On-Demand Service Platforms

Terry Taylor
UC Berkeley
Haas School of Business

On-Demand Service Platform Examples

Examples	
On-Demand Service	**Platform**
Hot food (restaurant) delivery	Caviar DoorDash Spoonrocket
Consumer goods delivery	UberRush
Taxi-style transport	Fasten Lyft Uber

zeel

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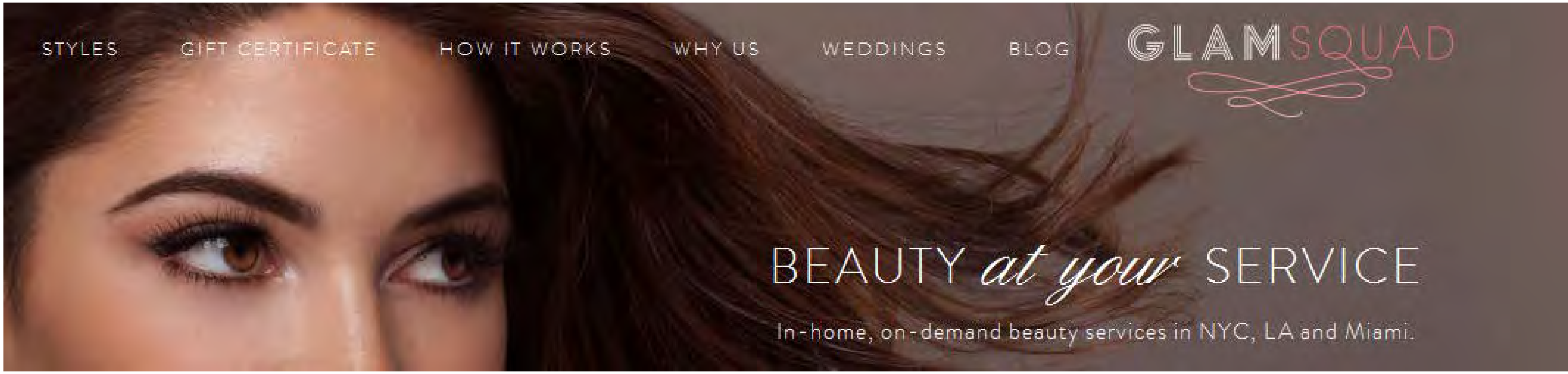
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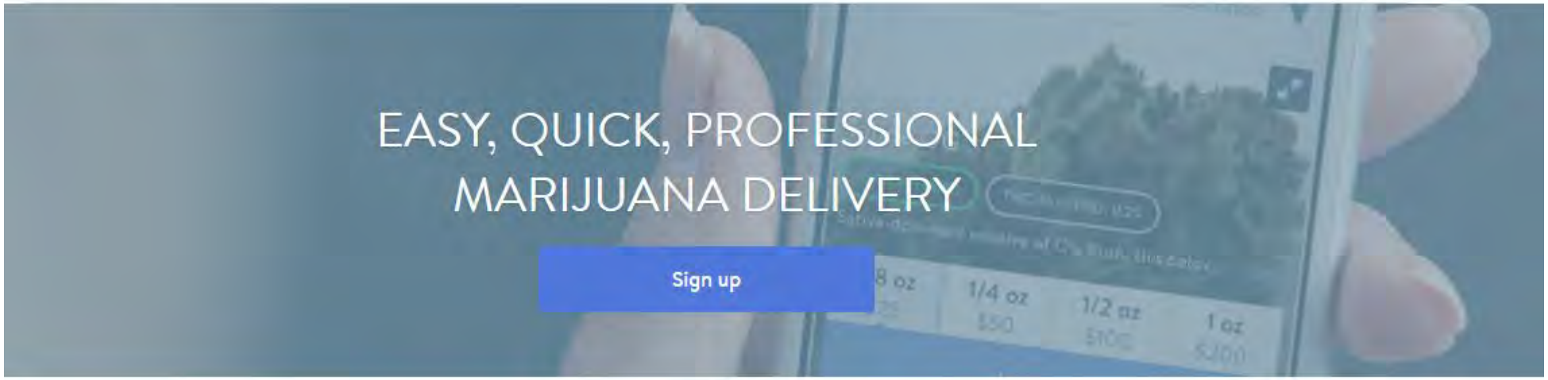
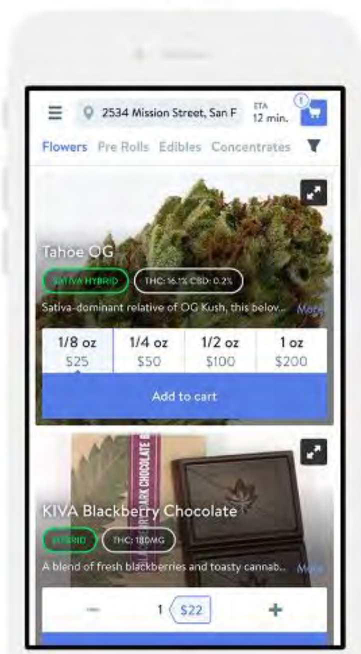


