# Game-Theoretic Analysis of Live-Streaming E-Commerce on TikTok

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**Abstract.** This paper analyzes the application of game theory in live streaming sales from three models: prisoner's dilemma, British auction, and Nash equilibrium. Firstly, using the prisoner's dilemma to analyze cooperation and competition in live streaming sales, using charts to analyze that competition appears to be the optimal strategy, but cooperation is more common. In the process of signing contracts with internet celebrities, the company also used English auctions for analysis. During the bidding process, it is necessary to avoid the curse of the winner, maintain fairness in competition, and reduce the minimum bidding increment. Finally, the application of Nash equilibrium was explored to find the balance of interests between sellers and buyers, while meeting their expectations. Overall, this research provides valuable insights into strategic decision-making in e-commerce, enhancing understanding of the interplay between influencers and brands and guiding them towards mutually beneficial outcomes in the evolving market of live-streaming commerce.

## 1 Introduction

In recent years, the evolution of social networks and media has provided wider access to various goods for consumers, coupled with the convenience of shopping from home. These factors have undeniably propelled the growth of e-commerce. Among various formats, live-streaming commerce, which involves influencers or celebrities introducing and selling products through online live broadcasts, has emerged as a significant form in the e-commerce market. In countries like the United States and China, live-streaming sales platforms such as Amazon Live, TikTok Live, and Taobao Live have attracted millions of viewers [1, 2]. Investigating the principles of live-streaming commerce is crucial for understanding this innovative sales approach and thus fosters the further development of e-commerce.

This paper aims to explore and analyze the application of game theory models in the process of live-streaming sales, mainly focusing on three key steps: live-streamers strategies for product promotion in live broadcasts, the competition among brands for advertising fees to live-streamers, and the dynamic process of finding a balance between price, product display, and market strategies by sellers and buyers. The "prisoner's dilemma model," "English auction model," and "Nash equilibrium model" will be used to analyze these stages respectively.

In this paper, section 2 will explore the application of the prisoner's dilemma model in the decision-making process of live streamers when promoting products during live broadcasts. Section 3 will discuss the use of the English auction model in the price bidding process among brands offering live-streamers advertising fees. In Section 4, the Nash equilibrium model's application in the dynamic process of sellers and buyers striving for balance through pricing, product presentation, and market strategies in live sales will be explored. Finally, Section 5 will summarize all sections and provide a comprehensive overview of the findings.

## 2 Prisoner‘s dilemma behind live-streaming

The Prisoner's Dilemma (PDG) is a classic model in game theory, primarily used to analyze the strategy of individuals when making decisions. This model basically involves two participants, each facing the decision to either cooperate or betray the other. If both choose to cooperate, they can achieve a relatively better outcome; if one betrays while the other cooperates, the betrayer gains maximum benefit at the expense of the cooperator; if both choose to betray, they both receive a relatively worse outcome. The Prisoner's Dilemma reveals the contradiction in individual decision-making: how to make a balance between personal interests and collective interests. In live-streaming commerce, every influencer faces the choice of either cooperating to promote each other's products or competing independently, which is similar to the cooperation and betrayal dynamics in the Prisoner's Dilemma.

### 2.1 Theoretical predictions of influencers’ strategies

The payoff for different strategies chosen by influencers is represented numerically. For instance, mutual cooperation, symbolized by (5,5), benefits through an

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increased range of promotion, creating a win-win situation. When either influencer opts for betrayal, potentially by disparaging others' products to better promote their own, audience credit may decrease due to perceived drawbacks in all products, thus harming both influencer's interests, represented by a payoff of (1,1) (see Table 1).

**Table 1.** Blogger B.

| | collaborate | compete |
|---|---|---|
| collaborate | 5 , 5 | 0 , 10 |
| BloggerA | 10 , 0 | 1 , 1 |

In a scenario where one chooses cooperation and the other betrayal, the betraying influencer, benefiting from others' recommendations and their disparagement of another's product, receives a payoff of 10, higher than mutual cooperation, while the cooperating influencer suffers with 0 payoff, lower than mutual betrayal (see Table 1).

How will influencers make their choices? Assuming a single-game scenario where influencers are rational and aim to maximize their interests, if an influencer believes the other will compete, he will also choose to compete as 1 (compete) > 0 (collaborate). Similarly, if he believes the other will collaborate, they will still choose to compete as 10 (compete) > 5 (collaborate), making the rational decision to always compete (dominant strategy). As a result, both parties end up with a payoff of (1,1).

