Consumer (and Driver) Decision-making Under Uncertainty on Digital Platforms

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Digital platforms

- Two or multi-sided markets.

- Our research focuses on user multi-homing and competition among ride-sharing platforms.

- Ride-sharing platforms facilitate transactions between riders and drivers.

- In 2018, the global uptake of ride-sharing services was around 11.8% (858 million riders), generating US$ 150 billion in revenue (Statista, 2019).

- The number of riders is projected to reach 1,500 million by 2023.
Platform pricing strategies

- Asymmetric pricing for different sides of the market (Rochet and Tirole, 2003).
- Merchant mode vs two-sided platform mode (Hagiu, 2007).
- Pricing mechanism to overcome competitive bottlenecks (Belleflamme and Peitz, 2019).
  - Users from one side of the market (but not the other) could multi-home.
Multi-homing

- Both sides of the market, consisting of consumers and drivers, can multi-home easily with free-to-install apps.
  - Low switching costs.

- In New Zealand, both consumers and drivers can choose between a few ride-sharing platforms.
  - For simplicity, we will focus on Uber and Zoomy.

- Uber and Zoomy offer different pricing options.
  - Uber offers a fixed price.
  - Zoomy offers an estimated price range.

- Also, we consider both platforms to offer similar contracts to their drivers.
  - Equal sharing of their revenues generated via rides.
  - Drivers can be ‘employees’ or ‘independent contractors’.
Popular
Affordable, everyday rides

UberX
$6.50
10:41am

CONFIRM UBERX

your trip

The University of Auckland
Auckland

Estimate
$5 - $7

request zoomy
Zoomy’s pricing scheme based on estimated price range potentially introduces ambiguity in the decision-making of both consumers and drivers.

What is ambiguity?
- Unmeasurable uncertainty.
- The probability distribution of events related to an individual’s decision-making process is unknown.

Consumers’ and drivers’ idiosyncratic ambiguity attitudes can influence whether they respectively choose to accept to ride with, and for, Uber or Zoomy.
**Savage axiom (sure-thing principle)**

\[ \Omega = \{..., s, ...\} \quad \varepsilon = \{..., E, ...\} \quad X = \{..., x, ...\} \]

\[ F = \{..., f(\cdot), ...\} \quad f : \Omega \rightarrow X \quad f(\Omega) = \{x\} \]

For all events \( E \) and acts \( f(\cdot), g(\cdot), h(\cdot) \) and \( h'(\cdot) \), \( f_E h \succeq g_E h \Rightarrow f_E h' \succeq g_E h' \).

\( f_E h \) denotes the act with outcome \( f(s) \) when \( s \in E \); \( h(s) \) when \( s \in \Omega \setminus E \).
Ambiguity attitudes

- Uncertainty should not change your choice between two acts if that uncertainty does not affect your preference over the two acts.

  - Violation of sure thing principle.
  - A person prefers to bet in situations for which they know specific odds, rather than in situations for which the odds are ambiguous.
Utility representations under ambiguity

- MaxMin expected utility (EU) model (Gilboa & Schmeidler, 1989).
  - Ambiguity averse.

- MaxMax EU model (Gilboa & Schmeidler, 1989).
  - Ambiguity loving.

- $\alpha$-MaxMin EU model (Hurvicz, 1951).
  - Parameter for the relative degree of optimism and pessimism, $\alpha \in [0, 1]$.

- Subjective EU model (Savage, 1954).
  - Ambiguity neutral.

- Prospect theory (Kahneman & Tversky, 1979).
  - Reference points can distort how individuals respond to ambiguity.
  - Loss aversion.
Research questions

- How do individuals (consumers and drivers) form decisions when they face different pricing schemes from competing ride-sharing platforms?

- Could platforms offer distinct pricing schemes to match consumers and drivers with different ambiguity attitudes to gain market share?
Model set-up

- Suppose two ambiguity neutral platforms - Uber and Zoomy - operate in the same market.
- There exist two masses of consumers $i$ and drivers $j$ in the ride-sharing market, each normalized to 1.
- Zoomy first offers a **price range guarantee** with spread equal to $\Delta$.
- Then, both rivals compete for attracting customers and drivers by simultaneously setting their prices as follows:
  - Uber offers a **fixed price** $p_u$.
  - Zoomy offers a **lower bound for their price** equal to $p$.
- Denote the parameter for the relative degree of optimism and pessimism of consumers and drivers by $\alpha^i$ and $\alpha^j$, respectively.
  - Assume each consumer $i$ to perceive the price of a Zoomy ride to be
    \[
    \tilde{p}_i^z = \left[ \alpha^i (\bar{p} + \Delta) + (1 - \alpha^i) \bar{p} \right]
    \]
  - Whereas assume each driver $j$ to perceive the gain from giving a ride with Zoomy (modulo the commission they receive) to be
    \[
    \tilde{p}_j^z = \left[ \alpha^j \bar{p} + (1 - \alpha^j) (\bar{p} + \Delta) \right]
    \]
Next, assume each consumer’s valuation of a ride from Zoomy or Uber to be the same and equal to $V$ (gross of the price they need to pay for riding with either).