How it works

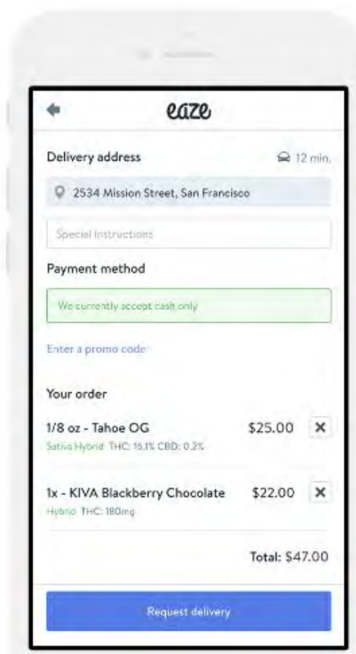
Browse menu

Explore flowers, edibles, concentrates, and more



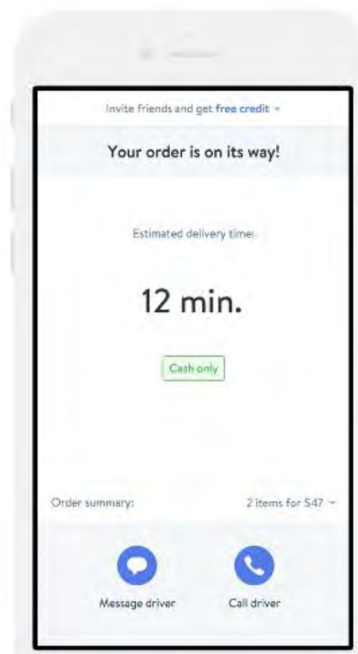
Request delivery

Order with the tap of a finger



Sit back and relax

Deliveries arrive in about 15 minutes



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On-Demand Service Platform Examples

Examples		
On-Demand Service	**Platform**	**Surge Pricing**
Hot food (restaurant) delivery	Caviar DoorDash Spoonrocket	No No No
Consumer goods delivery	UberRush	No
Taxi-style transport	Fasten Lyft Uber	No Yes Yes

On-Demand Service Platforms

On-demand service platform
connects

waiting-time sensitive customers

independent agents

On-Demand Service Platforms

On-demand service platform

connects

waiting-time sensitive customers

independent agents

On-Demand Service Platforms

On-demand service platform
connects

waiting-time sensitive customers

upon experiencing need, decide whether to seek service

pay per-service price

decision to seek service depends on expected waiting time

independent agents

On-Demand Service Platforms

On-demand service platform
connects

waiting-time sensitive customers	independent agents
upon experiencing need, decide whether to seek service	decide whether and when to work
pay per-service price	receive per-service wage
decision to seek service depends on expected waiting time	decision to work depends on expected demand

On-Demand Service Platforms

On-demand service platform
connects

waiting-time sensitive customers	independent agents
upon experiencing need, decide whether to seek service	decide whether and when to work
pay per-service price	receive per-service wage
decision to seek service depends on expected waiting time (prefer low agent utilization)	decision to work depends on expected demand (prefer high agent utilization)

What is impact of congestion and agent independence on platform's optimal decisions?

