On-Demand Service Platforms

Terry Taylor
UC Berkeley
Haas School of Business
## On-Demand Service Platform Examples

<table>
<thead>
<tr>
<th>On-Demand Service</th>
<th>Platform</th>
</tr>
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<tbody>
<tr>
<td>Hot food (restaurant) delivery</td>
<td>Caviar</td>
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<td></td>
<td>DoorDash</td>
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<tr>
<td></td>
<td>Spoonrocket</td>
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<tr>
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<tr>
<td>Taxi-style transport</td>
<td>Fasten</td>
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<tr>
<td></td>
<td>Lyft</td>
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<td>Uber</td>
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</tbody>
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zeel
Massage
On Demand®

Get Zeel Massage On Demand delivered to your doorstep.

Text me the link to download the app.

e.g., 212 323 4545

TEXT ME

Seen on

The New York Times  VOGUE  WALL STREET JOURNAL
BEAUTY at your SERVICE
In-home, on-demand beauty services in NYC, LA and Miami.
EASY, QUICK, PROFESSIONAL MARIJUANA DELIVERY

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 Platforms

On-demand service platform connects
waiting-time sensitive independent agents
customers
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

upon experiencing need, decide whether to seek service
pay per-service price
decision to seek service depends on expected waiting time
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
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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

Platform: Independent (self-scheduled) agents
- Platform with customer disutility from congestion
- Platform with no customer disutility from congestion

Business Model
- Traditional: Firm-scheduled employee-agents
- Traditional firm with customer disutility from congestion
What is impact of congestion and agent independence on platform’s optimal decisions?

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Customer Utility

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Platform: Independent (self-scheduled) agents

Business Model

Traditional: Firm-scheduled employee-agents

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?

**Customer Utility**

- 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 Model:**
- Firm-scheduled employee-agents
- Traditional firm with customer disutility from congestion

**Business Model Questions:**
- 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

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<th>Platform Type</th>
<th>Examples</th>
<th>Description</th>
<th>Literature</th>
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<tbody>
<tr>
<td>Product Sharing</td>
<td>Airbnb</td>
<td>Platform connects customers seeking to rent assets (e.g., cars, homes) with owners</td>
<td>Benjaafar, Kong, Courcoubetis (2015)</td>
</tr>
<tr>
<td></td>
<td>Turo</td>
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<td>Fraiberger, Sundararajan (2015)</td>
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<td>Jiang, Tian (2015)</td>
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<td>Freelancing</td>
<td>Upwork</td>
<td>Platform connects customers seeking professional services with skilled agents</td>
<td>Allon, Basamboo, Cil (2012)</td>
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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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- **Service is on-demand rather than scheduled.**
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<td>Related Literature</td>
<td>Authors and Years</td>
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<td>------------------------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
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Model of On-Demand Service Platform

Sequence of Events

| Platform commits to per-service price $p$, per-service wage $\omega$ | Uncertainty regarding agents’ opportunity costs $\{\hat{K}_i\}_{i=1,\ldots,N}$, 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

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<th>Platform</th>
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<th>Each agent $i$</th>
<th>Customer experiencing need</th>
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### Customer Service-Seeking Decision

Events triggering need for service occur according to a Poisson process at rate $\lambda$. 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

| Platform commits to per-service price $p$, per-service wage $\omega$ | Uncertainty regarding agents’ opportunity costs $\{K_i\}_{i=1,...,N}$, 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 |

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- $V$: valuation of service
- $p$: per-service price
- $c$: waiting disutility
- $W(\lambda,n)$: expected waiting time
Model – Customer Service-Seeking Decision

Sequence of Events

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Customer Service-Seeking Decision

Events triggering need for service occur at rate $\lambda$
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

equilibrium arrival rate $\lambda = q$

equilibrium number of participating agents $N$
## 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 $\mu$; service times are exponentially distributed. Agent $i$’s utility from participating is

$$\omega \times \frac{\lambda}{n} - K_i$$

where $\omega$ is the per-service wage, $\lambda$ is the equilibrium arrival rate, $n$ is the number of agents, and $K_i$ is agent $i$’s opportunity cost.
## Model – Agent Participation Decision

