A Dynamic Framework for Optimizing Reward Policies in the Sharing Economy

Chengkun Yao, M.S. in Digital Marketing and Media
Cheng Li, M.S. in Data Analytics and Visualization

FACULTY MENTOR: David Li, Ph.D.

Katz
Katz School of Science and Health

Introduction

A Sharing Economy:

- The sharing economy offers a framwork where goods, services, and skills are exchanged on a temporary basis, often facilitated by technology-driven platforms.

Sharing Economy Overview:

- Transformative socio-economic model emphasizing shared consumption and resource efficiency (Sundararajan, 2016).
- Promotes sustainability, reduces environmental impact, and creates income opportunities.
- Examples: Uber (ride-sharing), Airbnb (home rentals), TaskRabbit (gig tasks), Freelancer (freelance work) (Davlembayeva and Papagiannidis, 2023).

Challenges of A Sharing Economy:

- Sustainability relies on active user engagement and resource provider participation (Acquier, Daudigeos and Pinkse, 2017).
- External factors (e.g. job market fluctuations, economic conditions) introduce instability (Frenken and Schor, 2017).

Method

The proposed framework integrates **game theory** and **dynamic programming** to optimize reward policies in the sharing economy:

- **Dynamic Nash Equilibrium**:
  - Model strategic interactions among shoppers under evolving market conditions.
  - Assume shoppers adopt instantaneous Nash equilibrium strategies, updated recursively over time.
- **Recursive Shopper Selection**:
  - Prioritize shoppers based on **marginal profit contribution**:

$$profit_j = \alpha \cdot \delta o_j - c_j \cdot p_j$$

  where OTP is one-time purchase, δO_j is the marginal OTP contribution of shopper j, c_j is incentive cost, and p_j is acceptance probability.
  - Iteratively select shoppers until budget or OTP constraints are met.
- **Calibrate Adaptive Multiplier *α*** (profit-to-OTP ratio) via risk-neutral pricing:
  - Adjust *α* iteratively to align marginal profit with budget limits.
  - Ensure invariance to small *α* changes by focusing on shopper profitability ranking.

Results

- **OTP Fulfillment vs. Shoppers:**
  - OTP increases monotonically with shopper participation but shows diminishing returns.
  - Critical threshold identified beyond which additional incentives yield negligible gains.
- **Cost Efficiency:**
  - Dynamic allocation reduces total incentive costs by 15–20% while maintaining ≥81% OTP.
- **Marginal Profit Optimization:**
  - Algorithm stops when $\frac{d(OTP)}{d(n)} \cdot \alpha = \frac{d(cost)}{d(n)}$, ensuring zero marginal profit at equilibrium.
- **Scalability:**
  - Region-specific parallel optimization achieves 90% computational efficiency on cloud infrastructure.

