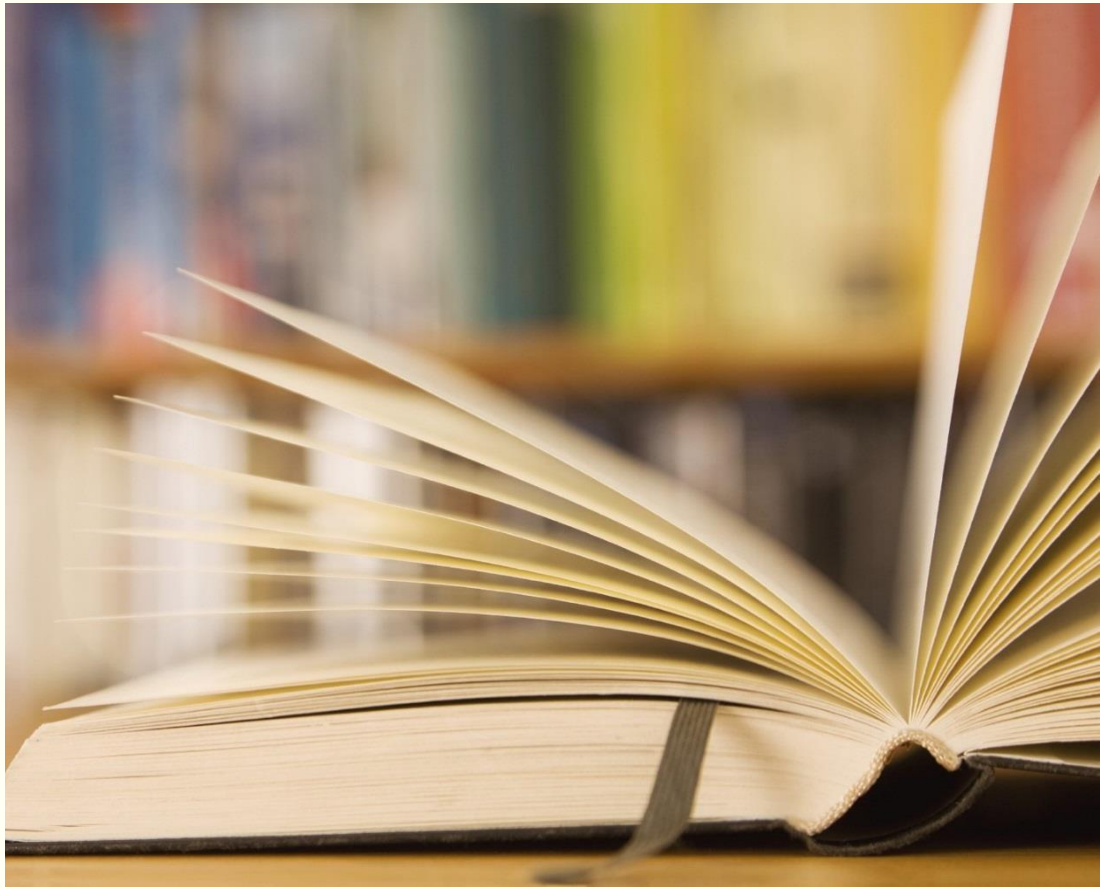
PLATFORM DELIVERY: A GAME-THEORETIC ANALYSIS OF A NEW DELIVERY MODEL IN THE SHARING ECONOMY

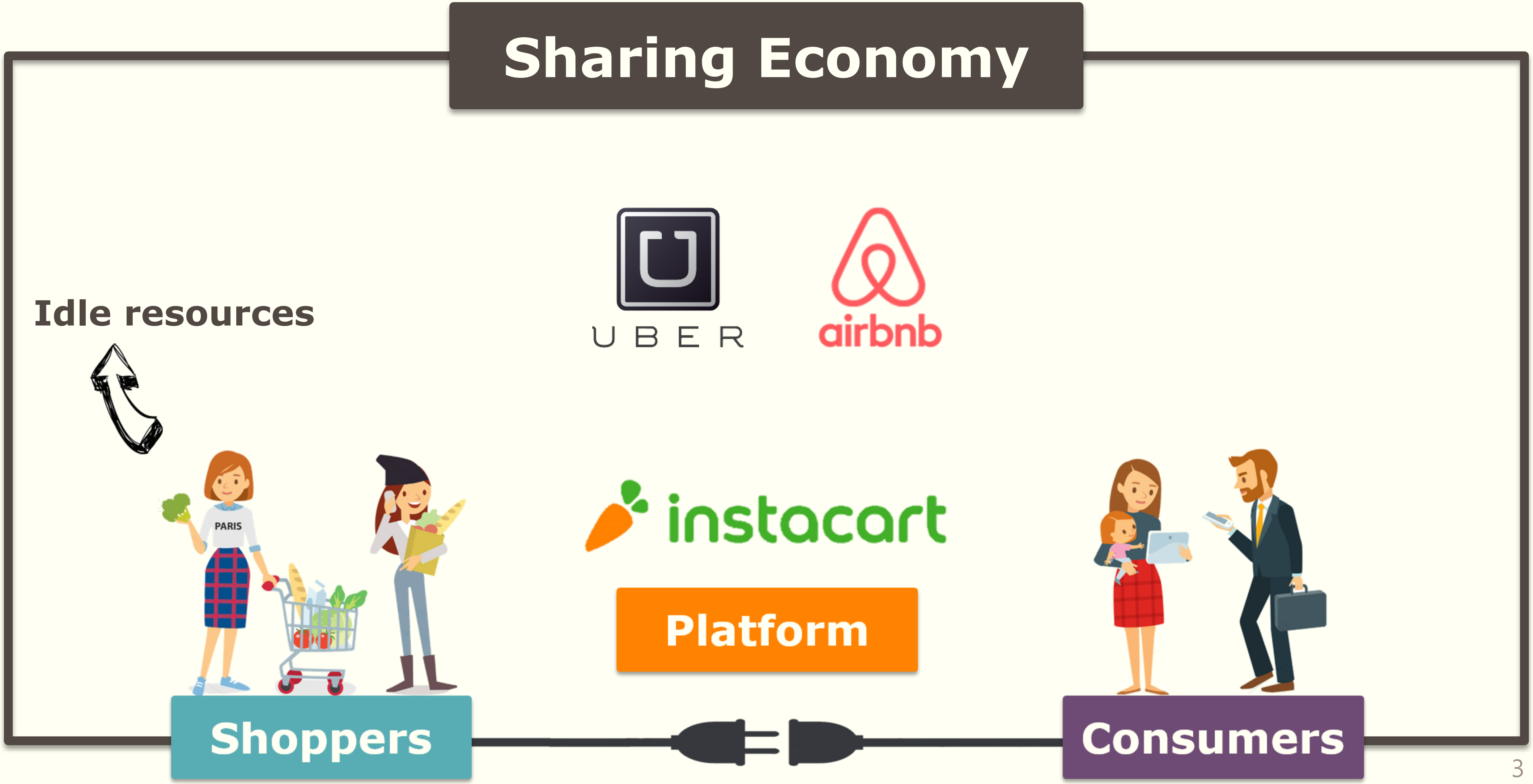
Guan-Yu Zhong
Adviser: Ling-Chieh Kung, Ph.D.

