Research Statement

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Using mathematical modeling and data analytics, my vision is to provide operational and regulatory insights to emerging businesses with an emphasis on enhancing the customer experience and societal benefits. Towards this vision, my doctoral research leverages stochastic modeling, optimization, and data for two important research areas. The first line of my research considers revenue and operations management problems in the video game industry, which is a nascent and burgeoning topic in the operations community. The other line of my research considers fairness issues in price discrimination practices, which has drawn significant attention from academia, media, and regulatory bodies. Below, I provide an overview of my current research as well as my future research agenda.

Video Game Analytics

Video games represent the largest and fastest-growing segment of the entertainment industry, which involves 3 billion video gamers[1] and garners $180 billion annually.[2] Despite its popularity in practice, it has received limited attention from the OM community. There are a lot of research opportunities for our field due to the unique characteristics of gaming platforms, including new revenue models and the challenge of managing player satisfaction in repeated (endogenously controlled) interactions. The goal of my research is to (1) help gaming companies improve monetization and engagement of their products; (2) improve players' experience and welfare; (3) provide insights for regulators to monitor the industry properly. In my two completed papers, we consider key questions in monetization and engagement, and have gained traction with practitioners and regulators. Specifically, we were invited to present our papers to *Activision* ($61B market cap), *ByteDance* ($250B valuation), *NetEase* ($59B market cap), and the *Federal Trade Commission*. These connections have proven to be valuable and will be useful for integrating research and practice going forward.

In the paper ***"Loot Box Pricing and Design"*** [1] (*Management Science,* 2021), we consider a prevailing selling mechanism in online gaming known as a loot box. A loot box can be viewed as a random bundle of virtual items, whose contents are not revealed until after purchase. Players receive random collectable items from loot boxes, such as armors and characters, resembling a modern version of a Pokémon or baseball card pack. Loot boxes accounted for $30 billion in revenue in 2018, and are a primary vehicle for monetization in video games. However, prior to our work, there has been little theoretical explanation on why loot boxes are popular, or how to price and design them optimally. Revenue management in online games has several unique features such as no inventory cost, full information on the customer inventory and ability to have fully adaptive strategies. We consider two types of loot boxes: a traditional one where customers can receive (unwanted) duplicates, and, a unique one where customers are guaranteed to never receive duplicates. Using stochastic models and asymptotic analysis, we provide several counter-intuitive and meaningful insights to the sellers, players, and regulators. For example, we show that the unique box strategy that generates no duplicates is actually revenue-optimal as the number of items goes to infinity, while the traditional box strategy earns only 37% of the optimal revenue. On the other hand, customers will earn more surplus from traditional boxes even though they receive duplicates, due to the lower price point compared to unique boxes. More surprisingly, we show that when the seller allows the customers to

[1] https://www.dfcint.com/product/video-game-consumer-segmentation-2/

[2] https://www.marketwatch.com/story/videogames-are-a-bigger-industry-than-sports-and-movies-combined-thanks-to-the-pandemic-11608654990

salvage unwanted items, it increases revenue but barely increases customer surplus (at most 1.4%). We also consider lying and manipulation on the allocation rule, and reveal some subtle manipulation strategies that gain substantially more revenue and thus need proper regulation. Our novel insights on customer surplus and allocation transparency got recognition from the Federal Trade Commission (FTC). In August 2019, FTC held a workshop on customer issues related to loot boxes, and our paper was selected as one of the four research presentations in this workshop. It also drew attention from practitioners and led to my internship as a data scientist at Activision (a leading gaming company in North America). This paper won first place in the *2019 INFORMS Service Science Best Student Paper Award*, and received the third prize in the *2021 CSAMSE Best Paper Award.*

Managing player engagement is also important for video game companies, as many games generate revenue via subscription models and advertisements. Many popular games nowadays are competitive, where players compete against each other online. In such games, managing engagement is particularly challenging, because a player's engagement is dependent on their past matches, which is influenced by the matchmaking system. In the paper ***"Matchmaking Strategies for Maximizing Player Engagement in Video Games"*** [2] (submitted to *Operations Research*), we propose a general yet tractable framework to find the optimal dynamic matchmaking policy that maximizes the cumulative player engagement. We also provide actionable insights based on a stylized model, where there are two skill levels and players churn only when they experience consecutive losses. We show that the optimal policy always myopically maximizes the reward in the next period, but also adjusts the player distribution for long-term reward. We then use our framework to analyze two common but controversial interventions to increase engagement: adding AI bots and a pay-to-win system. It is common for companies to add AI bots into human matches so that they can manipulate the match outcome and further increase player engagement. However, a high ratio of bots can backfire when the bots are clumsy and easy to identify. Many games deploy a high bot ratio to increase engagement, bearing criticism from players and media. Our research shows that optimal matchmaking policy may reduce the number of bots significantly, while maintaining the same level of engagement as the industry status quo. The pay-to-win system offers paying players competitive benefits in matches and has an impact on the optimal matchmaking policy. We show that the pay-to-win feature can influence player engagement positively when the majority of the players are low-skilled. Surprisingly, even non-paying low-skilled players may be better off in some scenarios. We also validate our insights numerically with real data from *Lichess*, an online chess platform. The optimal policy can improve engagement by 4-6% or reduce the percentage of bot matches by 15% relative to the status quo. Our paper was presented to gaming companies such as Activision, ByteDance, and NetEase, and has received positive feedback.

