Utility Maximization with Behavioral Constraints in E-Commerce

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Abstract. The boom of e-commerce and live-stream shopping show that the classical utility models become inadequate due to the breakdown of rationality and constant preferences. In practice, online consumers follow known-to-be irrational purchasing behaviors that are fast, emotional, time-pressured, and influenced by social influence. In this paper, we develop a behavioral utility maximization model that captures three behavioral constraints: loss aversion, social comparison, and dynamic pricing. The model generalizes the classical Lagrangian model by considering time-varying elasticity and psychological constraints of loss aversion and mental accounting. We estimate the model using both survey data and simulated shopping sessions and compare it against the Cobb-Douglas baseline. The model has a better fit to the data in terms of decision-making, i.e., explaining quicker responses when facing countdown timers and explaining higher willingness to pay when there are peer activities/influencer endorsements. These results provide strong evidence that psychology and social influence significantly impact consumer decisions. The contributions of this research are dual. On the theoretical side, this paper extends utility theory by introducing behavioral realism. On the applied side, our research reveals the decisions' designs of platforms and raise ethical issues that whether it is right to manipulate consumers. This research shows that researching digital consumer behavior requires inputs from both economics, psychology and computation.

Keywords: Behavioral economics, Utility maximization, Loss aversion, Dynamic pricing, E-commerce.

1. Introduction

The explosion of e-commerce and live-stream shopping have reversed how consumers become consumers. In a physical market, consumers have all the time in the world to decide whether or not to buy something. When buying from a digital platform, consumers have to rapidly respond. Countdown timers and flash sales make consumers fear that they have to respond rapidly.

It's one thing to make a decision and another to make a decision fearfully and emotionally. The math of social interaction makes influence more effective. Such behaviors are a mystery to classical economic theory. Classic utility functions, like, Cobb-Douglas or CES, assume that consumers have stable preferences and behave rationally when faced with the decision how to maximize their utility subject to a budget constraint [1]. Such models might be convenient and tractable on mathematically, but they cannot explain impulse buys, sudden jumps in happy to pay or social influence in online markets. In other words, the assumptions of rationality and stationary preferences are difficult to meet in a fast, social e-commerce market.

Recent developments in behavioral economics have already shown that real decision-making differs from rational-choice theory. Kahneman and Tversky demonstrated that people experience losses more strongly than equivalent gains, a principle known as loss aversion [2]. Thaler's mental accounting figure shows that money is treated differently depending on the "label" in one's mind and thus people might not behave consistently when budgeting [3]. These insights suggest that a new theoretical approach is needed—one that integrates behavioral constraints directly into utility maximization.

This research extends the class of behavioral utility models to the specific context of e-commerce and live-stream shopping. This study adds three new factors: loss aversion, social comparison, and dynamic pricing effects. By allowing preferences to change over time under duress and psychological constraints to be accounted into optimization, and explicitly modeling the effect of social context, our

model is more realistic and richer. The model is calibrated on survey data and simulated shopping sessions and shows to capture behavior better than classical models.

However, the value of this research goes beyond its technical innovation. In the digital marketplace, understanding consumer behavior is vital for private entities, policymakers, and scholars. Online platforms can apply the behavioral findings to improve pricing and recommendation mechanisms, while policymakers may use the results as a safeguard against unethical marketing practices that exploit psychological vulnerabilities. At the same time, this research advances economics, psychology, and computational science by showing how these fields can be integrated to explain human behavior in real-world environments.

2. Literature Review

The foundations of utility theory were laid in the mid-20th century [1]. offered an axiomatic development of expected utility theory, the idea that rational agents maximize expected utility for different outcomes. Extended this work to the general equilibrium with stable preferences while assuming uncertainty. These models are analytically convenient but attempts to connect model output to real-world consumer behavior have failed. Advances in behavioral economics have sought to fill these gaps. demonstrated the idea of prospect theory: people feel the loss of one unit twice as much as they feel the gain of one unit, a concept known as loss aversion [1]. Thaler 1985 introduced the theory of mental accounting, the idea that money is allocated to different 'money accounts' that can result in suboptimal money decisions [3]. Demonstrated the phenomenon of hyperbolic discounting, the tendency to prefer immediate rewards to future rewards, which violates classical assumptions of discounting [4]. Collectively, these works have challenged the assumption of fixed, optimal preferences and have revealed the importance of psychological factors in consumer behavior.

In parallel, bodies of work have examined the technology and social environment that influence consumer behavior. Ariely 2009 has detailed the irrational attraction of 'free,' which tends to trump logical thinking about value [5]. According to OECD 2023, more than 70 percent of young consumers are influenced by other consumers in a purchase they make, a function of the power of the peer effect in the social media environment. And further, according to The Economist 2023, consumers, faced with short video offerings on TikTok, have less time to be rationally convinced, and are thus more likely to make impulse purchases. These works have shown that consumers are highly influenced by the social context and platform design in which they make their decisions, a context that classical models do not account for [6].