Department of Information Management
National Taiwan University
2016/06/23

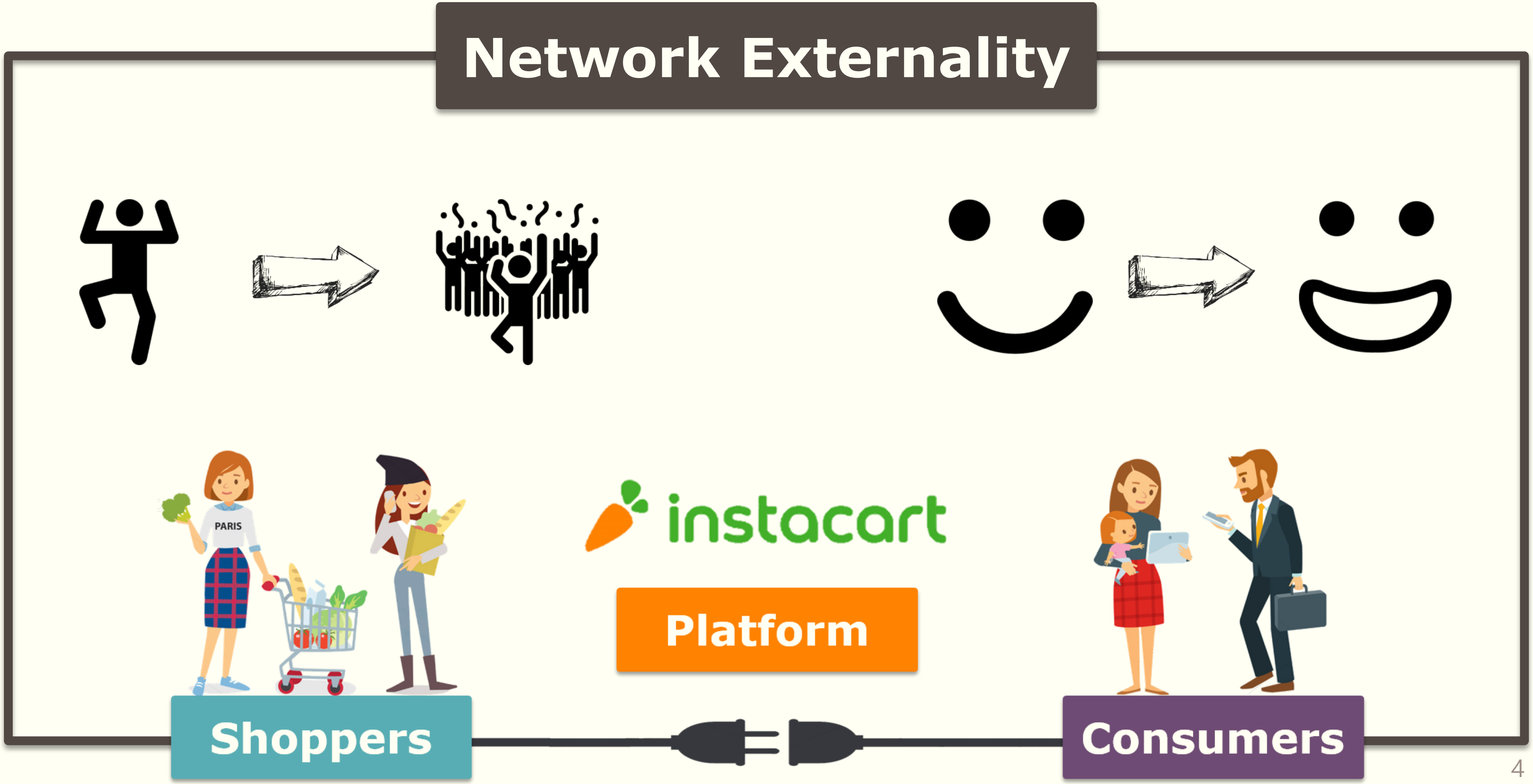


Introduction

Introduction

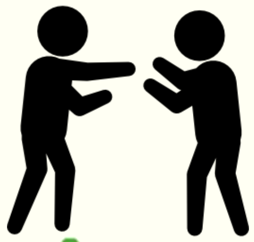


Introduction



Introduction

Platform delivery



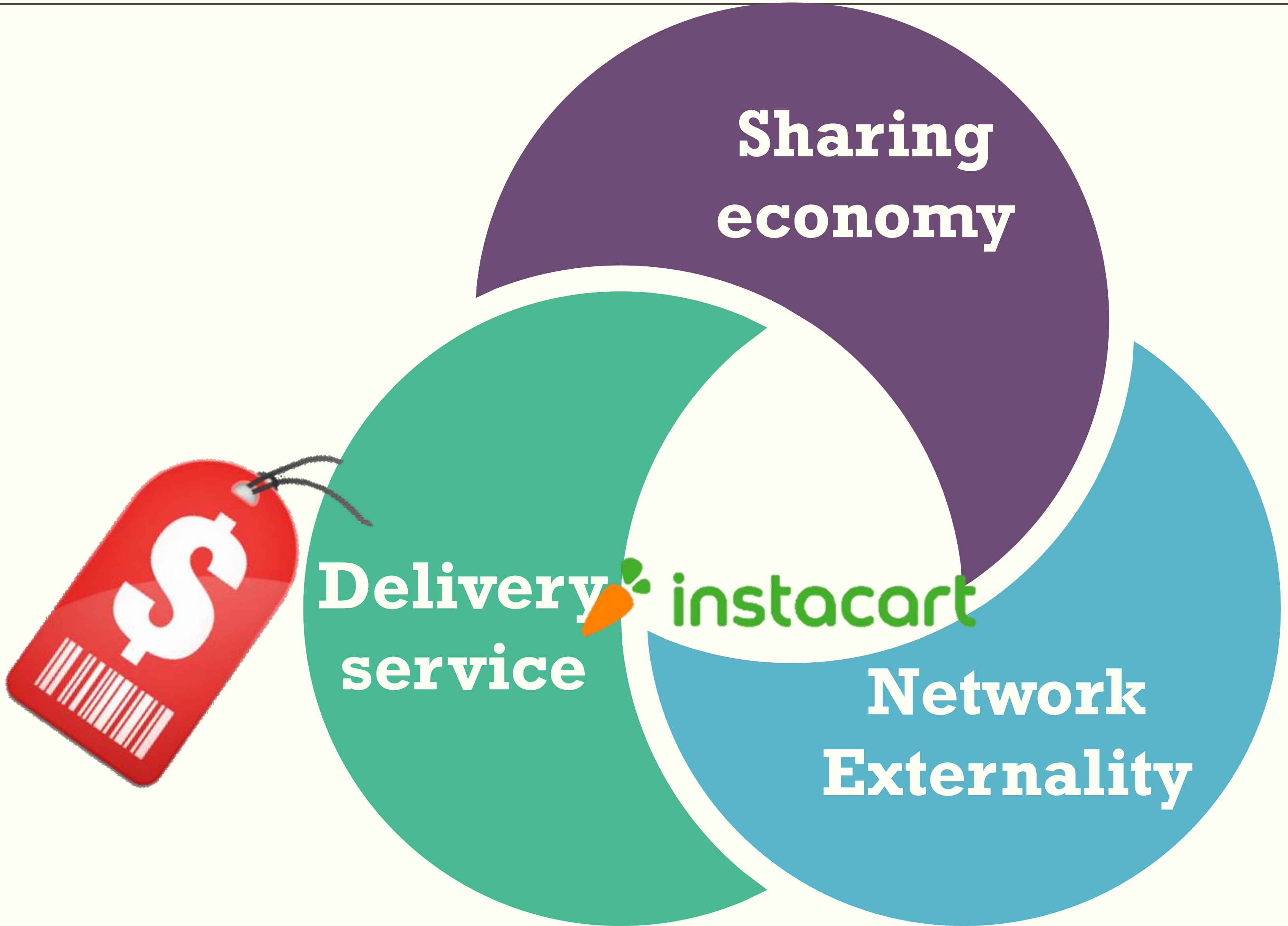
Integrated delivery

Flexibility

Efficiency

Cheap

Introduction



Introduction

Membership-based pricing

Transaction-based pricing

Cross-subsidization

Outline

01 - LITERATURE REVIEW

02 - MODEL

03 - ANALYSIS

- Optimal profits
- Comparisons

04 - EXTENSIONS

- Discount factor
- Marginal transaction cost
- Fixed shopper subsidization
- Price-sensitive number of orders