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### Agent Participation Decision

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- 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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<tr>
<th>Platform</th>
<th>Uncertainty regarding agents’ opportunity costs ( { \hat{K}<em>i }</em>{i=1,...,N} ), ( K_i ) is resolved</th>
<th>Each agent ( i ) observes her opportunity cost, customers’ valuation ( V ), and decides whether to participate</th>
<th>Customer experiencing need for service observes valuation ( V ), expected waiting time ( W(\lambda,n) ), and decides probability of seeking service</th>
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<tr>
<td>commits to per-service price ( p ), per-service wage ( \omega )</td>
<td>is resolved</td>
<td>( \omega \times \lambda/n - K_i ) ( \omega \times ) per-service wage ( \lambda/n ) equilibrium arrival rate at agent ( i ) ( K_i ) agent ( i )'s opportunity cost</td>
<td>Assume need for service is abundant: ( \square &gt; N\mu )</td>
</tr>
</tbody>
</table>
Model – Platform Price and Wage Decision

Sequence of Events

Platform commits to per-service price $p$, per-service wage $\omega$.

Uncertainty regarding agents’ opportunity costs $\{\tilde{K}_i\}_{i=1,...,N}$, 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 – Platform Price and Wage Decision

Platform Price and Wage Decision

\[
\max_{p \geq 0, \omega \geq 0} (p - \omega) E \left[ \lambda \left( \hat{V}, p, N \left( \hat{V}, \hat{K}_1, \ldots, \hat{K}_N \right) \right) \right]
\]

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

Agent Participation Decision

Each of \(N\) agents decides whether to participate (work). Agent \(i\)’s utility from participating is

\[
\omega \times \frac{\lambda}{n} - K_i
\]

per-service wage  equilibrium arrival rate at agent \(i\)  agent \(i\)'s opportunity cost

Customer Service-Seeking Decision

Events triggering need for service occur at rate \(\underline{\lambda}\). 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 – Valuation & Opportunity Cost Uncertainty

Sequence of Events

Platform commits to per-service price $p$, per-service wage $\omega$, Uncertainty regarding agents’ opportunity costs $\{K_i\}_{i=1,...,N}$, is resolved

Each agent $i$ observes her opportunity cost $K_i$, customers’ common 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 $\hat{K}_i$ and $\hat{K}_j$ for $j\neq i$ is $[0,1]$

For $i \in \{1,..,N\}$

$$\hat{K}_i = \begin{cases} k - \square & \text{with probability } \frac{1}{2} \\ k + \square & \text{with probability } \frac{1}{2} \end{cases}$$

Customer Valuation

$$\hat{V} = \begin{cases} v - \square & \text{with probability } \frac{1}{2} \\ v + \square & \text{with probability } \frac{1}{2} \end{cases}$$
Model – Valuation & Opportunity Cost Uncertainty

Sequence of Events

Platform commits to per-service price $p$, per-service wage $\omega$.

Uncertainty regarding agents’ opportunity costs $\{K_i\}_{i=1,\ldots,N}$, customers’ common valuation $V$, 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.

Customer Valuation

$$\hat{V} = \begin{cases} 
V & \text{with probability } \frac{1}{2} \\
V + \Box & \text{with probability } \frac{1}{2} 
\end{cases}$$

valuation uncertainty
Model – Valuation & Opportunity Cost Uncertainty

Sequence of Events

Platform commits to per-service price $p$, per-service wage $\omega$, uncertainty regarding agents’ opportunity costs $\{\hat{K}_i\}_{i=1,..,N}$, 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.

Agent Opportunity Cost

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$\Box$ 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
---|---
Platform with customer disutility from congestion | Platform with no customer disutility from congestion

Platform: Independent (self-scheduled) agents

Traditional: Firm-scheduled employee-agents

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

Approximation of setting where
- Stochastic variability in arrival and service process is limited, or
- Customers are patient
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 increases platform’s optimal per-service price if and only if valuation uncertainty is moderate.