Instead, each driver can either secure a portion of $\tilde{p}_z^i$ or $p_u$ when driving for Zoomy or Uber, respectively.

Therefore, to find the ambiguity attitudes of the indifferent consumer wanting to ride and the driver wanting to drive with Zoomy, the following needs to hold:

**Consumers**

\[ V - \tilde{p}_z^i = V - p_u \]

\[ \Rightarrow \tilde{\alpha}^i = \frac{p_u - p}{\Delta} \]

**Drivers**

\[ \tilde{p}_z^j = p_u \]

\[ \Rightarrow \tilde{\alpha}^j = \frac{p + \Delta - p_u}{\Delta} \]
Model

- Assume the ambiguity attitudes of consumers and drivers to be i.i.d. and to share the same pdf $f(\alpha)$ and cdf $F(\alpha)$.

**Conditional expected perceived price for consumers served by Zoomy**

$$E[\tilde{p}_z^i | \alpha \leq \tilde{\alpha}^i] = \frac{1}{\int_0^{\tilde{\alpha}^i} f(\alpha) d\alpha} \int_0^{\tilde{\alpha}^i} [ \alpha(p + \Delta) + (1 - \alpha)p ] f(\alpha) d\alpha$$

**Conditional expected perceived gain for drivers riding for Zoomy (modulo the commission they receive)**

$$E[\tilde{p}_z^j | \alpha \leq \tilde{\alpha}^j] = \frac{1}{\int_0^{\tilde{\alpha}^j} f(\alpha) d\alpha} \int_0^{\tilde{\alpha}^j} [ \alpha p + (1 - \alpha)(p + \Delta) ] f(\alpha) d\alpha$$
Assumption

The consumers’ and drivers’ attitudes toward ambiguity are i.i.d. and both follow a Beta distribution with probability and cumulative density distributions satisfying

\[ f(\alpha; a = 4, b = 2) = 20 \alpha^{a-1} (1 - \alpha)^{b-1} = 20 \alpha^3 (1 - \alpha) \]

and

\[ F(\alpha; a = 4, b = 2) = 20 \left( \frac{\alpha^4}{4} - \frac{\alpha^5}{5} \right) \]
Graphically:

Figure: Beta distributions for the density, \( f(\alpha; a = 4, b = 2) \), and cumulative, \( F(\alpha; a = 4, b = 2) \), functions of consumers’/drivers’ attitudes toward ambiguity, \( \alpha \), with \( 0 \leq \alpha \leq 1 \).
Consequently, by using this Beta distribution the conditional expected price Zoomy can charge consumers, and the one it can ‘promise’ to drivers can be rewritten, respectively as follows

\[
E[\tilde{p}_z^i | \alpha \leq \tilde{\alpha}^i] = \frac{1}{\int_{0}^{\tilde{\alpha}^i} 20\alpha^3(1 - \alpha) d\alpha} \int_{0}^{\tilde{\alpha}^i} [\alpha(p + \triangle) + (1 - \alpha)p] 20\alpha^3(1 - \alpha) d\alpha
\]

\[
E[\tilde{p}_z^j | \alpha \leq \tilde{\alpha}^j] = \frac{1}{\int_{0}^{\tilde{\alpha}^j} 20\alpha^3(1 - \alpha) d\alpha} \int_{0}^{\tilde{\alpha}^j} [\alpha(p + \triangle) + (1 - \alpha)(p + \triangle)] 20\alpha^3(1 - \alpha) d\alpha
\]
At equilibrium (when considering optimal pricing by the platforms), the mass of consumers riding with Zoomy should equal to the mass of drivers serving Zoomy

\[ F(\tilde{\alpha}_{opt}) = \min\{F(\tilde{\alpha}^i), F(\tilde{\alpha}^j)\} \]

Therefore, the location of the indifferent consumer and driver at the optimum should satisfy

\[ \tilde{\alpha}_{opt} = \min\{\tilde{\alpha}^i, \tilde{\alpha}^j\} \]

Leading to the following condition to hold in equilibrium

\[ \frac{p_u - p}{\Delta} = \frac{p + \Delta - p_u}{\Delta} \]

\[ p_{u opt} = p_{opt} + \frac{\Delta_{opt}}{2} \]
Platforms’ Problems

- Normalize costs of providing rides to zero for both Zoomy and Uber.
- As observed, denote the cdf for the mass of consumers that drivers are willing to serve via Zoomy that needs to hold in equilibrium by $F(\tilde{\alpha}_{\text{opt}})$.
- Conversely, denote the cdf for the mass of consumers that drivers are willing to serve via Uber by $1 - F(\tilde{\alpha}_{\text{opt}})$. 