05 - CONCLUSIONS

LITERATURE REVIEW

Literature review

Sharing economy

Reducing social cost
Zero marginal cost

- **Andersson et al. (2013)**
- **Santi et al. (2014)**
- **Felländer et al. (2015)**
- **Zervas et al. (2016)**
- **Rougés and Montreuil (2004)**
- **Teresa and Christy (2015)**

Saving inventory cost

Literature review

Network externality

- **Katz and Shapiro (1985)**: Pioneer
- **Fudenberg and Tirole (2000)**: Competition between incumbent and entrant
- **Armstrong (2006)**: Combining demand function with network externality
- **Rochet and Tirole (2006)**: Combining two trends of literature
- **Jing (2007)**: Product line design

Literature review

Delivery service

Decentralization or centralization

- **McGuire and Staelin (1983)**
- **Li and Lee (1994)**
- **So (2000)**

Service speed affects service quality, which affects pricing strategy.

Literature review

Sharing economy

Andersson et al. (2013)
Santi et al. (2014)
Fell¨ander et al. (2015)
Zervas et al. (2016)
Roug´es and Montreuil (2004)
Teresa and Christy (2015)

Network externality

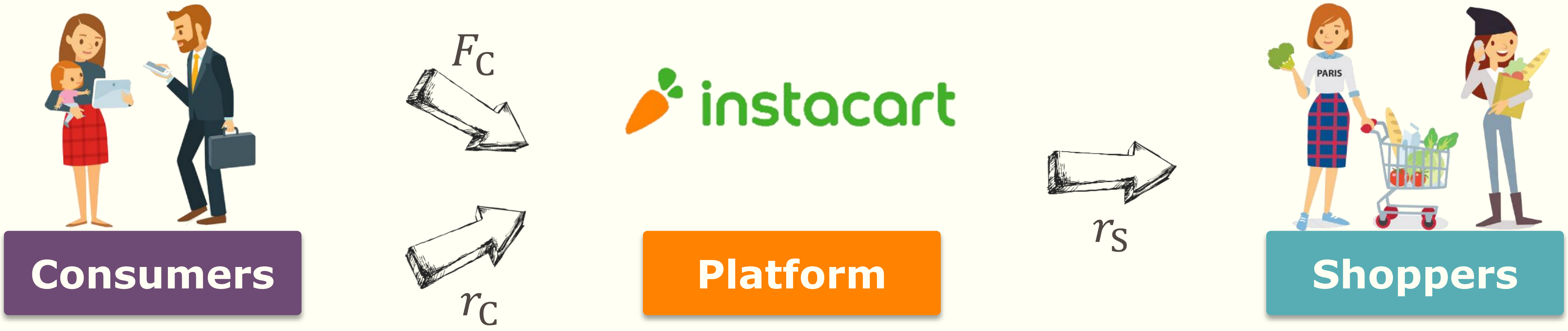
Katz and Shapiro (1985)
Fudenberg and Tirole (2000)
Armstrong (2006)
Rochet and Tirole (2006)
Jing (2007)

Delivery service

McGuire and Staelin (1983)
Li and Lee (1994)
So (2000)

MODEL

Model



Consumer side	Shopper side
n_C: number of consumers	n_S: number of shoppers
F_C: membership fee	Not consider F_S
r_C: per-transaction fee	r_S: per-transaction subsidy
θ: willingness to pay for one unit quality service	η: cost per transaction
N: consumption in one membership period	

Model

Consumers

F_C

r_C

instacart

Platform

r_S

Shoppers

θ

Not join	Join	
0	θ^*	1 θ

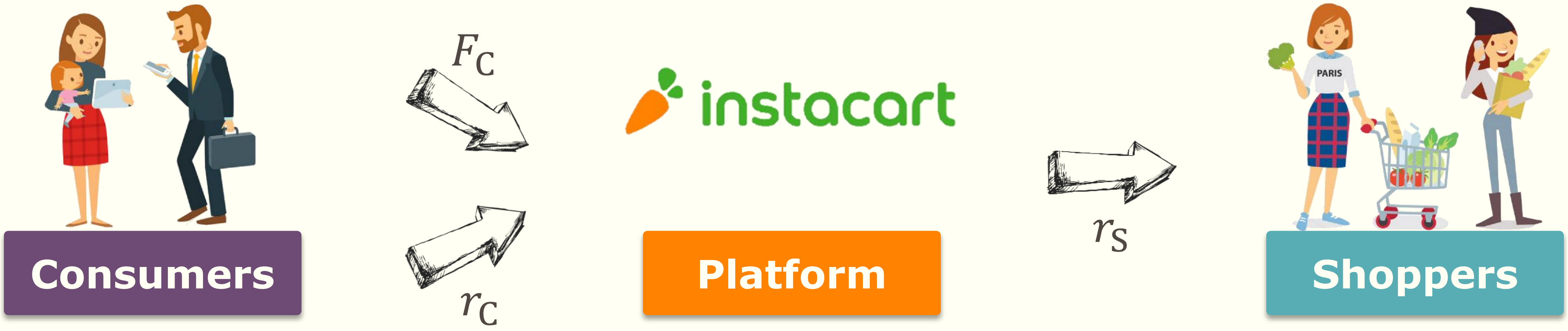
$$n_C = 1 - \theta^*$$

η

Join	Not join	
0	η^*	1 η

$$n_S = \eta^*$$

Model



$$u_C = N(\theta Q - r_C) - F_C$$
$$= N(\theta\sqrt{n_S} - r_C) - F_C$$

$$\pi = N n_C (r_C - r_S) + n_C F_C$$

$$u_S = \frac{N n_C}{n_S}(-\eta + r_S)$$

Model

M

Membership-based pricing

$r_C = 0$

T

Transaction-based pricing

$F_C = 0$

X

Cross-subsidization

$r_C = r_S$

ANALYSIS

Analysis

Consumers

$$u_C = N(\theta^* Q - r_C) - F_C = 0$$
$$n_C = 1 - \theta^*$$

Shoppers

$$u_S = \frac{N n_C}{n_S}(-\eta^* + r_S) = 0$$
$$n_S = \eta^*$$

$$\theta^* = \frac{\sqrt{r_S}(r_C N + F_C)}{r_S N}, \eta^* = r_S$$

Platform

$$\pi = N n_C (r_C - r_S) + n_C F_C$$

$$\pi = (1 - \theta^*)\big(F_C + N(r_C - r_S)\big)$$
$$= \underbrace{\left(1 - \frac{\sqrt{r_S}(r_C N + F_C)}{r_S N}\right)}_{\text{Number of consumers}} \underbrace{\big(F_C + N(r_C - r_S)\big)}_{\text{Earnings from each consumer}}$$

Analysis

$$\pi = (1-\theta^*)\big(F_C + N(r_C - r_S)\big)$$
$$= \left(1 - \frac{\sqrt{r_S}(r_C N + F_C)}{r_S N}\right)\big(F_C + N(r_C - r_S)\big)$$