Yet, there are still many gaps. Only a handful of studies have combined loss aversion, social influence and time pressure into a comprehensive utility model. Most research considers only one factor, reducing predictive power. In addition, most empirical work has been conducted in Western or high-income countries, leaving it uncertain whether the results generalize well to other populations. Larger datasets like the China Household Finance Survey offer the possibility of validating models in different cultures [7,8].

Overall, the literature has moved from purely rational models towards models that incorporate psychology, social context, and computational techniques, but they are still missing. This study aims to bridge this gap by offering a three-factor behavioral utility model that unifies insights from behavioral economics and computational techniques and tests them on survey and simulated data.

the results of this study extend both theory and practice by demonstrating how consumers in digital marketplaces differ from the assumptions of classical utility models. The behavioral utility framework that results includes time pressure, loss aversion, and social influence, and the results further demonstrate that these factors are crucial to understanding modern consumption.

This section presents the discussion of results in three models: model results, behavioral results, and practical results.

3. Theoretical Framework & Contribution

Classical Utility ModelsCobb-Douglas and CES models assume that consumers' preferences are constant, rationally formed, and independent of context. Although analytically convenient, these models do not capture the actual situation faced by consumers in contemporary e-commerce, where purchase decisions are driven by time pressure, social proof, and psychological biases. To address these differences, this study develops a behavioral utility maximization framework that accounts for three factors: 1) dynamic elasticity of preferences, 2) behavioral Lagrangian optimizer, and 3) our contributions that combine behavioral and computational advances.

Dynamic Elasticity of PreferencesIn traditional theory, substitution between goods is modeled as a fixed parameter. However, in practice, online shopping environments suggest that substitution is not constant: when faced with countdown timers or limited-time goods, consumers tend to make faster and less deliberate choices. To capture this change, this study introduces a new time-dependent elasticity parameter ρ(t) that varies with decision pressure. With this adjustment, the model can capture how preferences change when some goods are involved in the decision-making process due to decision pressure [9].

The Lagrangian method has been widely used in economics to model consumer choice under budget constraints [10]. In this study, this study extends the method by considering psychological factors such as mental accounting and loss aversion. According to mental accounting, consumers will treat each money as belonging to a separate "budget" and may result in a consumer buying goods beyond the monetary constraints [3]. Loss aversion describes the fact that the consumer feels more regret about the loss of a discount than the gain of an amount that is considered equivalent [2]. With these behavioral terms included in the Lagrangian optimizer, this study keeps the mathematical rigor but is more reasonable in terms of consumers' behaviors in online markets.

This extension expands the framework in three significant directions within the literature, respectively. First, this integrated model extends the exploration of loss aversion, social comparison, and dynamic pricing from separate factors into a single utility maximization model [6]. Second, it provides a "social utility premium" value which represents the value of seeing what others bought or recommended. Finally, it provides processed data and computational code to enable other researchers to reproduce, test, and extend the model in future work.

4. Methodology

To evaluate the effectiveness of the proposed behavioral utility framework, this study compares it with a classical baseline: the Cobb–Douglas utility model. The Cobb–Douglas function is widely used in microeconomics to represent consumer preferences, as it assumes that utility is derived from the consumption of two goods, x and y, with constant parameters α and β representing preference weights. The consumer maximizes utility subject to a budget constraint [9,10]:

$$\max f(x,y) = x^{\alpha} y^{\beta} \qquad \text{subject to} \quad p_x x + p_y y = M \tag{1}$$

There are two ways to get the same result with standard solution methods.

First, the substitution method substitutes the budget constraint into the utility function and finds the maximum with respect to one variable (closed form solutions). Second, the Lagrangian multiplier method sets up the Lagrangian and finds the first order conditions (same result) [10].

$$x^* = \frac{\alpha M}{(\alpha+\beta)p_x}, \quad y^* = \frac{\beta M}{(\alpha+\beta)p_y} \tag{2}$$

This shows that income is allocated proportionally between goods x and y. While mathematically clear, this framework assumes stable, rational preferences and does not account for behavioral factors such as loss aversion, social influence, or time pressure. Building on this baseline, our behavioral model introduces time-varying elasticity, psychological constraints, and social interaction parameters.

5. Result

The results of our study indicate that the behavioral utility maximization model is a more accurate and realistic representation of consumers' choice in an online shopping environment than traditional models. This study found three significant results: the improved model performance, the behavioral realism, and the practical implications for digital commerce.

5.1. Model Performance

The results indicate that the static preference assumption used in Cobb-Douglas is insufficient, and that time-dependent elasticity and behavioral constraints must be incorporated to explain choices in a digital marketplace. The results show that the model performance is better, which provides solid evidence that extending classical theory with behavioral realism leads to more accurate predictions.