		Customer Utility	
		Disutility from congestion-driven delay	No disutility from congestion-driven delay
Business Model	Platform: Independent (self-scheduled) agents	Platform with customer disutility from congestion	Platform with no customer disutility from congestion
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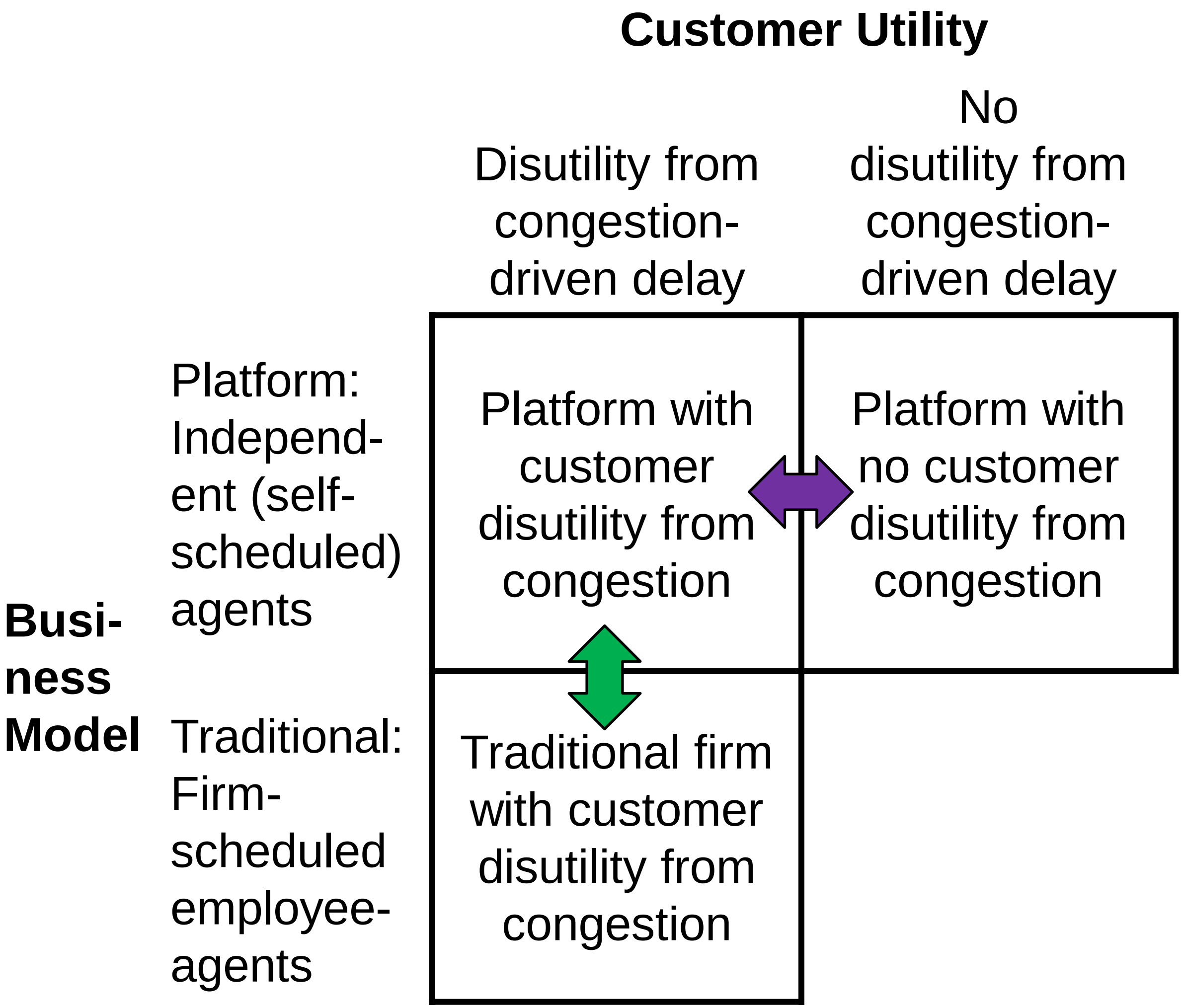
What is impact of congestion-driven delay disutility (i.e., congestion) on platform’s optimal price and wage?