$r_C = 0$

M $$\pi^{M} = \left(1 - \frac{\sqrt{r_S}F_C}{r_S N}\right)(F_C - N r_S)$$

$F_C = 0$

T $$\pi^{T} = \left(1 - \frac{\sqrt{r_S}r_C}{r_S}\right)N(r_C - r_S)$$

$r_C = r_S$

X $$\pi^{X} = \left(1 - \frac{\sqrt{r_S}(r_S N + F_C)}{r_S N}\right)F_C$$

Analysis

M $\pi^{\mathrm{M}} = \left(1 - \frac{\sqrt{r_{\mathrm{S}}} F_{\mathrm{C}}}{r_{\mathrm{S}} N}\right)(F_{\mathrm{C}} - N r_{\mathrm{S}})$

T $\pi^{\mathrm{T}} = \left(1 - \frac{\sqrt{r_{\mathrm{S}}} r_{\mathrm{C}}}{r_{\mathrm{S}}}\right) N (r_{\mathrm{C}} - r_{\mathrm{S}})$

X $\pi^{\mathrm{X}} = \left(1 - \frac{\sqrt{r_{\mathrm{S}}}(r_{\mathrm{S}} N + F_{\mathrm{C}})}{r_{\mathrm{S}} N}\right) F_{\mathrm{C}}$

Lemma 1

$r_{\mathrm{S}}^{\mathrm{M}} = \frac{1}{9},\ F_{\mathrm{C}}^{\mathrm{M}} = \frac{2}{9} N$

Lemma 2

$r_{\mathrm{S}}^{\mathrm{T}} = \frac{1}{9},\ r_{\mathrm{C}}^{\mathrm{T}} = \frac{2}{9}$

Lemma 3

$r_{\mathrm{S}}^{\mathrm{X}} = \frac{1}{9},\ r_{\mathrm{C}}^{\mathrm{X}} = \frac{1}{9},\ F_{\mathrm{C}}^{\mathrm{X}} = \frac{1}{9} N$

Analysis - Comparisons

Proposition 1

$$r_{\mathrm{S}}^{\mathrm{X}} = r_{\mathrm{S}}^{\mathrm{M}} = r_{\mathrm{S}}^{\mathrm{T}}$$
$$r_{\mathrm{C}}^{\mathrm{T}} > r_{\mathrm{C}}^{\mathrm{X}} > 0$$
$$F_{\mathrm{C}}^{\mathrm{M}} > F_{\mathrm{C}}^{\mathrm{X}} > 0$$

Proposition 2

$$\pi^{\mathrm{M}} = \pi^{\mathrm{T}} = \pi^{\mathrm{X}}$$

Proposition 3

A solution $(r_{\mathrm{C}}, r_{\mathrm{S}}, F_{\mathrm{C}})$ *is optimal to the platform's problem if and only if* $r_{\mathrm{S}} = \frac{1}{9}$ *and* $r_{\mathrm{C}}N + F_{\mathrm{C}} = \frac{2}{9}N$.

EXTENSIONS

Extensions

1. **Discount factor** — Take account of how sensitive the platform is to cash flow in each transaction.
2. **Marginal transaction cost** — Take the platform's marginal cost into account.
3. **Fixed shipper subsidization** — The platform employs shippers with a fixed payment rather than a per-transaction one.
4. **Price-sensitive number of orders** — The number of orders would decrease in the per-transaction fee.

Extension 1 - Discount factor

Let $a \in [0,1]$

$$\pi_{discount} = \left(1 - \frac{\sqrt{r_S}(r_C N + F_C)}{r_S N}\right)(F_C + Na(r_C - r_S))$$

Lemma 4

$$r_S^M = \frac{a^2+1}{18},\ F_C^M = \frac{(\sqrt{1+a^2}(a+a^2)+3\sqrt{2}(1+a^2))}{36\sqrt{1+a^2}}N$$

Lemma 5

$$r_S^T = \frac{1}{9},\ r_C^T = \frac{2}{9}$$

Lemma 6

$$r_S^X = \frac{1}{9},\ r_C^X = \frac{1}{9},\ F_C^X = \frac{1}{9}N$$

Proposition 4

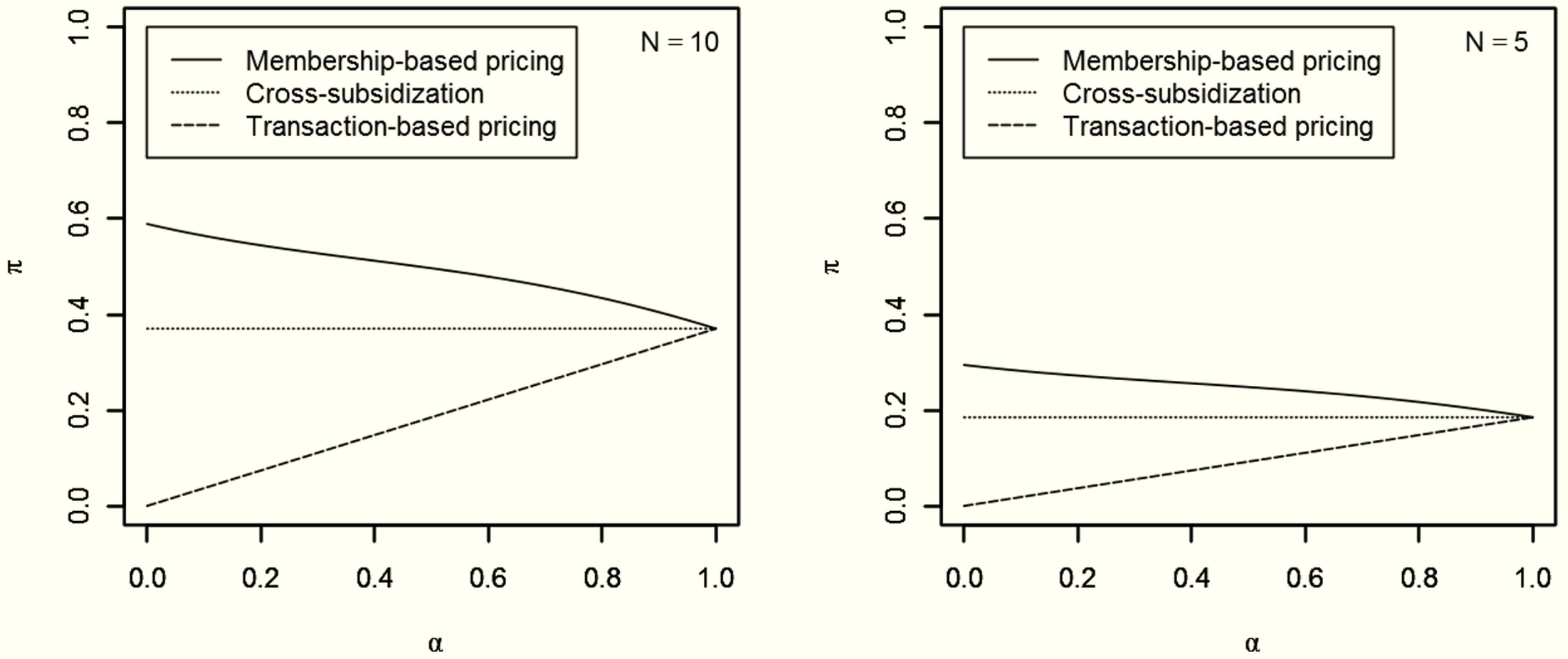
$$r_S^T = r_S^X > r_S^M$$
$$r_C^T > r_C^X > 0$$
$$F_C^M > F_C^X > 0$$

Extension 1 - Discount factor

Proposition 5

$$\pi^{M}_{discount} > \pi^{X}_{discount} > \pi^{T}_{discount}$$

Why Instacart Express



Extension 2 - Marginal transaction cost

$$\pi_{cost} = \left(1 - \frac{\sqrt{r_S}(r_C N + F_C)}{r_S N}\right)(F_C + N(r_C - r_S - c))$$