5.2. Behavioral Realism

The results also demonstrate the central position of psychology in consumer behavior. First, consumers are more sensitive to losses than to gains; that is, if a discount or a deal is missed, consumers feel a stronger negative effect than the positive effect brought by an equivalent saving. This result supports the principle of loss aversion in prospect theory. Second, this study found that social influence has a positive effect on willingness to pay. When consumers see others purchase, particularly when a product is endorsed by an influencer or when peers actively compared prices, demand from consumers increased. The results show that purchasing is not merely an economic process, but also a social and emotional one. More importantly, the model allows these effects to be measured, which connects behavioral theory and predictive modeling.

5.3. Practical Implications.

Beyond their theoretical significance, the results indicate how online platforms shape consumers' decisions. Countdown timers, limited time offers, and flash sales forced consumers to buy impulsively without deep consideration by creating artificial urgency. Meanwhile, comparisons with peers and providing social proof increased demand by exerting pressure on consumers' communities. These features are effective at boosting sales; however, they raise ethical concerns. Platforms should use behavioral insights to design shopping environments not only to extract more profit from consumers, but also to protect them from overspending and manipulation.

The results indicate that the behavioral model explains both the explanatory process and the practical process. It explains how modern consumers' behavior differs from classical assumptions and how behavioral constraints are important in utility maximization.

6. Discussion and future Implication

6.1. Model Performance

The relative success of the behavioral utility model versus the Cobb-Douglas baseline demonstrates the importance of moving beyond traditional rational-choice models. Classic models posit that consumer preferences are constant and context-invariant, but the evidence documented here shows that consumers are extremely sensitive to dynamic conditions in which their preferences change. The model's inclusion of a time-dependent elasticity parameter allows for faster choices when stressed. This not only advances a more behaviorally realistic utility theory, but also shows how computational models can be combined with psychological constraints. Consistent with recent calls to upgrade consumer theory, our results contribute concrete evidence that utility functions must reflect the realities of online commerce [1].

6.2. Policy implications: Behavioral insights from the study.

The results are relevant to and extend two classes of classic behavioral economics results in two ways. Relevance of loss aversion in e-commerce is consistent with Kahneman and Tversky's observation that people fear more than they gain [2]. Importance of social influence confirms OECD's finding that peer effects are a large factor in youth spending [6]. The difference is that their discoveries are relevant to a utility maximization framework and are therefore measurable and predictive. For instance, the model tells you how much extra willingness to pay consumers have when they see that others are buying the product. Therefore, the psychological theory is more relevant to us and we are able to close the loop with economic modeling.

6.3. Practical implications

Descriptively, based on our results, how do e-commerce websites influence consumers' behavior? Countdown timers, time-limited sales and flash sales stimulate impulsive buying by creating a false sense of urgency; comparisons with similar consumers and opinion leaders' recommendations stimulate the level of demand by social proof. These may be useful for commercial purposes, but they may also cause irrationally spending and influencing consumers. Thus, using behavioral models not only for commercial purposes, but also to gain insights into creating more behavioral shopping spaces is worthwhile. Government and regulatory authorities may find our results useful when developing policies.

6.4. Summary

In other words, this study cannot understand consumers in a digital marketplace without behavioral factors. Again, the results have shown that combining economic models with behavioral psychology and computational methods is meaningful both from a theoretical and applied perspective because capturing the impact of time pressure, loss aversion, and social comparison pave the way for future research on digital consumers.

7. Conclusion

This study was conducted to overcome the weakness of classical utility models in explaining the contemporary consumer's decision-making process. Classical utility models such as Cobb-Douglas postulate rational consumers with fixed preferences, but in reality, consumers in the digital marketplace make decisions quickly and emotionally, and their preferences are heavily context-dependent, influenced by social factors such as the countdown timers, the appearance of "flash" sales, and comparisons with peers.

To address these issues, this study developed a behavioral utility maximization model that considers three types of factors: loss aversion, social comparison, and dynamic pricing effects. These models allow preferences to change under time pressure, embed psychological constraints into optimization, and model social influence explicitly, thus going beyond the range of rational-choice theory. The model has better explanatory power and represents consumers in a more reasonable way in both e-commerce and live-stream shopping.

Its research makes two key contributions from a theoretical perspective, it extends utility theory by considering behavioral psychology and computational methods to show that consumer preferences are flexible and not fixed. From a practical perspective shows how we can help platform and marketers understand and anticipate consumers' purchasing behavior.

At the same time, the results also lead to a number of ethical issues that we should carefully discuss, such as using behavioral information to manipulate consumers and harm them financially.

However, what can be said about the message of this work? The bottom line is this: Very soon, meaningful research on consumer's decision making in online marketplaces will have to be cross-disciplinary. Future research will need to integrate work from economists, behavioral psychologists, and computer scientists to properly model human behavior in digital settings. Such cooperation will

serve academia well, but it will also serve the digital consumer by helping to build a more fair and human-friendly digital economy.

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