What is impact of congestion and agent independence on platform’s optimal decisions?



What is impact of congestion-driven delay disutility (i.e., congestion) on platform’s optimal price and wage?

What is impact of agent independence on optimal price?

On-demand service platforms distinct from other "sharing economy" platforms

Platform Type	Examples	Description	Literature
Product Sharing	Airbnb Turo	Platform connects customers seeking to rent assets (e.g., cars, homes) with owners	Benjaafar, Kong, Courcoubetis (2015) Fraiberger, Sundararajan (2015) Jiang, Tian (2015)
Free-lancing	Upwork	Platform connects customers seeking professional services with skilled agents	Allon, Basamboo, Cil (2012) Arnosit, Johari, Kanoria (2014), Hu, Zhou (2015)

On-demand service platforms are distinct in that:

- Service is on-demand rather than scheduled
- Offering is undifferentiated rather than agent-specific
- Platform sets price rather than agent

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Related Literature

Pricing in queueing systems	Naor (1969), Mendelson (1985), Mendelson and Whang (1990), Hassin and Haviv (2003), Maglaras and Zeevi (2003), Chen and Frank (2004), Plambeck (2004), Çelik and Maglaras (2008), Kumar and Randhawa (2010), Anand, Paç and Veeraraghavan (2011), Cachon and Feldman (2011), Afèche (2013), Ata and Olsen (2013), Afèche and Pavlin (2015), Debo, Rajan and Veeraraghavan (2013), Maglaras, Yao and Zeevi (2015), Nazerzadeh and Randhawa (2015),…
Incentives for servers (agents) in queueing systems	Gilbert and Weng (1998), Cachon and Zhang (2007), Gopalakrishnan, Doroudi, Ward and Wierman (2014), Zhan and Ward (2015), Ibrahim and Arifoglu (2015)
On-Demand Service Platforms	Cachon, Daniels and Lobel (2015), Gurvich, Lariviere and Moreno (2015), Riquelme, Banerjee and Johari (2015)

Model of On-Demand Service Platform

Sequence of Events

Platform commits to per-service price p, per-service wage ω

Uncertainty regarding agents' opportunity costs $\{\hat{K}_i\}_{i=1,..,\bar{N}}$, customers' common valuation $\hat{V}$, is resolved

Each agent i observes her opportunity cost K_i, customers' valuation V, and decides whether to participate

Customer experiencing need for service observes valuation V, expected waiting time $W(\lambda,n)$, and decides probability of seeking service

Model – Customer Service-Seeking Decision

Sequence of Events

Platform commits to per-service price p, per-service wage ω

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Customer Service-Seeking Decision

Events triggering need for service occur according to a Poisson process at rate □.
Customer, upon experiencing need,
decides to seek service with probability q.
Customer's utility from seeking service is

V	$-$	p	$-$	c	$\times$	$W(\lambda,n)$
valuation of service		per-service price		waiting disutility		expected waiting time

Model – Customer Service-Seeking Decision

Sequence of Events

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$$V - p - c \times W(\lambda,n)$$

valuation of service — per-service price — waiting disutility — expected waiting time

Model – Customer Service-Seeking Decision

Sequence of Events

Platform commits to
- per-service price p,
- per-service wage ω

Uncertainty regarding
- agents' opportunity costs $\{\hat{K}_i\}_{i=1,..,\bar{N}}$,
- customers' common valuation $\hat{V}$,