Lemma 7

$$r_S^M = \frac{6c+1+\sqrt{12c+1}}{18},\ F_C^M = \frac{\left(\sqrt{\sqrt{12c+1}+6c+1}\left(\sqrt{12c+1}+24c+1\right)+3\sqrt{2}\left(\sqrt{12c+1}+6c+1\right)\right)}{36\sqrt{\sqrt{12c+1}+6c+1}}N$$

Lemma 8

$$r_S^T = \frac{6c+1+\sqrt{12c+1}}{18},\ r_C^T = \frac{6c+1+\sqrt{12c+1}}{9}$$

Lemma 9

$$r_S^X = r_C^X = \frac{6c+1+\sqrt{12c+1}}{18},\ F_C^X = \frac{6c+1+\sqrt{12c+1}}{18}N$$

Extension 2 - Marginal transaction cost

Proposition 1

=

Proposition 6

$$r_S^{\mathrm{X}} = r_S^{\mathrm{M}} = r_S^{\mathrm{T}}$$
$$r_{\mathrm{C}}^{\mathrm{T}} > r_{\mathrm{C}}^{\mathrm{X}} > 0$$
$$F_{\mathrm{C}}^{\mathrm{M}} > F_{\mathrm{C}}^{\mathrm{X}} > 0$$

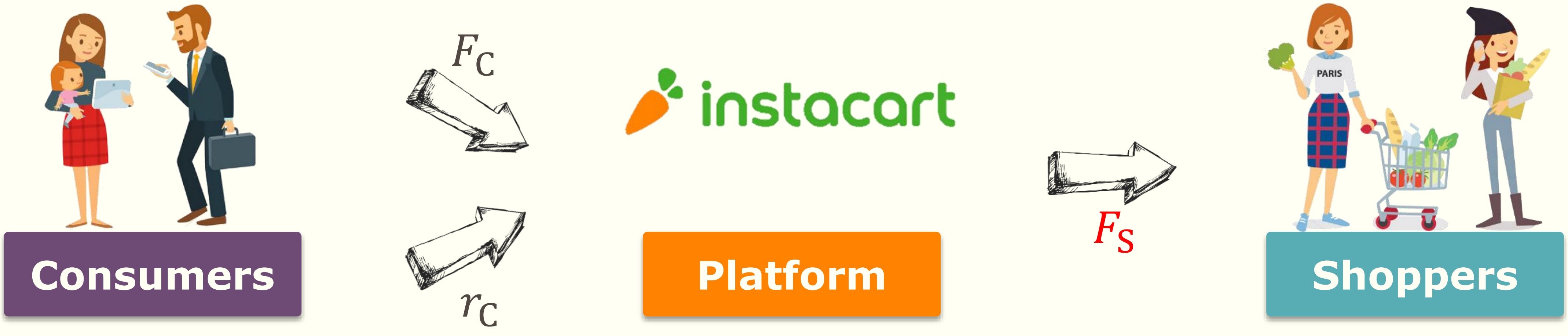
Proposition 2

=

Proposition 7

$$\pi_{cost}^{\mathrm{M}} = \pi_{cost}^{\mathrm{T}} = \pi_{cost}^{\mathrm{X}}$$

Extension 3 - Fixed shopper subsidization



$$u_C = N(\theta Q - r_C) - F_C \qquad \pi = Nan_C(r_C) + n_C F_C + n_S F_S \qquad u_S = \frac{Nn_C}{n_S}(-\eta) - F_S$$

$$\pi_{fixed} = -\frac{F_S}{N}(Nar_C + F_C) + \left(\frac{r_C N + F_C}{F_S + N}\right)^2 F_S$$

Extension 3 - Fixed shopper subsidization

Proposition 8

When we set $a = 1$, a plan $(r_{\mathrm{C}}, F_{\mathrm{C}}, F_{\mathrm{S}})$ is the platform's optimal solution if and only if

$$F_{\mathrm{S}} = -\frac{N}{3} \text{ and } r_{\mathrm{C}}N + F_{\mathrm{C}} = \frac{2}{9}N.$$

Furthermore, no matter the platform subsidizes shippers with fixed or per-transaction subsidization, the platform's profits are the same (cf. proposition 3).

Fixed subsidization = **Per-transaction subsidization**

Extension 3 - Fixed shopper subsidization

Proposition 9 – part 1

When we set $a < 1$, the platform's optimal solution under transaction-based and membership-based pricing strategies would be

$$F_{\mathrm{S}}^{\mathrm{T}} = -\frac{N}{3}, r_{\mathrm{C}}^{\mathrm{T}} = \frac{2}{9}a \text{ and}$$

$$F_{\mathrm{S}}^{\mathrm{M}} = -\frac{N}{3}, F_{\mathrm{C}}^{\mathrm{M}} = \frac{2}{9}N.$$

And the platform's optimal profits under these two strategies would have the following relation

$$\pi_{fixed}^{\mathrm{M}} > \pi_{fixed}^{\mathrm{T}}.$$

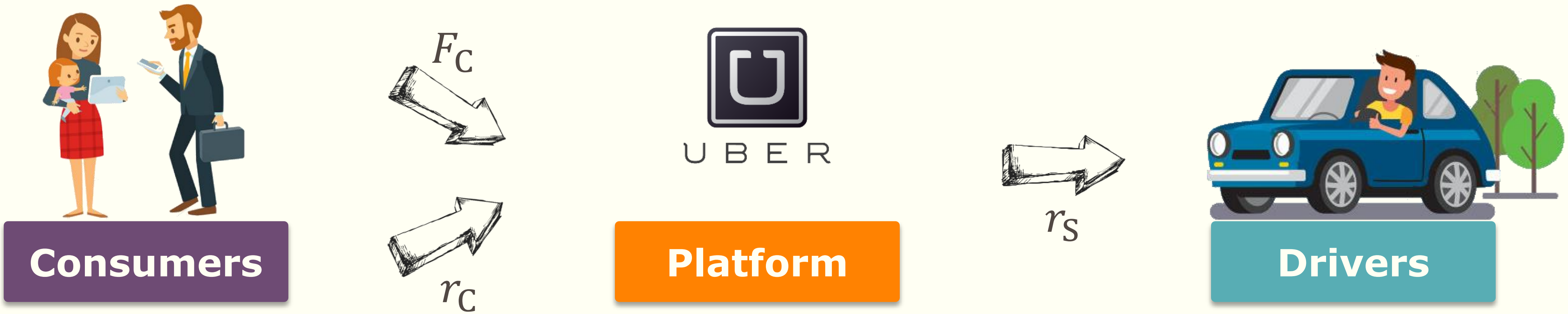
Extension 3 - Fixed shopper subsidization

Proposition 9 – part 2

Furthermore, no matter the platform employs which pricing strategy here, subsidizing shippers with per-transaction subsidization is better for it, i.e., $\pi^{\mathrm{M}}_{discount} > \pi^{\mathrm{M}}_{fixed}$ *and* $\pi^{\mathrm{T}}_{discount} > \pi^{\mathrm{T}}_{fixed}$.