### 2.2 Influencers' strategies in the real world

Contrary to theoretical predictions, decision-making in the real world is often more complex than simply relying on the payoff obtained in a single-game scenario theoretically; cooperation can sometimes be achieved and more common in specific scenarios [3].

In reality, the decisions of cooperation and competition among influencers tend to be interpreted as a practical application of the Iterated Prisoner's Dilemma model. In this model, participants engage in multiple rounds of the game, making decisions based on the strategies of their counterparts and the specific context. This approach accounts for long-term interactions and payoff. While choosing to betray may offer short-term benefits theoretically, long-term cooperation can yield greater potential advantages in terms of brand development, audience credibility, and sales growth [4]. Consequently, influencers in their practical decision-making process tend to favor cooperation to achieve long-term gains.

In addition, this can also be analyzed by calculating the relationship between influencers' expected payoff and the probability of cooperation:

If both choose to cooperate (C, C), each receives a payoff of R.

If one chooses to cooperate and the other betrays (C, D or D, C), the cooperator's payoff is S, while the betrayer's payoff is T.

If both choose to betray (D, D), each receives a payoff of P.

Here, T > R > P > S [5].

A cooperation probability p ($0 \leq p \leq 1$) can be set, representing the likelihood of each participant choosing to cooperate. Thus:

The probability of both cooperating is $p^2$, and the probability of both betraying is $(1-p)^2$, and the probability of one cooperating and one betraying is $p(1-p)$, and vice versa.

The expected payoff for an individual player is calculated as the probability of these scenarios occurring multiplied by the corresponding payoff value:

(1) $R \cdot p^2$ represents the expected payoff when both players cooperate.

(2) $T \cdot p(1-p)$ represents the expected payoff as a betrayer (with the other player cooperating).

(3) $S \cdot p(1-p)$ represents the expected payoff as a cooperator (with the other player betraying).

(4) $P \cdot (1-p)^2$ represents the expected payoff when both players betray.

Therefore, the expected payoff for an individual player at any given cooperation probability p should be expressed as:

$$E(p)=R \cdot p^2+T \cdot p(1-p)+S \cdot p(1-p)+P \cdot (1-p)^2 \quad (1)$$

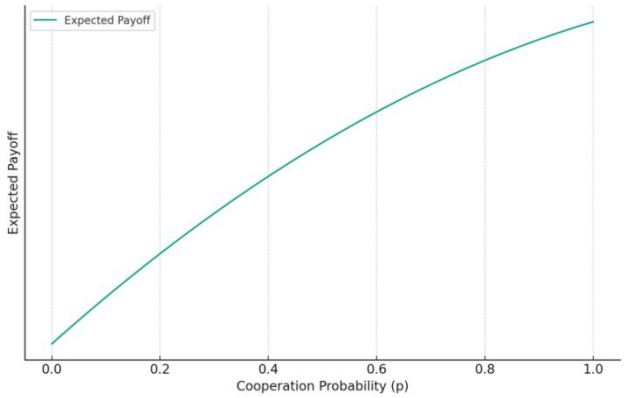


**Figure 1.** Expected payoff vs cooperation probability (Picture credit: Original).

As indicated by Figure 1, as the probability of cooperation increases, players' expected payoffs show an upward trend [6]. This suggests that even though competition might seem more beneficial in the short term, the expected payoff for influencers increases with the likelihood of cooperation. This means that in ongoing interactions between influencers, long-term cooperation can lead to more stable and sustained benefits, thus encouraging them to choose collaboration over competition. Therefore, from the perspective of long-term cooperative decision-making, influencers' tendency to cooperate is based on a logic of maximizing long-term benefits, supporting the idea that cooperation could be a more advantageous strategy in certain contexts.

### 2.3 Market dynamics and strategic adjustments

Furthermore, influencers must closely focus on market dynamics, including audience responses and competitors' strategic changes. Based on this information, they may adjust their live broadcast content, promotional activities, or partnership choices to attract more viewers, increase sales, and maintain market competitiveness. Such dynamic strategic adjustments help influencers maintain an edge in the competitive live-streaming market and achieve long-term success.

## 3 English auction behind live-streaming

### 3.1 English auctions belong to dynamic games.

In English auctions, players will continuously bid, and each player will see the bids of other players and adjust their bids based on their own strategies and goals. In the process of live streaming sales, there are also applications of English auctions.