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Each agent i observes
- her opportunity cost K_i,
- customers' valuation V,

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- valuation V,
- expected waiting time $W(\lambda, n)$,

and decides probability of seeking service

Customer Service-Seeking Decision

Events triggering need for service occur at rate □.
Customer, upon experiencing need, decides to seek service with probability q.
Customer's utility from seeking service is

equilibrium arrival rate $\lambda = q$ □

equilibrium number of participating agents

$$V \quad - \quad p \quad - \quad c \quad \times \quad W(\lambda, n)$$

valuation of service — per-service price — waiting disutility — expected waiting time

Model – Agent Participation Decision

Sequence of Events

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Agent Participation Decision

Each of $\bar{N}$ agents decides whether to participate (work).

Each agent has service rate μ; service times are exponentially distributed.

Agent i's utility from participating is

$$\omega \times \lambda/n - K_i$$

per-service wage × equilibrium arrival rate at agent i − agent i's opportunity cost

Model – Agent Participation Decision

Sequence of Events

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ω	$\times$	λ/n	$-$	K_i
per-service wage		equilibrium arrival rate at agent i		agent i's opportunity cost

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ω	$\times$	λ/n	$-$	K_i
per-service wage		equilibrium arrival rate at agent i		agent i's opportunity cost

Assume need for service is abundant: $\square > \bar{N}\mu$

Model – Platform Price and Wage Decision

Sequence of Events

Platform commits to per-service price p, per-service wage ω

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Each agent i observes her opportunity cost K_i, customers' valuation V, and decides whether to participate

Customer experiencing need for service observes valuation V, expected waiting time $W(\lambda,n)$, and decides probability of seeking service

Model – Platform Price and Wage Decision

Platform Price and Wage Decision

$$\max_{p \geq 0, \omega \geq 0} (p-\omega)E\left[\lambda\left(\hat{V}, p, \mathrm{N}\left(\hat{V}, \hat{K}_1, .., \hat{K}_{\overline{N}}\right)\right)\right]$$

where (λ, N) is the equilibrium arrival rate and number of participating agents

Agent Participation Decision

Each of $\overline{N}$ agents decides whether to participate (work).
Agent i's utility from participating is

ω	$\times$	λ/n	$-$	K_i
per-service wage		equilibrium arrival rate at agent i		agent i's opportunity cost

Customer Service-Seeking Decision

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Customer, upon experiencing need,
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Customer's utility from seeking service is

V	$-$	p	$-$	c	$\times$	$W(\lambda,n)$
valuation of service		per-service price		waiting disutility		expected waiting time

Model – Valuation & Opportunity Cost Uncertainty

Sequence of Events

Platform commits to per-service price p, per-service wage ω

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Each agent i observes her opportunity cost K_i, customers' valuation V, and decides whether to participate

Customer experiencing need for service observes valuation V, expected waiting time $W(\lambda,n)$, and decides probability of seeking service

Agent Opportunity Cost

Correlation of $\widehat{K}_i$ and $\widehat{K}_j$ for $j \neq i$ is □□□$[0,1]$

For i□$\{1,..,\bar{N}\}$

$$\widehat{K}_i = \begin{cases} k - \square & \text{with probability } ½ \\ k + \square & \text{with probability } ½ \end{cases}$$

Customer Valuation

$$\hat{V} = \begin{cases} v - \square & \text{with probability } ½ \\ v + \square & \text{with probability } ½ \end{cases}$$

Model – Valuation & Opportunity Cost Uncertainty

Sequence of Events

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Customer Valuation

$$\hat{V} = \begin{cases} v - \square & \text{with probability } 1/2 \\ v + \square & \text{with probability } 1/2 \end{cases}$$

valuation uncertainty

Model – Valuation & Opportunity Cost Uncertainty

Sequence of Events

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cost uncertainty

What is impact of congestion on platform’s optimal decisions?