Analytical Result: Under agent cost uncertainty, congestion decreases 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

Disutility from congestion-driven delay

No disutility from congestion-driven delay

Platform: Independent (self-scheduled) agents
- Platform with customer disutility from congestion
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Business Model
- 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 $\omega$ | Uncertainty regarding agents’ opportunity costs $\{\hat{K}_i\}_{i=1,\ldots,N}$, customers’ common valuation $\hat{V}$, is resolved | Each agent $i$ observes her opportunity cost $K_i$, customers’ valuation $V_i$, 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 |

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Note: The table format is used to organize the sequence of events in the model. Each agent $i$ observes her opportunity cost $K_i$, customers’ valuation $V_i$, and decides whether to participate. The customer experiencing the need for service observes valuation $V$, expected waiting time $W(\lambda, n)$, and decides the 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 $\{\hat{K}_i\}_{i=1,...,N}$, customers’ common valuation $\hat{V}$, is resolved

Firm observes agents’ opportunity costs $\{K_i\}_{i=1,...,N}$, 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

\[
\max_{p \geq 0} p \mathbb{E} \left[ \max_{\{I_i\}_{i=1}^{\bar{N}}} \lambda \left( \hat{V}, p, \sum_{i=1}^{\bar{N}} I_i \right) - \sum_{i=1}^{\bar{N}} I_i \hat{K}_i \right]
\]

where \( I_i = 1 \) if agent \( i \) works and \( I_i = 0 \) otherwise, and \( \lambda \) is the equilibrium arrival rate.

Customer Service-Seeking Decision

Events triggering need for service occur at rate \( \lambda \).
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 strictly decreases 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?

Customer Utility

- Disutility from congestion-driven delay
  - Platform with customer disutility from congestion
  - Traditional firm with customer disutility from congestion
  - Platform with no customer disutility from congestion

- No disutility from congestion-driven delay
  - Platform with no customer disutility from congestion

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

Business Model

- Platform: Independent (self-scheduled) agents
- Traditional: Firm-scheduled employee-agents
Summary: What is impact of agent independence on platform’s optimal decisions?

Forces pushing agent independence to decrease price
Because agent independence makes it more costly for platform to induce agent participation, platform induces few agents to work. Compensating 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 increase 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…
…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 congestion on platform’s optimal decisions?

Customer Utility

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<tr>
<th>Disutility from congestion-driven delay</th>
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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

Business Model

Platform: Independent (self-scheduled) agents

Traditional: Firm-scheduled employee-agents
Summary: What is impact of congestion on platform’s optimal decisions?

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).

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
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APPENDIX
On-demand service platforms distinct from other “sharing economy” platforms

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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
## On-demand service platforms distinct from other “sharing economy” platforms

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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
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

\[
(p^*, \omega^*) = \begin{cases} 
(p^L, \omega^L) & \text{if } \delta \leq \overline{\delta} \\
(p^H, \omega^H) & \text{if } \delta > \overline{\delta}
\end{cases}
\]

where \(\overline{\delta} \in (0, \nu)\), \(p^H \in \arg \max_{p \geq 0} p \lambda(V^H, p, \overline{N})\),
\(p^L \in \arg \max_{p \geq 0} \left\{ \left[ p - \overline{N}k / \lambda(V^L, p, \overline{N}) \right] \sum_{j \in \{H, L\}} \lambda(V^j, p, \overline{N}) / 2 \right\}\),
\(\omega^j = \overline{N}k / \lambda(V^j, p^j, \overline{N}) \text{ for } j \in \{H, L\}\).
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**
  - Platform: Independent (self-scheduled) agents
  - Traditional: Firm-scheduled employee-agents

- **No disutility from congestion-driven delay**
  - Platform with customer disutility from congestion
  - 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?