Per-transaction subsidization > **Fixed subsidization**

Extension 4 - Price-sensitive number of orders



$$u_C = \frac{N}{r_C}(\theta Q - r_C) - F_C \qquad \pi = \frac{N}{r_C} n_C (r_C - r_S) + n_C F_C \qquad u_S = \frac{N}{r_C}\frac{n_C}{n_S}(-\eta + r_S)$$

Capacity constraint: $\frac{N}{r_C}\frac{n_C}{n_S} \leq K$

Extension 4 - Price-sensitive number of orders

$$\max \quad \left(1 - \frac{\frac{F_C r_C}{N} + r_C}{\sqrt{r_S}}\right)\left(\frac{N}{r_C}(r_C - r_S) + F_C\right)$$

$$s.t. \quad r_C \geq \frac{\sqrt{r_S}N}{r_S^{3/2}K + N + F_C}$$

T

$$\max \quad \left(1 - \frac{r_C}{\sqrt{r_S}}\right)\left(\frac{N}{r_C}(r_C - r_S)\right)$$

$$s.t. \quad r_C \geq \frac{\sqrt{r_S}N}{r_S^{3/2}K + N}$$

X

$$\max \quad \left(1 - \frac{\frac{F_C r_C}{N} + r_C}{\sqrt{r_S}}\right) F_C$$

$$s.t. \quad F_C \geq \frac{N}{\sqrt{r_S}} - r_S^{\frac{3}{2}} K - N$$

Extension 4 - Price-sensitive number of orders

T

$$\max \quad \underbrace{\left(1 - \frac{r_C}{\sqrt{r_S}}\right)}\underbrace{\left(\frac{N}{r_C}(r_C - r_S)\right)}$$

$$s.t. \quad r_C \geq \frac{\sqrt{r_S}N}{r_S^{3/2}K+N}$$

X

$$\max \quad \underbrace{\left(1 - \frac{\frac{F_C r_C}{N}+r_C}{\sqrt{r_S}}\right)}\underbrace{F_C}$$

$$s.t. \quad F_C \geq \frac{N}{\sqrt{r_S}} - r_S^{\frac{3}{2}}K - N$$

n_C**: Number of consumers**

m: **Earnings from each consumer**

$TC = \frac{N}{r_C}n_C$

Extension 4 - Price-sensitive number of orders

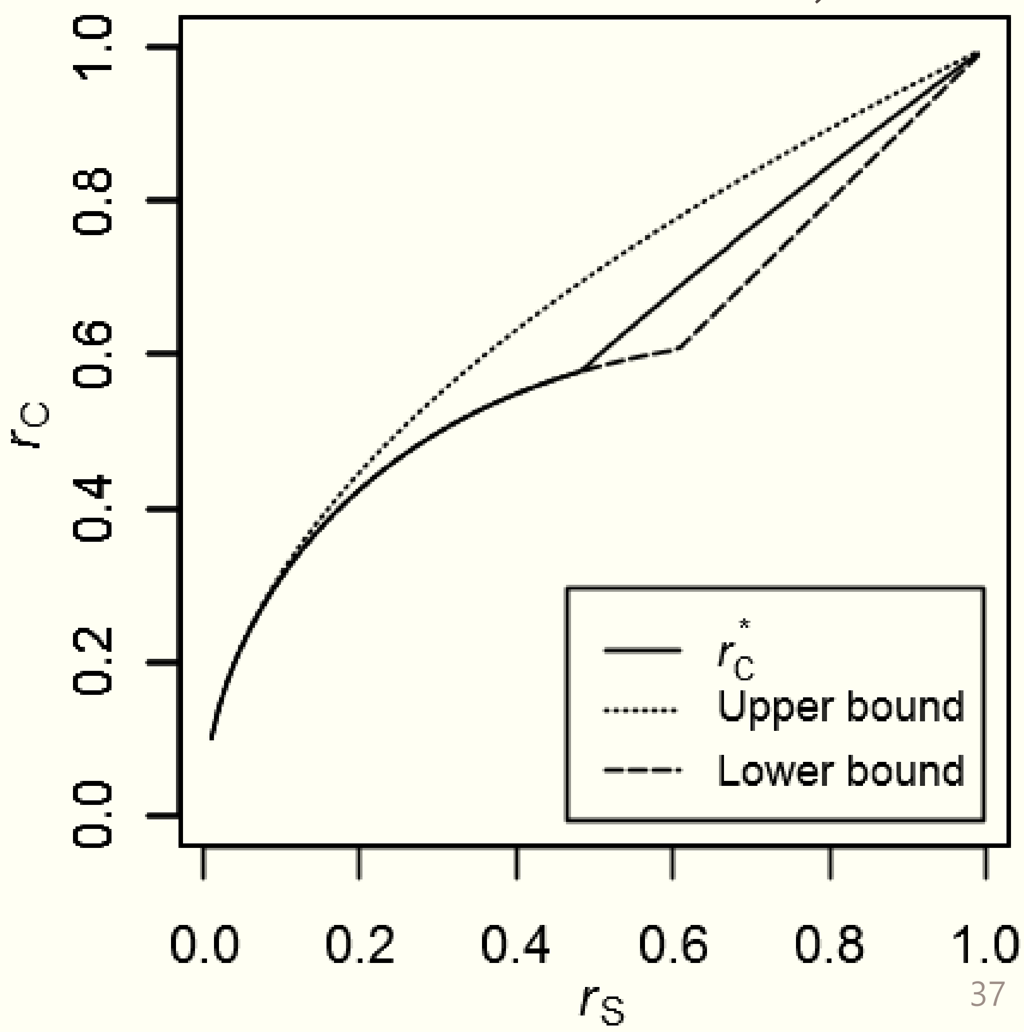
$$\max \quad \left(1 - \frac{r_C}{\sqrt{r_S}}\right)\left(\frac{N}{r_C}(r_C - r_S)\right)$$