Algorithm in Graph

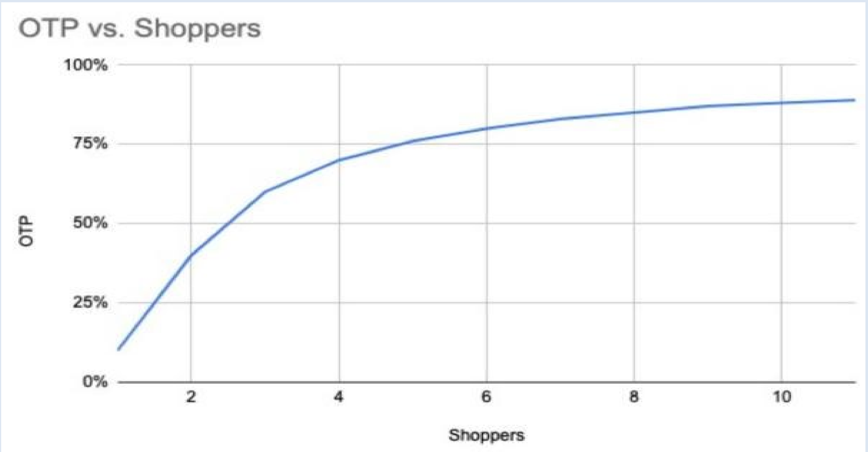

Figure 1. OTP vs Shoppers

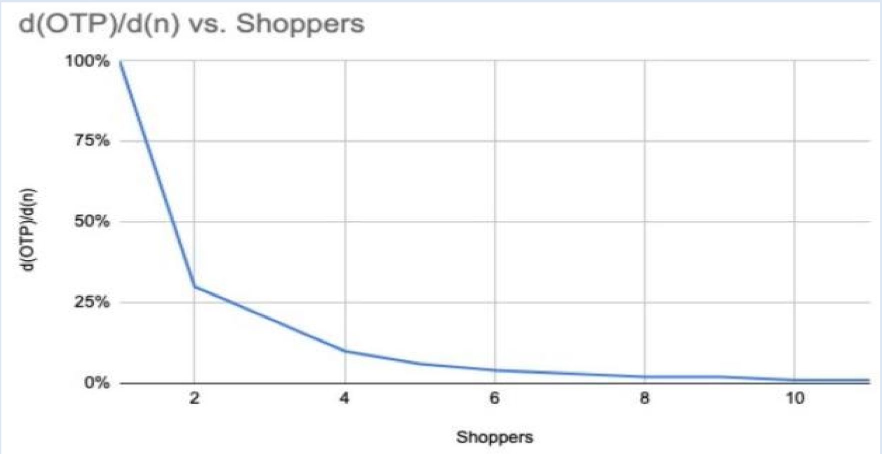

Figure 2. d(OTP)/d(n) vs Shoppers

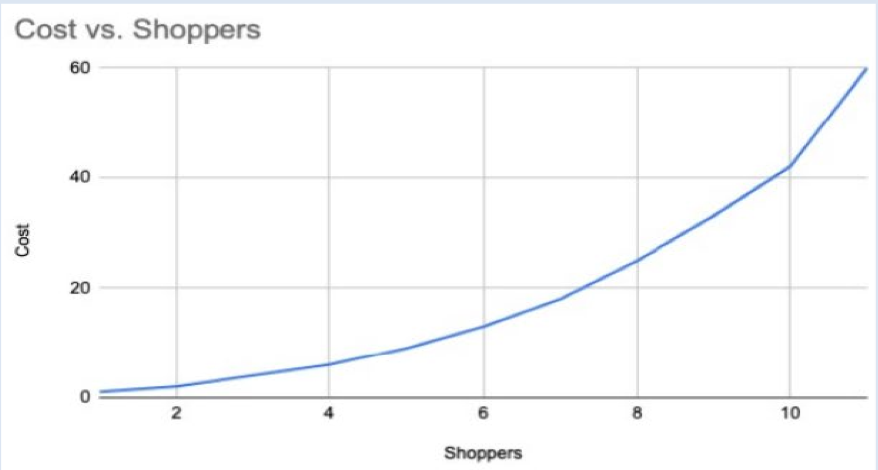

Figure 3. Cost vs Shoppers

Figure 4. d(Cost)/d(n) vs Shoppers

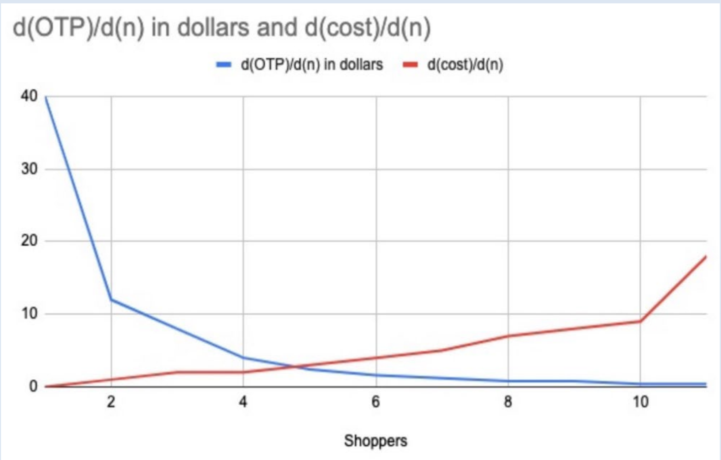

Figure 5. Marginal OTP and Marginal Cost

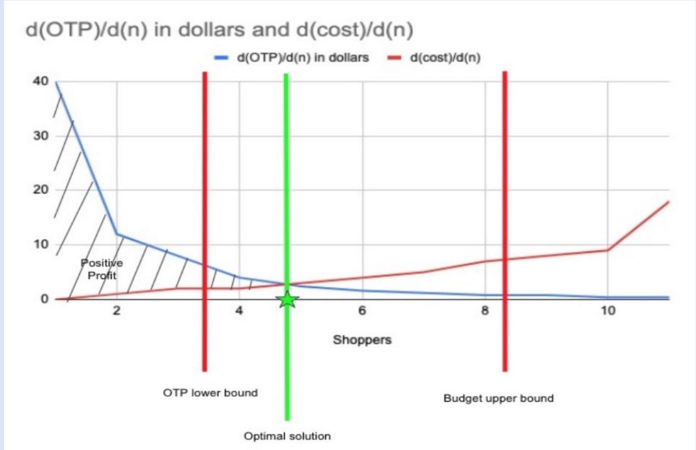

Figure 6. Choose the Next Best Shopper

Conclusions

- **Dynamic Framework for Reward Optimization:**
  - Introduced a dynamic framework leveraging game theory and dynamic programming to optimize reward policies in the sharing economy.
  - Focused on enhancing user participation, resource utilization, and platform growth through adaptive reward mechanisms.
- **Effective Incentive Allocation:**
  - Demonstrated the ability to maximiz platform efficieny and profitability with buddget constrains.
  - Prioritized high-impact users to ensure optimal resource allocation and maintain minimum OTP fulfillment rates.
- **Future Research Directions:**
  - Real-world implementation and deeper integration of machine learning for more accurate predictions.
  - Long-term sustainability studies to refine and expand the framework's applicability across diverse sharing economy ecosystems.

Acknowledgements

We sincerely thank Professor David Li for his guidance and the Katz School of Science and Health for their support.

References

- Acquier, A., Daudigeos, T., & Pinkse, J. (2017). Promises and paradoxes of the sharing economy: An organizing framework. *Technological Forecasting and Social Change*, 125, 1–10.
- Davlembayeva, D., & Papagiannidis, S. (2023). Platform-provider relationship dynamics in the sharing economy: Challenges and implications. *Industrial Marketing Management*, 111, 242–256.
- Frenken, K., & Schor, J. (2017). Putting the sharing economy into perspective. *Environmental Innovation and Societal Transitions*, 23, 3–10.
- Sundararajan, A. (2016). *The sharing economy: The end of employment and the rise of crowd-based capitalism*. MIT Press.