English auctions start from the direction that bidders are most likely to accept and gradually move towards the target price of the auctioneer. In live sales, starting from the lowest price, most bidders are willing to accept it and then proceed to the next round of price increases until the price reaches a certain level. At this point, only one bidder is willing to accept, and the English auction ends. When combining English auctions with live streaming sales, there are three aspects that need to be noted here.

### 3.2 Avoiding the winner's curse

As shown in Figure 2, if the actual value of the auction project (profit x) is lower than the bid (loss y), the psychological perception of profit and loss v (x) v (y) will inevitably lead to the curse of winner 1; If the actual value (profit x) of the auction project is equal to the winning bidder's bid (loss y), and the psychological feeling of losing the same value is equal to the winning bidder's bid. The psychological feeling is still V (X). If the actual value of the auction item (income x) is greater than the winner's bid (loss Y) but lower than their actual valuation of the item before the auction, then the curse of winner 2 will still occur. When and only when the actual value of the auction project (profit x) is significantly higher than the bid of the winning bidder (loss y), resulting in the influence of the winning bidder's curse, the psychological feelings of the winning bidder [7].

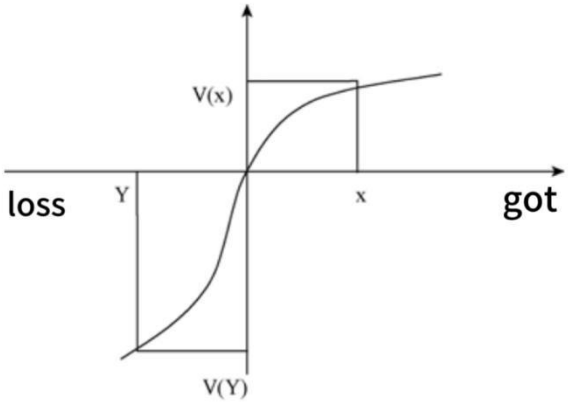


**Figure 2.** Encoding rules for the "gain and loss" of the value function (Picture credit: Original).

Given the strategies for dealing with the winner's curse, current strategies for dealing with the winner's curse mainly include joint bidding and sharing information, enjoying and learning. Collaborating with the rest of bidders can decline the number of bidders after the alliance, the bidders' bidding power is stronger, so their ability to effectively avoid the curse of the winner is also stronger. Another way to reduce the curse effect of the winner is to share information with your competitors, including both feedback and situational information. Feedback information refers to providing the average profit or loss information of all participants to the participants after each round of the experiment so that they can realize that they will suffer losses no matter how hard they try, so what they need to do is how to narrow the gap between their bid and the actual value of the product. Be careful when determining information about the winner's curse. The information on the occurrence of the winner's curse in existing research mainly includes the degree of uncertainty in the value of bidding products and the number of contractors. Individuals must first clarify the credibility of this information and gain a deeper understanding of whether the information they have obtained can be used for bidding activities. In addition, learning can also be used to avoid the curse of winners. Learning the curse of the winner requires a long process. If a person has a gradual process and multiple bidding experiences, bidders can gradually learn to reduce the losses caused by the winner's curse [8].

### 3.3 Minimum price increment

In the design of English auction, the most important part is how to design the minimum price increment, which is the minimum change of each round of price. During the bidding process， we need adjust the minimum price increase to maximize the value of the bidder.

### 3.4 Avoiding unfair agreements

When conducting online live streaming sales, the platform interacts with sellers should avoid unfair competition. Taking Amazon as an example, as a leading online shopping platform, it has provided trading

opportunities for countless small and medium-sized platform operators, but at the same time, it is also suspected of using data collected from operators on other platforms to replicate similar products for self sales, thereby improving Amazon, with high self operated business sales, was investigated for antitrust by the European Commission in July 2019 At the same time, the Austrian Federation. The Bureau of Competition (BWB) has also issued a document stating that it has received multiple complaints over Amazon's favoritism towards its own services in the past three years. December 2018.In the month, the Austrian Retail Association also filed a lawsuit against Amazon on behalf of platform retailers. Currently, the Austrian Federal Competition Agency has been launched the antitrust investigation procedure against Amazon. In addition, Amazon has signed unfair agreements with other platform operators, which allow for Xu Amazon unilaterally modified the terms of the contract or closed its seller account without explanation, resulting in being banned by France in September 2019 The Li Commercial Court fined 4 million euros [9]. It is important to reduce the occurrence of unfair competition through policy restrictions

## 4 Nash equilibrium in live-streaming sales

### 4.1 An model for Nash equilibrium

Regard the Nash equilibrium problem in general. GNEP expanding the classical Nash equilibrium problem by assuming the feasibility of each participant. The strategy of competitors determines this set. N players, and each player ν controls the variables x ν ∈ ℜnν .