Customer Utility

		Disutility from congestion-driven delay	No disutility from congestion-driven delay
Business Model	Platform: Independent (self-scheduled) agents	Platform with customer disutility from congestion ⇔	Platform with no customer disutility from congestion
	Traditional: Firm-scheduled employee-agents	Traditional firm with customer disutility from congestion	Approximation of setting where • Stochastic variability in arrival and service process is limited, or • Customers are patient

What is impact of congestion-driven delay disutility (i.e., congestion) on platform’s optimal price and wage?

Presence of cost uncertainty reverses impact of congestion on platform's optimal wage

Analytical Result: In benchmark setting without uncertainty in costs or valuation, congestion
increases platform's optimal per-service wage. [trivial]

Intuition: Because congestion reduces the agent's utility (through idleness), platform must raise its wage.

Analytical Result: Under agent cost uncertainty, congestion
decreases platform's optimal per-service wage
when cost uncertainty is high and expected cost is moderate.

Intuition: Congestion reduces marginal revenue generated by incremental agent, making it too costly for the platform to offer the high wage required to induce high-cost agents to participate.

Presence of valuation uncertainty reverses impact of congestion on platform's optimal price

Analytical Result: In benchmark setting without uncertainty in costs or valuation, congestion
decreases platform's optimal per-service price. [trivial]

Intuition: Because congestion reduces the customer's utility, platform must lower its price.

Analytical Result: Under customer valuation uncertainty, congestion
increases platform's optimal per-service price
if and only if valuation uncertainty is moderate.

Intuition: Congestion reduces marginal revenue from serving low-valuation customers, making it too costly for the platform to offer the low price required to induce low-valuation customers to seek service.

Platform should be wary of naive intuition that congestion decreases price and increases wage

Analytical Result: Under valuation uncertainty, congestion <u>increases</u> platform's optimal per-service price
if and only if valuation uncertainty is moderate.

Analytical Result: Under agent cost uncertainty, congestion <u>decreases</u> platform's optimal per-service wage
when cost uncertainty is high and expected cost is moderate.

Results may provide directional guidance for how platform should change price and wage when:
Stochastic variability in arrival and/or service process changes
- Change in service area (e.g., lower-customer density)
- Change in service offering (e.g., more specialized)

Customers' waiting sensitivity changes
- Shift from food to consumer good delivery (e.g., Postmates)
- Shift from scheduled to on-demand service (e.g., Shuddle)

What is impact of agent independence on platform’s optimal decisions?

Customer Utility

Business Model		Disutility from congestion-driven delay	No disutility from congestion-driven delay
	Platform: Independent (self-scheduled) agents	Platform with customer disutility from congestion	Platform with no customer disutility from congestion
	Traditional: Firm-scheduled employee-agents	Traditional firm with customer disutility from congestion	

What is impact of agent independence on optimal price?

Model of Traditional Firm with Firm-Scheduled Employee-Agents

Sequence of Events – Platform

Platform commits to per-service price p, per-service wage ω

Uncertainty regarding agents' opportunity costs $\{\hat{K}_i\}_{i=1,..,\bar{N}}$, customers' common valuation $\hat{V}$, is resolved

Each agent i observes her opportunity cost K_i, customers' valuation V, and decides whether to participate

Customer experiencing need for service observes valuation V, expected waiting time $W(\lambda,n)$, and decides probability of seeking service

Model of Traditional Firm with Firm-Scheduled Employee-Agents

Sequence of Events – Traditional Firm

Firm commits to per-service price p

Uncertainty regarding agents' opportunity costs $\{\hat{K}_i\}_{i=1,..,\bar{N}}$, customers' common valuation $\hat{V}$, is resolved

Firm observes agents' opportunity costs $\{K_i\}_{i=1,..,\bar{N}}$, customers' valuation V, and decides whether each agent will work (participate)

Customer experiencing need for service observes valuation V, expected waiting time $W(\lambda,n)$, and decides probability of seeking service

