Ride Sharing Platform Vs Taxi Platform: the Impact on the Revenue

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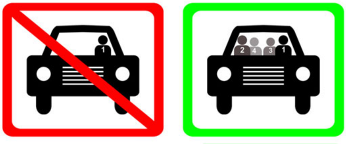
Introduction

There is great need of mobility in major cities!

Possibilities to get a ride:

- Public transportation
- One's own car
- Ride sharing
- A taxi



Introduction: related work

Consists in optimizing the choices of a platform

- Choose efficiently the point of departure and arrival[1]
- An optimization algorithm to efficiently match supply and demand[2]

[1] Service region design for urban electric vehicle sharing systems, Long He et al., 2017

[2] On-demand high-capacity ride-sharing via dynamic trip-vehicle assignment, Alonso-Mora et al., 2017

Introduction: our approach

Our point of view

- Effect of the introduction of a ride sharing/taxi platform
- Game theory $\rightarrow$ predict the outcome

Original paper[1]

- Impact of the introduction of a ride sharing platform
- Game theory: new model of the population

Extension

- What happens if a taxi platform competes with the ride sharing platform ?
- Impact on the revenue (can it increase ?)
- Original model + choice for the users

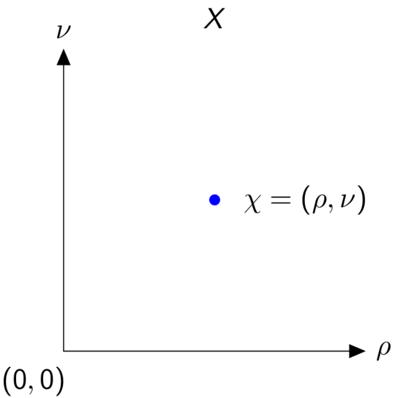
[1] Drivers, riders and service providers: the impact of the sharing economy on mobility, Courcoubetis et al., 2017

Outline

1. The Model
2. Theoretical analysis
3. Numerical analysis
4. Conclusion

The individuals

Society $= \{$*Individual*$\}$. Individuals have type $\chi \in X = \mathbb{R}^2_+$:



Nonatomic game:

- negligible impact of any individual
- continuum of players

$\rho > 0$ = utility for using private transportation
$\nu > 0$ = wage rate when working at a regular job

The platforms

The ride sharing platform

- Rental price r_1:
  - user(s), + riders
- Supply: from the population
- Demand: from the population

The taxi platform

- Rental price r_2: - user(s)
- Supply: fixed number of taxis n_t
- Demand: from the population

Some other constants of the game:

- Number of seats per car: k
- Cost of ownership: ω
- Cost of usage: c

Individuals' possibilities

Transport state

Has to fulfill a transportation need:

- Use public transport
- Request in one of the two platforms (get $\rho > 0$)
- Offer seats (get $\rho > 0$)

$\rightarrow$ Time spent: $1/\lambda_t$

Non-Transport state

Two possiblities:

- Work to get an income at rate $\nu > 0$
- Drive and offer seats (no utility ρ)

$\rightarrow$ Time spent: $1/\lambda_n$

Standardized time: $1/\lambda_n + 1/\lambda_t = 1$, $\lambda_t, \lambda_n > 1$.

