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

Yen Ling Tan[1,3] Simona Fabrizi[2,3]

[1]University of Virginia
[2]University of Auckland
[3]Centre for Mathematical Social Science

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Digital platforms

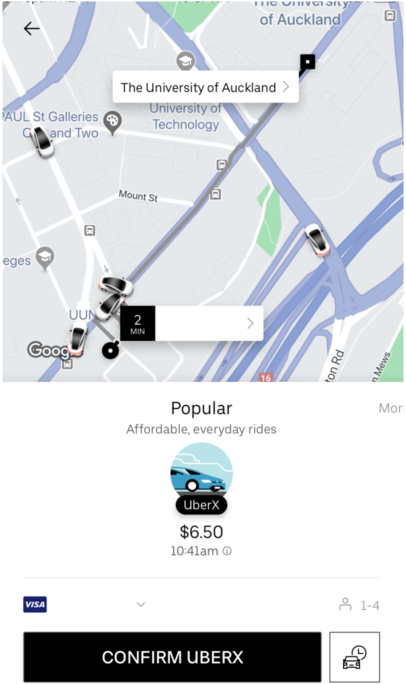
- Two or multi-sided markets.
- Our research focuses on user multi-homing and competition among ride-sharing platforms.
- Ride-sharing platforms facilitate transactions between riders and drivers.
- In 2018, the global uptake of ride-sharing services was around 11.8% (858 million riders), generating 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’.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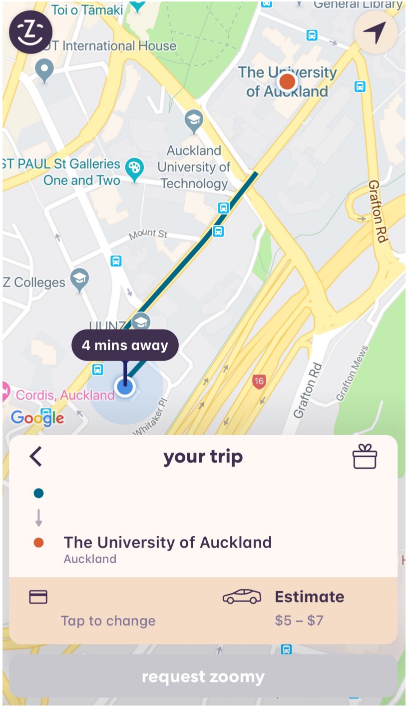
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Ambiguity

- 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.

Ambiguity attitudes

Savage axiom (sure-thing principle)

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

$$F = \{..., f(\cdot), ...\} \quad f : \Omega \to X \quad f(\Omega) = \{x\}$$

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.
- Ellsberg Paradox (1961).
  - 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.
- α-MaxMin EU model (Hurwicz, 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 $\triangle$
- 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 $\underline{p}$.
- Denote the parameter for the relative degree of optimism and pessimism of consumers and drivers by α^i and α^j, respectively.
  - → Assume each consumer i to perceive the price of a Zoomy ride to be

$$\widetilde{p}_z^i = [\ \alpha^i(\underline{p} + \triangle) + (1 - \alpha^i)\underline{p}\ ]$$

  - → Whereas assume each driver j to perceive the gain from giving a ride with Zoomy (modulo the commission they receive) to be

$$\widetilde{p}_z^j = [\ \alpha^j \underline{p} + (1 - \alpha^j)(\underline{p} + \triangle)\ ]$$

Model

- 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 $\widetilde{p}_z^j$ 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

$$V - \widetilde{p}_z^i = V - p_u$$

$$\Rightarrow \quad \tilde{\alpha}^i = \frac{p_u - \underline{p}}{\triangle}$$

Drivers

$$\widetilde{p}_z^j = p_u$$

$$\Rightarrow \quad \tilde{\alpha}^j = \frac{\underline{p} + \triangle - p_u}{\triangle}$$

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

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

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

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

Model

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

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

Model

Graphically:

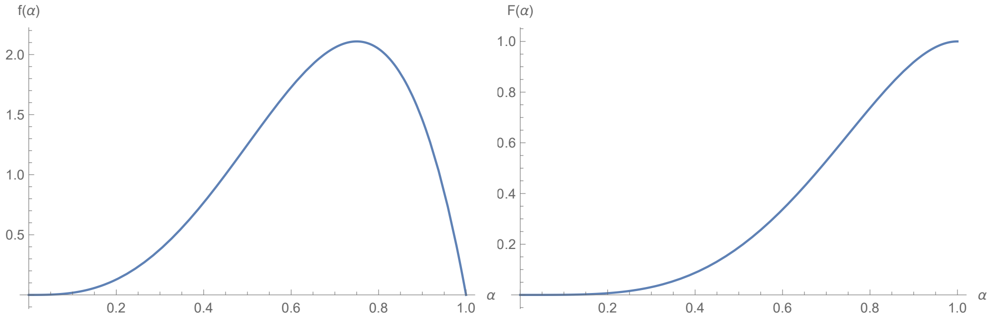

Figure: Beta distributions for the density, $f(\alpha; a = 4, b = 2)$, and cumulative, $F(\alpha; a = 4, b = 2)$, functions of consumers'/drivers' attitudes toward ambiguity, α, with $0 \leq \alpha \leq 1$.

Model

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

$$E[\widetilde{p}_z^i|\alpha \leq \widetilde{\alpha^i}] = \frac{1}{\int_0^{\tilde{\alpha^i}} 20\alpha^3(1-\alpha)d\alpha} \int_0^{\tilde{\alpha^i}} [\alpha(\underline{p}+\triangle)+(1-\alpha)\underline{p}]\, 20\alpha^3(1-\alpha)d\alpha$$

$$E[\widetilde{p}_z^j|\alpha \leq \widetilde{\alpha^j}] = \frac{1}{\int_0^{\tilde{\alpha^j}} 20\alpha^3(1-\alpha)d\alpha} \int_0^{\tilde{\alpha^j}} [\alpha\underline{p}+(1-\alpha)(\underline{p}+\triangle)]\, 20\alpha^3(1-\alpha)d\alpha$$

Model

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

$$F\left(\widetilde{\alpha}^{opt}\right) = min\{F\left(\widetilde{\alpha}^{i}\right)\ ,\ F\left(\widetilde{\alpha}^{j}\right)\}$$

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

$$\widetilde{\alpha}^{opt} = min\{\widetilde{\alpha}^{i}\ ,\ \widetilde{\alpha}^{j}\}$$

Leading to the following condition to hold in equilibrium

$$\frac{p_u\ -\ \underline{p}}{\Delta} = \frac{\underline{p} + \Delta - p_u}{\Delta}$$

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

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 $F(\widetilde{\alpha}^{opt})$.
- Conversely, denote the cdf for the mass of consumers that drivers are willing to serve via Uber by $1 - F(\widetilde{\alpha}^{opt})$.

Zoomy's Profit

Zoomy's profit is equal to

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

By Assumption 1

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

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

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

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

Uber's Profit

Uber's profit is equal to

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

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

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

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

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

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, $p_u^{opt} = V$.

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

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

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

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

(iv) The equilibrium market share are:

Zoomy

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

Uber

$$1 - F(\widetilde{\alpha}^{opt}) = \frac{13}{16}$$

Summarizing results (Cont'd)

Now as anticipated, suppose a platform charges the driver a commission rate of γ 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

$$DS_u = p_u^{opt}(1 - F(\tilde{\alpha}^{opt}))\,(1-\gamma) = \frac{13}{16}p_u^{opt}(1-\gamma) = \frac{13}{16}\,V(1-\gamma)$$

Results (Cont'd)

We can now also compute the aggregate expected consumer surplus for the mass of consumers served by Zoomy, which is equal to

$$CS_z = \left(V - E[\widetilde{p}_z^i | \alpha \leq \widetilde{\alpha}^{opt}]\right) F(\widetilde{\alpha}^{opt})$$

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

$$CS_u = (V - p_u^{opt})(1 - F(\widetilde{\alpha}^{opt})) = 0$$

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).