$$s.t. \quad r_C \geq \frac{\sqrt{r_S}N}{r_S^{3/2}K+N}$$

$1 - \frac{r_C}{\sqrt{r_S}} > 0$ and $r_C - r_S > 0$

$\Rightarrow \quad r_S < r_C < \sqrt{r_S}$

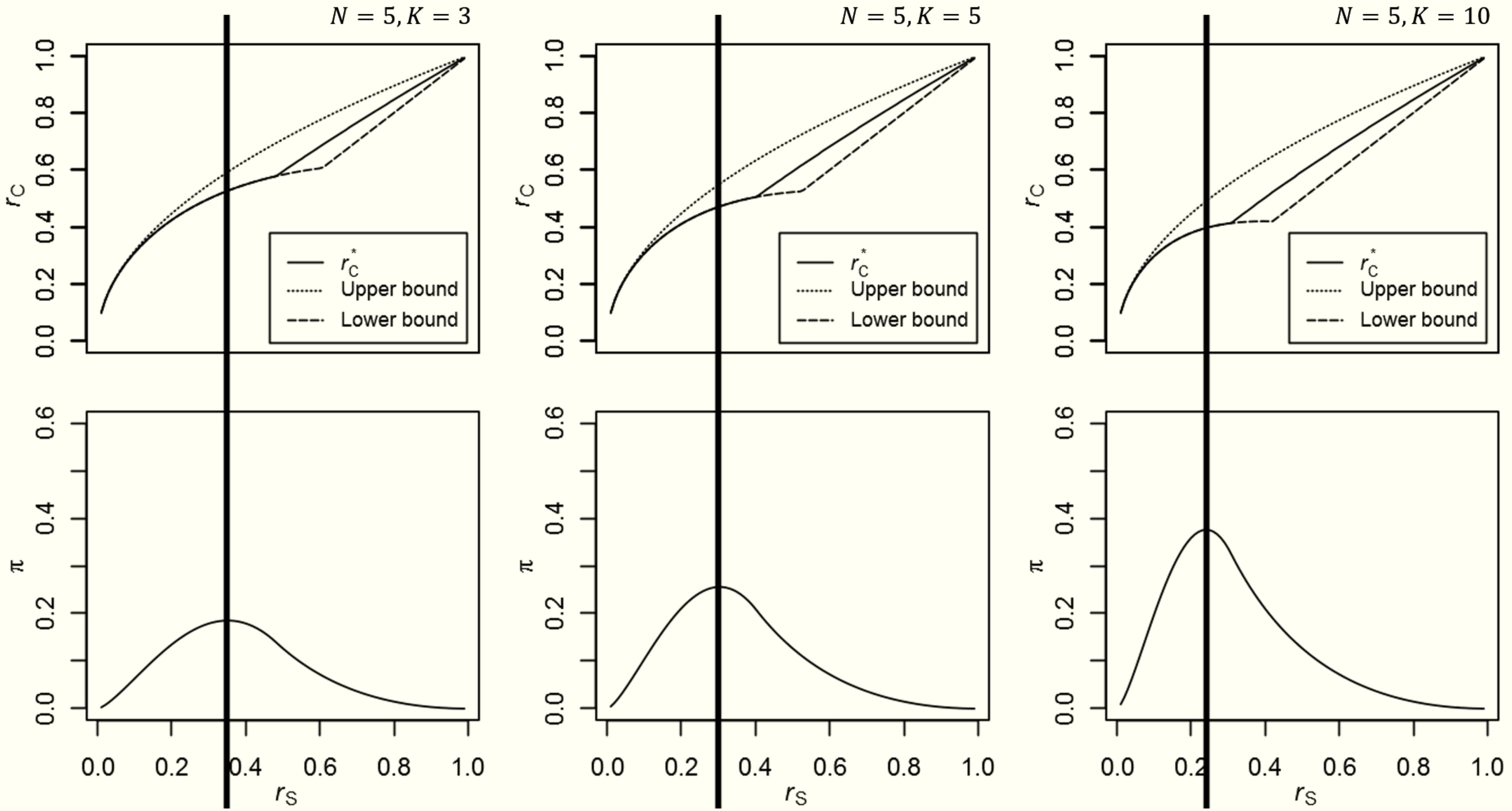
$N = 5, K = 3$



Extension 4 - Price-sensitive number of orders

Observation 1

Given an arbitrary set of N and K , the optimal solution would bind to the capacity constraint under pure-transaction pricing and cross-subsidization strategies.



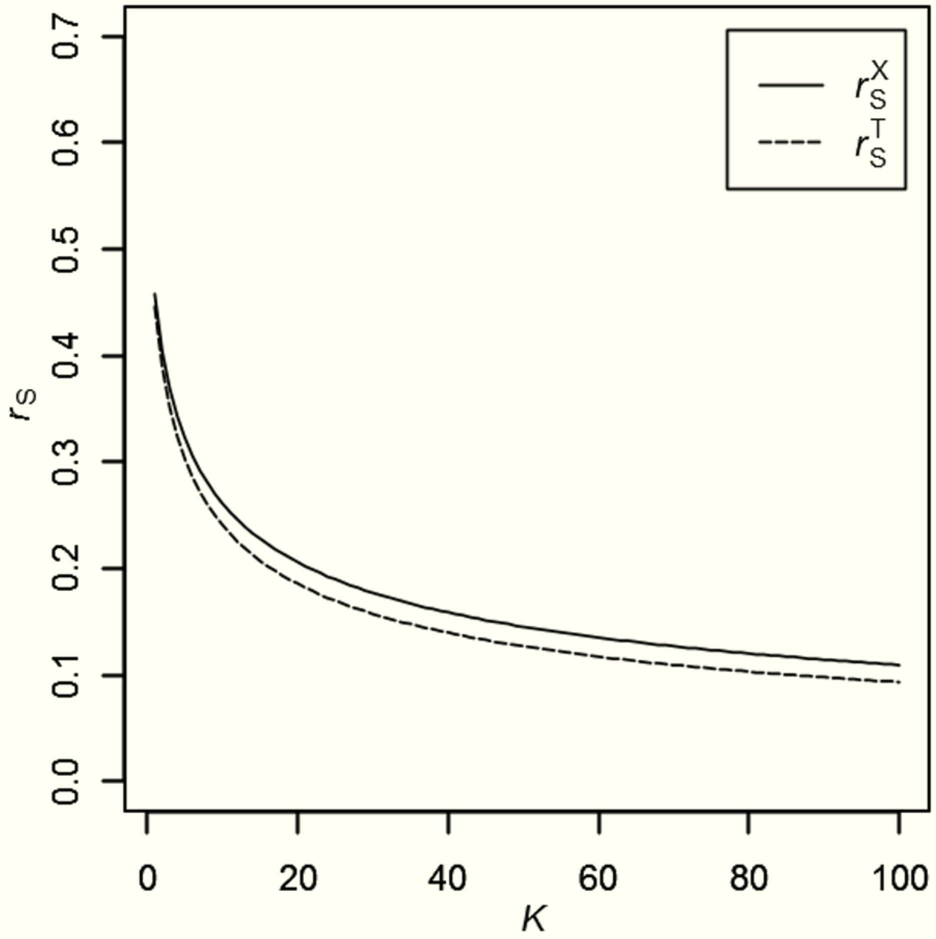
Extension 4 - Price-sensitive number of orders

Observation 2

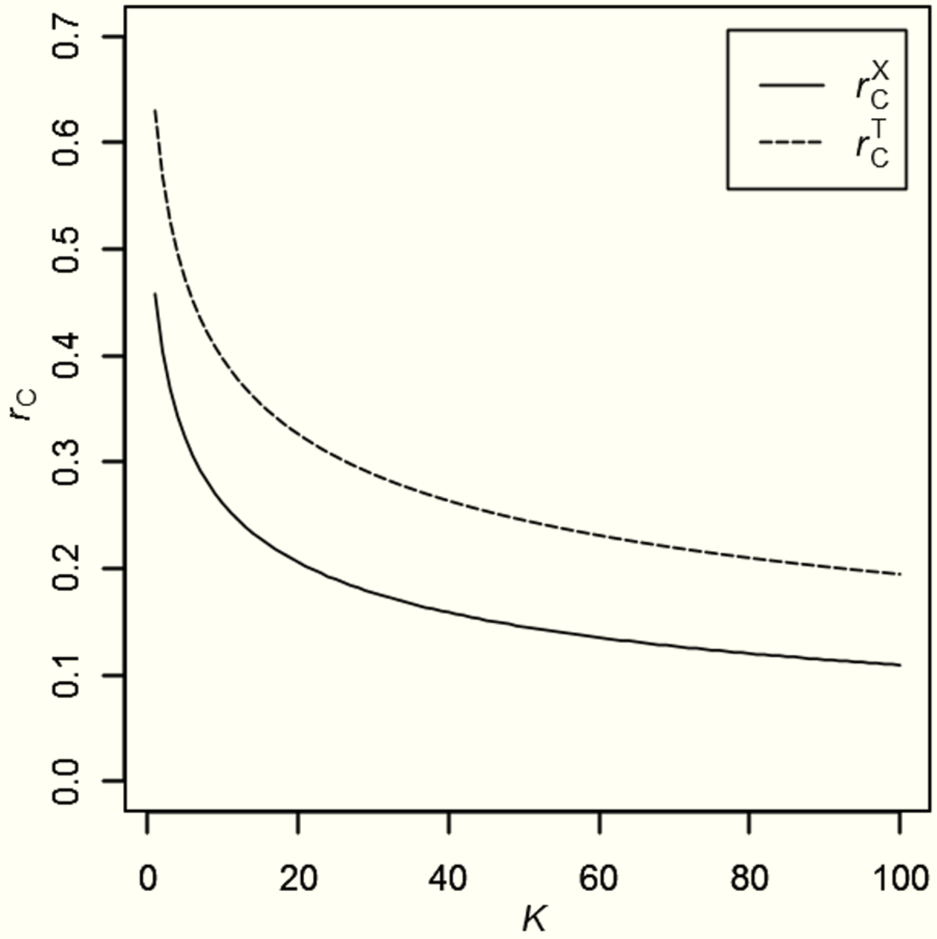
$$r_{\mathrm{C}}^{\mathrm{T}} > r_{\mathrm{C}}^{\mathrm{X}} = r_{\mathrm{S}}^{\mathrm{X}} > r_{\mathrm{S}}^{\mathrm{T}}$$