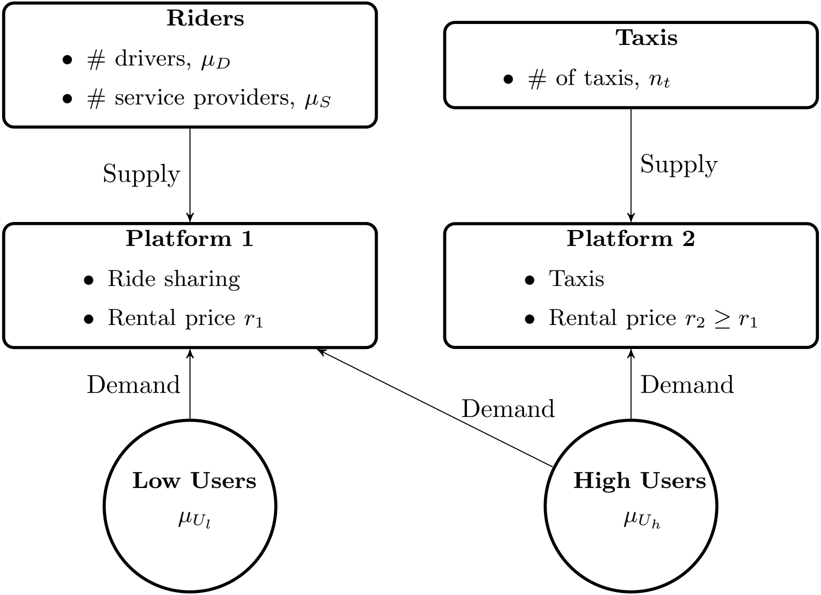
Strategies

Five strategies in $\Sigma = \{A, D, S, U_l, U_h\}$:

- Abstinent (A)
- Driver (D)
- Service Provider (S)
- Low User (U_l)
- High User (U_h)

For $\sigma \in \Sigma$, μ_σ: fraction of the population opting for strategy σ

Strategies (in the case $r_1 \leq r_2$)



Payoffs: $r = min(r_1, r_2)$, $\bar{r} = max(r_1, r_2)$

- $\pi_A(\rho, \nu) = \nu/\lambda_n$
- $\pi_D(\rho, \nu) = \nu/\lambda_n + \rho - \omega + k\bar{p}r_1 - c$
- $\pi_S(\rho, \nu) = \rho - \omega + \lambda_t(k\bar{p}r_1 - c)$
- $\pi_{U_l}(\rho, \nu) = \nu/\lambda_n + p_l(\rho - r)$
- $\pi_{U_h}(\rho, \nu) = \nu/\lambda_n + p_l(\rho - r) + (1 - p_l)p_h(\rho - \bar{r})$

$p_l, p_h, \bar{p}$: probabilities, depends on the distribution $\mu = (\mu_A, \mu_D, \mu_S, \mu_{U_l}, \mu_{U_h})$.

Nash Equilibrium

Informal definition

A situation where it is not in the interest of any player to unilaterally change his strategy

At equilibrium:

- Strategy of players given by $\sigma^* : X \to \Sigma$
- $\forall \chi = (\rho, \nu) \in X, \forall \sigma \in \Sigma, \pi_{\sigma^*(\chi)}(\rho, \nu) \geq \pi_\sigma(\rho, \nu)$
- X partitionned into sets
  $P_\sigma = \{\text{Player choosing strategy } \sigma\}, \sigma \in \Sigma$

Example of equilibrium

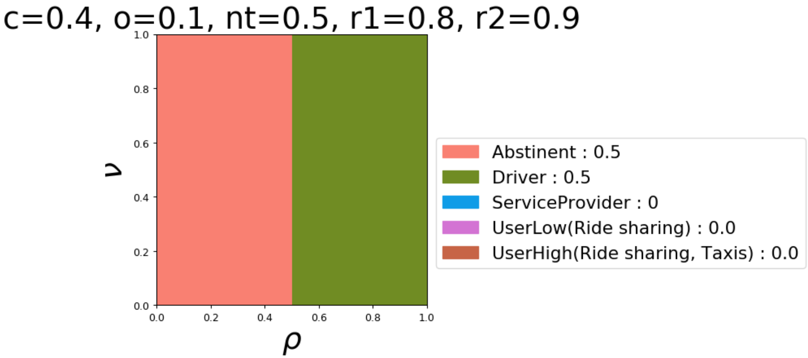


Figure: Equilibrium with parameters $\lambda_t = 6, k = 2$ (o stands for ω)

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The revenue of the ride sharing platform: $\mathcal{R}$

Proportionate to:

- The rental price r_1
- The number of seats sold (depends on which is the cheapest platform)

If $r_1 \leq r_2$:

$$\mathcal{R} = r_1 \times p_l \times (\mu_{U_l} + \mu_{U_h})$$

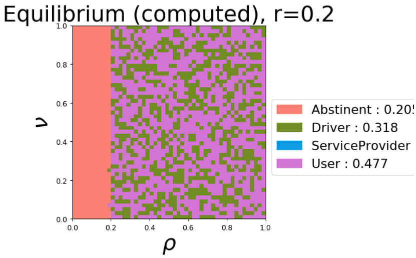
If $r_1 > r_2$:

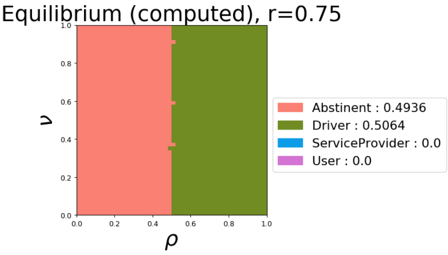
$$\mathcal{R} = r_1 \times p_h \times (1 - p_l)\mu_{U_h}$$

Some results: when $r_1 \leq r_2$ ($r = r_1$)

Theorem

If $r_1 \geq \frac{\omega+c}{k+1}$, then the equilibrium is the same as in the original game (without taxis).



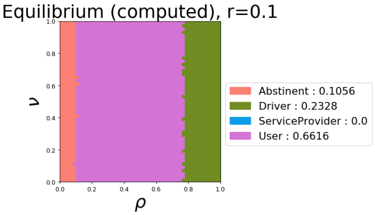


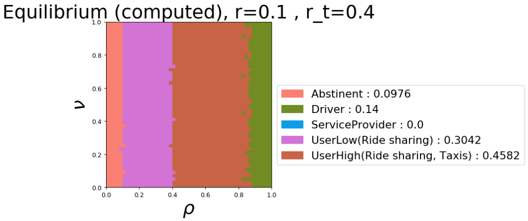
$$\omega = 0.1,\ c = 0.4,\ k = 2,\ n_t = 0.1,\ \lambda_t = 6.$$

Some results: when $r_1 \leq r_2$ ($r = r_1$, $r_t = r_2$)

Theorem

If $\omega \leq c/k$ then adding the taxi platform can not increase the revenue of the ride sharing platform





$$\omega = 0.1, c = 0.4, k = 2, n_t = 0.1, \lambda_t = 6.$$

Some results: The revenue can increase

Theorem

There exists some values of our parameters for which the revenue of the ride sharing platform strictly increases

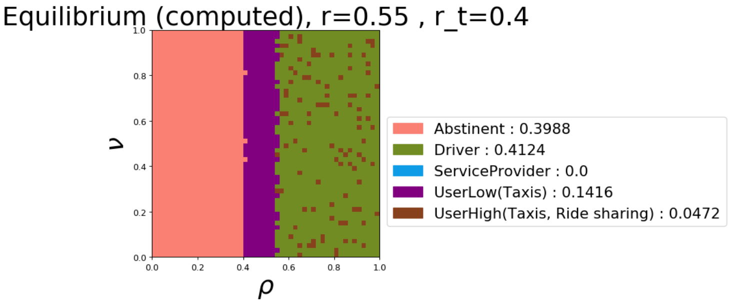


Figure: Equilibrium with parameters $\omega = 0.1$, $c = 0.4$, $k = 2$, $n_t = 0.1$, $\lambda_t = 6$.

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The Best Response Dynamics Algorithm

Algorithm 1 Best Response Dynamics

```
1: Each player is assigned a strategy randomly
2: while a player changed strategy do
3:     for each player do
4:         Choose the payoff-maximizing strategy;
5:         Update distribution
```

This algorithm:

- Works on a large number of players (5000)
- Does not necessarily converge
- When it does, we have a Nash Equilibrium