Tan & Fabrizi (UVA, UoA, CMSS)
Zoomy’s profit is equal to

$$\pi_z = E[\tilde{p}_z^i|\alpha \leq \tilde{\alpha}^{opt}] F(\tilde{\alpha}^{opt})$$

By Assumption 1

$$\pi_z = \int_0^{\tilde{\alpha}^{opt}} [\alpha(p + \Delta) + (1 - \alpha)p] 20\alpha^3 (1 - \alpha) d\alpha$$

When using the matching condition for consumers and drivers, this simplifies to

$$\pi_z = \frac{7}{96}\Delta + \frac{3}{16}p$$

This implies that Zoomy’s profit is increasing in $p$ for any given $\Delta$. Since $p$ contributes more to Zoomy’s profit than $\Delta$ ($\frac{3}{16} > \frac{7}{96}$) and the profit function is linear in $p$, Zoomy would set $p$ to the highest level possible and $\Delta$ to some arbitrary $\epsilon > 0$ in order to maximize profits.
Uber’s Profit

Uber’s profit is equal to

$$\pi_u = p_u \left[ 1 - F(\bar{\alpha}^{opt}) \right]$$

By Assumption 1, we can rewrite Uber’s profit as

$$\pi_u = p_u \left( 1 - \int_0^{\bar{\alpha}^{opt}} 20 \alpha^3 (1 - \alpha) d\alpha \right)$$

Solving for the integral, this simplifies to

$$\pi_u = \frac{13}{16} p_u$$

where, once more, we used the following condition that needs to hold in equilibrium

$$p_u^{opt} = p^{opt} + \frac{\Delta^{opt}}{2}$$
Summarizing results

(i) Since Uber’s profit function is linear in $p_u$, Uber would set $p_u$ to the highest level possible; but $p_u$ is bounded by the consumers’ maximum willingness to pay $V$. Thus, $p_u^{\text{opt}} = V$.

(ii) Zoomy will react to any possible level of $p_u$ set by Uber, by setting its lowest bound such that

$$p^{\text{opt}} = V - \frac{\Delta^{\text{opt}}}{2}$$

(iii) Plugging in the optimality conditions above into the optimal threshold for the ambiguity attitudes as obtained earlier on, we obtain the following result:

$$\tilde{\alpha}^{\text{opt}} = \frac{p_u^{\text{opt}} - p^{\text{opt}}}{\Delta^{\text{opt}}} = \frac{V - V + \frac{\Delta^{\text{opt}}}{2}}{\Delta^{\text{opt}}} = 0.5$$

(iv) The equilibrium market share are:

**Zoomy**

$$F(\tilde{\alpha}^{\text{opt}}) = 20 \left( \frac{0.5^4}{4} - \frac{0.5^5}{5} \right) = \frac{3}{16}$$

**Uber**

$$1 - F(\tilde{\alpha}^{\text{opt}}) = \frac{13}{16}$$
Now as anticipated, suppose a platform charges the driver a commission rate of $\gamma$ per ride. The aggregate expected driver surplus for the mass of drivers serving Zoomy is given by

$$DS_z = E[\tilde{p}_z^j | \alpha \leq \tilde{\alpha}^{opt}] F(\tilde{\alpha}^{opt}) (1 - \gamma)$$

Leading to:

$$DS_z = \left( V - \frac{1}{9} \Delta^{opt} \right) \left( \frac{3}{16} \right) (1 - \gamma) = \left( \frac{3}{16} V - \frac{1}{48} \Delta^{opt} \right) (1 - \gamma)$$

Whereas the driver surplus that goes to the mass of drivers working for Uber can be derived as follows

$$DS_u = p_u^{opt} (1 - F(\tilde{\alpha}^{opt})) (1 - \gamma) = \frac{13}{16} p_u^{opt} (1 - \gamma) = \frac{13}{16} V (1 - \gamma)$$
We can now also compute the aggregate expected consumer surplus for the mass of consumers served by Zoomy, which is equal to

\[ CS_z = (V - E[p^i_z | \alpha \leq \tilde{\alpha}^{opt}]) \cdot F(\tilde{\alpha}^{opt}) \]

This is equivalent to

\[ CS_z = \frac{11}{96} V - \frac{29}{192} \Delta^{opt} \]

Similarly, we can obtain the consumer surplus for the mass of consumers served by Uber, as follows

\[ CS_u = (V - p^{opt}_u)(1 - F(\tilde{\alpha}^{opt})) = 0 \]
Conclusion

Limitations and novelty of our approach

- The theoretical assumptions that the consumers’ ambiguity types in the market follow a Beta distribution, skewed towards ambiguity-averse types is a convenient, yet realistic, assumption to impose on our model.

- We directed our attention to competition in the ride-sharing market across platforms in the presence of potentially multihoming consumers and drivers.
  - The legal distinction between drivers as “employees” and “independent contractors” has real implications for the possible findings of our model.

- Equally, we could look at more general models of competing mixed price offers (fixed & range) in a variety of mkts (e.g. hotel bookings, labor contracts).