$$n_{\mathrm{S}}^{\mathrm{X}} > n_{\mathrm{S}}^{\mathrm{T}}$$

$N = 5$

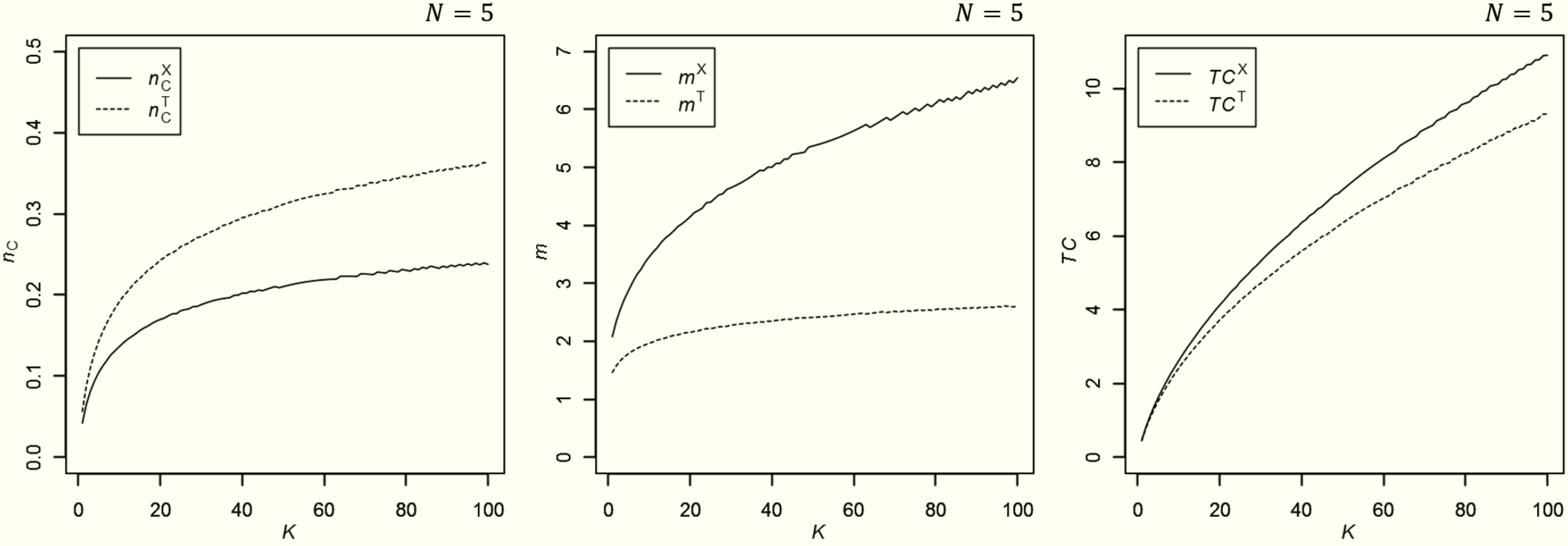


$N = 5$



Extension 4 - Price-sensitive number of orders

Observation 3

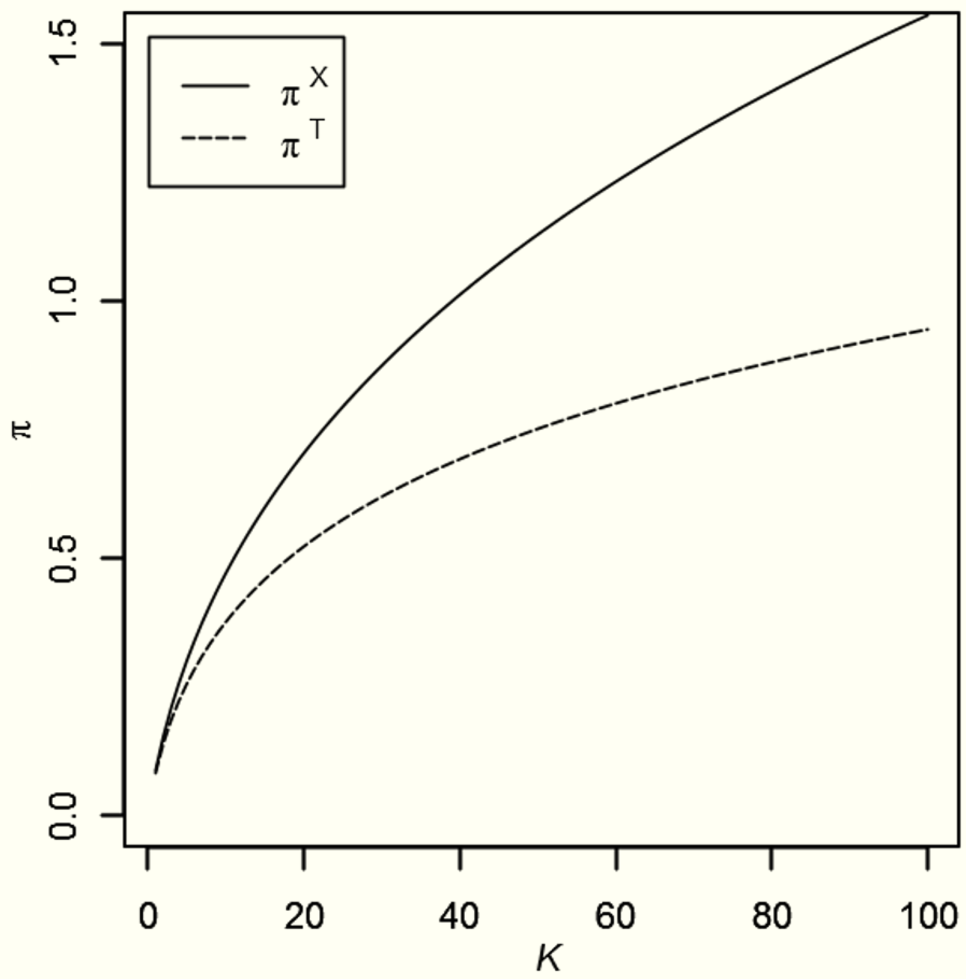


Extension 4 - Price-sensitive number of orders

Observation 4

$\pi^{\mathrm{X}} > \pi^{\mathrm{T}}$

$N = 5$



Extension 4 - Price-sensitive number of orders

	r_S	r_C	n_S	n_C	m	TC	π
X	higher		more		more	more	higher
T		higher		more			

CONCLUSIONS

Conclusions

01 **Basic model**

All the three strategies are equivalent.

02 **Extension 1**

Discount factor: Membership-based pricing is the best.

03 **Extension 2**

Marginal cost: It does not matter.

04 **Extension 3**

Fixed subsidy rather than the per-transaction one: Per-transaction subsidy is better for platform to adopt.

05 **Extension 4**

Price-sensitive number of orders: Cross-subsidization strategy is better.

Conclusions

06 **Future work**

- Competition between integrated delivery and platform one.
- Take Uber's *surge pricing* strategy into account.

Q & A

& Thank You!