Model of Traditional Firm with Firm-Scheduled Employee-Agents

Traditional Firm Price and Employee-Agent Activation Decision

$$\max_{p \geq 0} pE\left[\max_{\{\mathbf{I}_i\}_{i=1,..\bar{N}}} \lambda\left(\hat{V}, p, \sum_{i=1}^{\bar{N}} \mathbf{I}_i \right) - \sum_{i=1}^{\bar{N}} \mathbf{I}_i \hat{K}_i \right]$$

where $\mathbf{I}_i = 1$ if agent i works and $\mathbf{I}_i = 0$ otherwise, and λ is the equilibrium arrival rate

Customer Service-Seeking Decision

Events triggering need for service occur at rate □.
Customer, upon experiencing need,
decides to seek service with probability q.
Customer's utility from seeking service is

V	$-$	p	$-$	c	$\times$	$W(\lambda, n)$
valuation of service		per-service price		waiting disutility		expected waiting time

Agent independence increases optimal price if valuation uncertainty is high

Analytical Result: Agent independence
strictly increases optimal price
if and only if valuation uncertainty is high.

Intuition: As valuation uncertainty increases, becomes increasingly costly for platform to offer the high wage required to induce agents to participate even when customers' valuation is low. Consequently, when valuation uncertainty is high, platform gives up on serving low-valuation consumers (and so charges a high price), while traditional firm continues to do so (and so charges a low price).

Agent independence decreases optimal price if valuation uncertainty is low

Analytical Result: Agent independence
strictly decreases optimal price
if and only if valuation uncertainty is low.

Intuition: When valuation uncertainty is low, optimal to serve all customers. When agents are independent, doing so requires high wage, so as to induce participation of agents even when realized valuation is low. In doing so, platform cedes rents to agents. Decreasing the price allows platform to decrease the wage and expected rent paid to each agent.

Agent independence decreases optimal price if agent opportunity cost uncertainty is high

Analytical Result: Agent independence decreases optimal price, strictly so if cost uncertainty is high.

Intuition: When cost uncertainty is high, agent independence leads platform to induce stochastically fewer agents to participate. Resulting increase in congestion-driven delay reduces customer’s expected utility from seeking service, compelling platform to reduce price.

Agent independence decreases optimal price if valuation uncertainty is low

Analytical Result: Agent independence
<u>strictly decreases</u> optimal price
if and only if valuation uncertainty is low.

Provides directional guidance for:

- New ventures considering platform model for on-demand services
- Firms shifting from platform business model to traditional firm-employee business model (e.g., Instacart, Munchery, Shyp) perhaps due to pressure from lawsuits and/or regulatory agencies

Summary: What is impact of agent independence on platform's optimal decisions?

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What is impact of agent independence on optimal price?

Shifting to platform business model…

…decreases price if and only if cost uncertainty is high

…increases price if and only if valuation uncertainty is high

Summary: What is impact of agent independence on platform's optimal decisions?

Forces pushing agent independence to <u>decrease</u> price
Because agent independence makes it more costly for platform to induce agent participation, platform induces few agents to work. Compen-sating customers for degraded service pushes platform to decrease price.
By reducing agent idleness, decreasing price allows platform to reduce wage and rent paid to agents.

Force pushing agent independence to <u>increase</u> price
Agent independence makes it costly for platform to induce agents to serve low-valuation customers, which pushes platform to give up on serving these customers (and so charge high price).

What is impact of agent independence on optimal price?

Shifting to platform business model…
…<u>decreases</u> price if and only if cost uncertainty is high
…<u>increases</u> price if and only if valuation uncertainty is high

Summary: What is impact of congestion on platform's optimal decisions?

Customer Utility

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What is impact of congestion-driven delay disutility (i.e., congestion) on platform's optimal price and wage?

In contrast to setting without uncertainty, congestion…

…increases price when valuation uncertainty is moderate and

…decreases wage when cost uncertainty is high

Summary: What is impact of congestion on platform's optimal decisions?

What is impact of congestion-driven delay disutility (i.e., congestion) on platform's optimal price and wage?