Revenue Management with Fairness

While the practice of discriminatory pricing is generally widespread, it can result in disparate impact against protected groups. One infamous example is the 'pink tax', which charges higher prices to female customers for essentially the same product.[3] Such a practice systematically exploits half of the population, and is definitely against our goal toward a diversified, equitable, and inclusive world. The fairness issue in price discrimination has received extensive attention from media, industry, and regulatory agencies. Yet, a theoretical analysis on how to incorporate fairness into revenue management in practice has been missing in the literature prior to our work. In the paper ***"Price Discrimination with Fairness Constraints"*** [3] (*Management Science*, forthcoming), we consider the problem of setting prices for different groups of customers under fairness constraints. Customers within the same group share the same protected feature, and their valuations follow a known distribution. We then consider fairness constraints that limit the differences of various metrics (such as price and demand) across the groups, and provide insightful results on the trade-off between fairness levels and social welfare. For example, we find that

[3] https://www.huffpost.com/entry/pink-tax-examples_l_5d24da77e4b0583e482850f0

fully discriminatory pricing or uniform pricing may both be suboptimal, and the socially optimal solution should limit the price difference across the groups to a subtle level. We also show that limiting the range of demand or consumer surplus across different groups may not increase the social welfare at all, and may even hurt consumer surplus due to the incentive misalignment between the seller and the regulator. Our paper was accepted to interdisciplinary conferences that focus on socially responsible considerations, such as *MD4SG* and *FAccT*. Through our communication with researchers from various backgrounds, we believe there are growing interests in revenue management with fairness, and much more we can do.

Other Research Projects

Going beyond the existing two topics, I'm also broadly interested in operational problems in other e-commerce contexts. For example, in my recent work ***"Herding, Learning, and Incentives for Online Reviews"*** [4] (reject and resubmit at *Manufacturing and Service Operations Management*), we develop a model in which customer reviews affect the demand of a product both through herding and learning effects and compare several incentive schemes for customer reviews. Another of my working projects is in the context of service platforms such as online grocery delivery, where some service providers offer large overlapping delivery time windows (with a discount) to garner more flexibility from the consumer's side. In ***"The Value of Consumer Flexibility in Scheduled Service Systems"*** [5] (working paper), with data from *FreshDirect* and surveys, we investigate how customers make choices with overlapping alternatives and analyze the capacity pooling benefit using large time windows alongside regular small time windows.

Future Directions

Moving forward, my vision is to provide operational insights and improve customer well-being in various business contexts. Regarding video games analytics, I plan to explore additional operational problems such as fundraising for small developers, incentive design for educational games, and revenue management for e-sports. I'm confident that my first-hand industry experience and regular communication with practitioners can provide me with relevant problems and adequate data, and I'm eager to deliver real impact in collaboration with industry leaders. I will also keep working on revenue management with customer-centric considerations. In this vein, I plan to consider fairness issues in more general settings, such as in assortment optimization or under competition. Moreover, I also plan to take other issues such as privacy into consideration. I am also actively exploring research opportunities and data sources in various e-commerce contexts, and I look forward to collaborating with future colleagues from different research backgrounds. With my academic background and research experience, I am both excited and confident to work on problems that benefit both businesses and customers alike.

References

[1] N. Chen, A. N. Elmachtoub, M. Hamilton, and X. Lei. 2021. Loot Box Pricing and Design. *Management Science*, *67*(8), 4809-4825. Extended abstract appeared in *EC*, 2020.

[2] M. Chen, A. N. Elmachtoub, and X. Lei. 2021. Matchmaking Strategies for Maximizing Player Engagement in Video Games. Submitted.

[3] M. Cohen, A. N. Elmachtoub, and X. Lei. 2021. Price Discrimination with Fairness Constraints. *Management Science*, forthcoming. Extended abstract appeared in *FAccT*, 2021.

[4] R. Kohli, X. Lei, and Y. Zhou. 2020. Herding, Learning, and Incentives for Online Reviews. Reject and resubmit at *Manufacturing and Service Operations Management*.

[5] A. N. Elmachtoub, X. Lei, Y. Zhou. The Value of Consumer Flexibility in Scheduled Service Systems. Working paper.