Better revenue

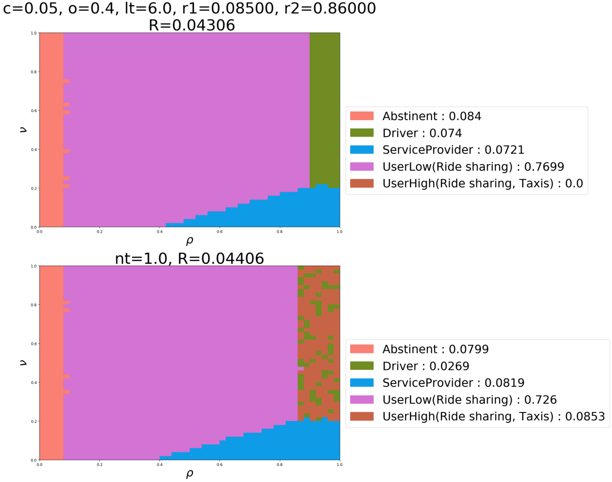

Figure: Equilibria without (top) and with (bottom) taxis, for $k = 1$

Price dynamics

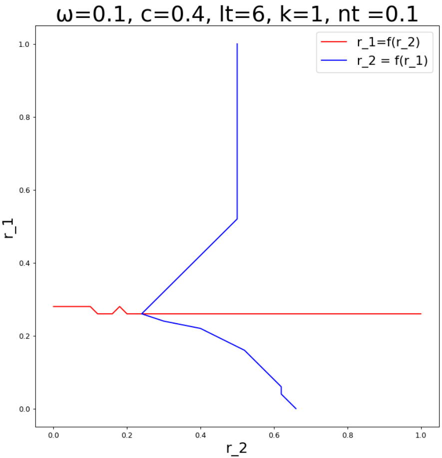

Figure: Optimizing price of one platform as a function of the price of the other platform

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Conclusion and future work

- Model difficult to study: the model changes if $r_1 \leq r_2$ or if $r_2 > r_1$
- However, we do have some results:
  - Conditions that ensure that the revenue does not increase
  - Numerical/Analytical example of an increasing revenue
  - Situations that do not change by adding taxis

Future possibilities

- Condition of existence of service providers (independent of the distribution)
- Study the price dynamics: numerical simulations may suggest what happens

Other functions of interest: definition

- Distribution: $\mu_\sigma(s) = \int_X \delta_{s,\sigma} d\chi$
- Ownership: $\Omega(\mu) = \mu_S + \mu_D$;
- Traffic intensity: $\Gamma(\mu) = \mu_S + \mu_D/\lambda_t$;
- Social Welfare: $W(s) = \sum_{\sigma \in \Sigma} \int_X \pi_\sigma(\chi) \cdot \delta_{s,\sigma} d\chi$.

Other functions of interest: curves

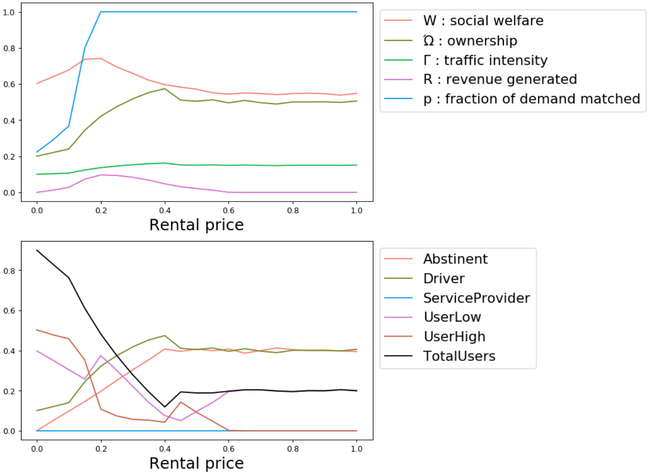

Figure: Curves with parameters $\omega = 0.1$, $c = 0.4$, $k = 2$, $n_t = 0.1$, $\lambda_t = 6$.

The matching functions

If $r_1 \leq r_2$:

- $p_l = \frac{k(\mu_D+\lambda_t\mu_S)}{\mu_{U_l}+\mu_{U_h}} \wedge 1$
- $p_h = \frac{n_t}{(1-p_l)\mu_{U_h}} \wedge 1$
- $\bar{p} = \frac{\mu_{U_l}+\mu_{U_h}}{k(\mu_D+\lambda_t\mu_S)} \wedge 1$

If $r_1 > r_2$:

- $p_l = \frac{n_t}{\mu_{U_l}+\mu_{U_h}} \wedge 1$
- $p_h = \frac{k(\mu_D+\lambda_t\mu_S)}{(1-p_l)\mu_{U_h}} \wedge 1$
- $\bar{p} = \frac{(1-p_l)\mu_{U_h}}{k(\mu_D+\lambda_t\mu_S)} \wedge 1$