In contrast to setting without uncertainty, congestion…

…increases price when valuation uncertainty is moderate and

…decreases wage when cost uncertainty is high

Force pushing congestion to increase price and decrease wage

Congestion decreases the marginal revenue from

- serving low-valuation customers and
- inducing high-cost agents to participate.

Consequently, congestion prompts the platform to give up on

- serving low-valuation customers (and so charge a high price) and
- inducing high-cost agents to participate (and so offer a low wage).

APPENDIX

On-demand service platforms distinct from other "sharing economy" platforms

Platform Type	Examples	Description
Product Sharing	Airbnb Turo	Platform connects customers seeking to rent assets (e.g., cars, homes) with owners
Free-lancing	Upwork	Platform connects customers seeking professional services with skilled agents

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- Platform sets price rather than agent

Platform's optimal price and wage, under customer valuation uncertainty

Interpretation:

When valuation uncertainty is high,

serve only high-valuation customers:

charge *high price* and offer *low wage.*

When valuation uncertainty is low,

serve all customers:

charge *low price* and offer *high wage*.

Analytical result: Under valuation uncertainty, platform's optimal price and wage

$$(p^*, \omega^*) = \begin{cases} (p^L, \omega^L) & \text{if } \delta \le \bar{\delta} \\ (p^H, \omega^H) & \text{if } \delta > \bar{\delta}, \end{cases}$$

where $\bar{\delta} \in (0, v)$, $p^H \in \arg\max_{p \ge 0} p\lambda(V^H, p, \bar{N})$,

$$p^L \in \arg\max_{p \ge 0} \left\{ \left[p - \bar{N}k / \lambda(V^L, p, \bar{N}) \right] \sum_{j \in \{H,L\}} \lambda(V^j, p, \bar{N})/2 \right\},$$

$\omega^j = \bar{N}k / \lambda(V^j, p^j, \bar{N})$ for $j \in \{H, L\}$.

Platform's optimal price and wage, under customer valuation uncertainty

Interpretation:

When valuation uncertainty is high,

serve only high-valuation customers:

charge *high price* and offer *low wage.*

When valuation uncertainty is low,

serve all customers:

charge *low price* and offer *high wage*.

Intuition: Agents are less inclined to participate when realized valuation is low, because this translates to a lower demand rate for each agent. Consequently, platform has choice to offer a *high wage* so as induce participation of agents even when realized valuation is low, or offer a *low wage*, in which case agents will participate only when realized valuation is high.

I want to spend a little time here because this result contrasts with the findings of another paper that looks at this same question--Gurvich, Lariviere and Moreno.

Gurvich et al employs a price-dependent newsvendor formulation and finds that agent independence always *increases* the platform's optimal price.

There is a difference, but there is also a similarity. The similarity is that in Gurvich and here, agent independence causes the platform to induce *fewer* agents to work. However, this common reduction in agents has an opposite effect on the platform’s price in the queueing model and the price-dependent newsvendor model.

Let me try to unpack why. Having fewer agents translates to worse expected service (delay for service, low fill rate). In a queueing formulation, poor service discourages customers from seeking service. This compels the platform to reduce its price.

In price-dependent newsvendor formulation, the service level does not influence customer decisions to seek service. Consequently, there, it is optimal for the platform to set a high price so as to sell only to customers with very high valuations.

In sum, Gurvich demonstrates that *customer valuation heterogeneity* drives agent independence to *increase* the platform’s price. In contrast, we demonstrate that *service-level-dependent demand* drives agent independence to *decrease* the platform’s price.

Summary: What is impact of congestion and agent independence on platform’s optimal decisions?

		Customer Utility	
		Disutility from congestion-driven delay	No disutility from congestion-driven delay
Business Model	Platform: Independent (self-scheduled) agents	Platform with customer disutility from congestion	Platform with no customer disutility from congestion
	Traditional: Firm-scheduled employee-agents	Traditional firm with customer disutility from congestion	

What is impact of congestion-driven delay disutility (i.e., congestion) on platform’s optimal price and wage?

What is impact of agent independence on optimal price?