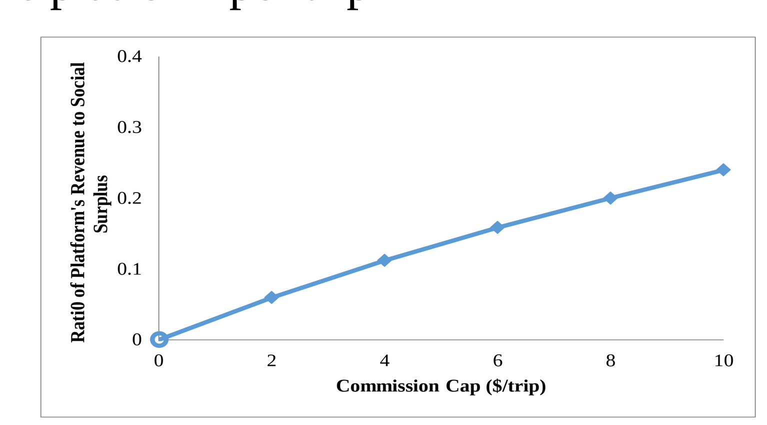
$$\boldsymbol{\lambda} \geq \boldsymbol{\pi}_{\mathbf{R}}$$

$$\hat{\eta}_b \leq \bar{\eta},\ \forall b \in A_1$$

where $\boldsymbol{\pi}_{\mathbf{R}}, \bar{\eta}$ are respectively the reservation value of drivers' profit and the cap of the commission charged by the platform per trip



Share of the platform's revenue (left) and the platform's efficiency(right)



Market outcomes under different commission caps