We use x to represent the vectors formed by all these decisions variable:

$$x \equiv \begin{pmatrix} x^1 \\ \dots \\ x^N \end{pmatrix} \tag{2}$$

Which has dimension n: $=\sum_{\nu=1}^{N} n_\nu$ and by $X^{-\nu}$ the vector formed by all the players'decision variables except those of player ν. Each player's strategy should be included in a set Xν($x^{-\nu}$) ⊆ $\Re^{n^\nu}$ that depends on the rival players' strategies. Player ν's aim, given the other players' strategies $x^{-\nu}$ is to choose a strategy $x^\nu$ that solves the minimization problem.

$$minimize_{x^\nu}\ \theta_\nu(x^\nu, x^{-\nu}) \tag{3}$$

$$subject\ to\ x^\nu \in X_\nu(x^{-\nu}) \tag{4}$$

For every $x^{-\nu}$, the solution set of this problem is denoted by Sν($x^{-\nu}$). The GNEP is the problem of finding a vector $\bar{x}$ such that

$$\bar{x}^\nu \in S_\nu(\bar{x}^{-x}) \tag{5}$$

Point $\bar{x}$ is named a (generalized) Nash equilibrium [10].

### 4.2 When it comes to Nash equilibrium in the context of live streaming sales

Considering seller expectations, the seller hopes to achieve maximum profit and sell the most products. Sellers need to make timely price and inventory adjustments to cater to market and customer needs. Sellers need to find Nash equilibrium between pricing, product display, and audience groups. Then, considering customers' expectations, customers hope to buy high-quality and affordable products, and hope to receive more preferential policies and benefits. The Nash equilibrium of customers may need to consider factors such as product quality, discounts, and marketing methods. In the process of live streaming sales and customer purchasing, it constitutes a dynamic process, because the factors that need to be considered in the Nash equilibrium of customers include those determined by the seller, and the factors considered in the Nash equilibrium of sellers include those influenced by the seller. Therefore, sellers will make better choices based on the buyer's behavior, and buyers will also search for the most suitable product among multiple sellers. To achieve Nash equilibrium, neither buyer nor seller has a better choice.

## 5 Conclusion

In conclusion, in live-streaming commerce, influencers need to choose between cooperation and competition, and the Prisoner's Dilemma model helps explain the complex dynamics behind these decisions. While competition may seem likely to be the dominant strategy theoretically, cooperation is more common in the real world and can bring more long-term benefits. Also, this paper discusses the bidding strategies of brands for advertising fees in collaboration with influencers by applying the English auction model, this auction model emphasizes the importance of dynamic pricing, where brands must consider how to avoid the "winner's curse" to balance expected profits and actual costs. The setting of the minimum bid increment is important in attracting potential bidders. Additionally, maintaining the fairness and transparency of auctions is vital for protecting consumer rights and sustaining market competition. This process is dynamic and interactive, not only involving strategic decisions between brands and influencers, but also the ongoing adaptation to market evolving and consumer behavior. Finally, by analyzing the application of the Nash equilibrium model in live-streaming sales, this paper explores how sellers can predict optimal pricing points and product promotion strategies, finding a stable strategic balance in a highly competitive market, satisfying both sellers' and buyers' expectations. This dynamic process involves factors determined by sellers and choices made by buyers, creating an interactive game scenario.

This research applies the Prisoner's Dilemma, English auction, and Nash equilibrium models to the context of live-streaming commerce, offering new perspectives for understanding and analyzing strategies

used in the e-commerce market. These theoretical models reveal the dynamics between brands and influencers, providing insights into effective strategies in a competitive market.

However, as the e-commerce market continuously changes, existing models may not be enough to accurately predict future rapid market changes. Therefore, continual exploration and development of these theoretical frameworks are necessary for adapting to new market trends and ensuring long-term market prosperity. Additionally, while this research offers deep insights into live-streaming commerce, its generalizability may be limited due to a focus on specific social media platforms or region-specific influencers. Future research should expand the sample range and explore more diverse live-streaming platforms to enhance the broad applicability of the study's conclusions.

## Authors Contribution

All the authors contributed equally and their names were arranged in alphabetical order.

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