

An overview of the analysis of e-commerce price wars based on game theory

Xuran Cheng *

Shanghai University, Shanghai, 200000, China

Abstract. In the field of e-commerce, price wars have become a common means for firms to compete for market share. This paper takes price wars in e-commerce platforms as a background, and reviews the game theories used in them, as well as the ways in which firms adjust and optimize their pricing strategies in the context of dynamic competition. Based on the definitions of price wars e-commerce, sting models of static and dynamic games, the paper analyses the patterns of price wars and proposes suggested strategies for firms to cope with them, and illustrates the impact on market stability and firms' long-term revenues. Finally, the paper discusses the impact of price wars on the long-term development of the industry, and puts forward corresponding policy recommendations and future plans, with the aim that through rational strategy optimization, enterprises can achieve sustainable competitive advantages and maximize their market performance in the midst of fierce price competition.

1 Introduction

The rise of e-commerce has completely changed the traditional retail industry, providing consumers with more convenient and diversified shopping choices, but it has also brought about unprecedented market patterns and market competition - price wars have become a common means for many e-commerce platforms to compete for market share. In such a competitive environment, how to develop an effective pricing strategy and maintain an advantage in the competition has become a focus of attention for enterprises. Under the framework of game theory, a firm's pricing decision can be regarded as a strategic choice, whose goal is to maximize its own revenue. By constructing different game models, a deeper understanding of the evolution of strategies in price wars and their long-term effects on market structure. This paper studies e-commerce price wars and coping strategies based on game theory. Firstly, it defines the definition of price war and reviews the relevant theories and applications of game theory, then focuses on the field of e-commerce and discusses the current situation. This is followed by further analyzing the process of strategy selection and interaction in e-commerce price wars and giving examples. Finally, suggestions for strategy optimization in e-commerce competition are presented. Through these review studies, it is expected to provide theoretical references for e-commerce enterprises to formulate more

*Corresponding author: huhu448511041@tzc.edu.cn

effective strategies in the complex market competition, so as to gain long-term competitive advantages.

2 Theoretical and research background

2.1 Theoretical foundation

2.1.1 *The Price war*

It refers to the behaviour of firms competing for market share by lowering prices, which is commonly found in the field of e-commerce [1]. Due to the relatively low entry threshold of the online market, firms often adopt a substantial price reduction strategy to quickly capture the market. Price war refers to the behavior of market participants competing for market share through aggressive pricing strategies, which can be divided into active and passive [2, 3]. However, excessive price competition not only compresses the profit margins of enterprises, but also may lead to the disruption of the market order [4].

2.1.2 *E-commerce*

As one of the four new inventions, e-commerce is a new mode of economic activity born based on the Internet [3]. It not only meets people's daily needs, but also provides a more convenient, faster and more transparent way of consumption. In the fast-paced present, online shopping has become the DNA of life [5].

At present, e-commerce platforms have two main sales models. One is the platform model, where the manufacturer enters the platform and sells the products by paying commission, and the price is decided by the manufacturer. The other is the self-operated model, in which the platform wholesales products from manufacturers, determines the price and sells them to consumers, earning the price difference [6].

2.1.3 *Game theory*

It is a theory that studies the decision-making behaviour of rational decision-makers under conditions where the strategies of the parties interact [7]. A game needs to set the following aspects: the participants of the game, the information of the game, the set of all behaviours or strategies that the players can choose, the order of the game, and the payoffs of the players. Game theory is a clear and effective tool for studying e-commerce price wars, starting from studying the predicted and actual behaviour of the interested parties and studying their optimization strategies [4].

2.2 E-commerce Business Price War Drivers

For a long time, the e-commerce industry has a certain degree of convergence in its development process. The low degree of product differentiation, the homogeneity of the product structure, and the convergence of manufacturers in the cost structure is an important factor leading to the persistence of price wars in the e-commerce industry [8]. The lack of product heterogeneity, consumers are thus unable to distinguish the value of products on the market based on the brand [9]. So, when the market share is overwhelmingly concentrated in a number of brands, the price factor will become almost the only important consideration in

the consumer's purchasing decision, which makes the price competition, as a competitive strategy, can easily be imitated by other competitors, thus losing its strategic significance [9].

Increased transparency of commodity price information and lower search costs for consumers also provide conditions for price wars. Although information transparency is conducive to the display of corporate brand influence, consumers can better understand the commodity information, reducing the risk of purchase, and reduce the cost of price comparison [4]. When the price search cost is high, the number of consumer searches is low, regardless of whether the enterprise takes the strategy of reducing the price, that is, the consumer's pursuit of low prices is reduced, and the industry will not start a large-scale price competition [10]. On the contrary, if the price search cost of consumers is small, consumers will be more sensitive to the price, and easy to search for lower price goods, in this case, the firm to reduce the price effect is good, the possibility of enterprises within the industry to use the price competition strategy increases [10]. Reducing the buyer's price search cost without changing the product design will increase price competition, but endogenous product design leads to increased product differentiation, which reduces price competition [11].

It is founded that consumers can access information services at no cost by first procuring goods at low prices from sellers that do not provide information services and then obtaining information services from sellers that offer such services [12]. Sellers engage in competitive technology-driven strategies to reduce consumers' search costs and provide differentiated services [12]. As competition in the information services market intensifies, sellers are less motivated to provide information services. The cost of consumers searching for commodity price information, the cost of transferring from one e-commerce platform to another e-commerce platform also affects the e-commerce platform pricing decisions, if the cost of consumers collecting price information and transferring e-commerce platforms is greater than the benefits that can be achieved, the consumer accepts the price set by the e-commerce platform, e-commerce platforms have incentives to collude in the setting of high prices, to obtain monopoly profits [13, 14]. Conversely, there is an incentive for e-commerce platforms to compete with low prices and gain more consumers and market share with low prices.

2.3 E-commerce enterprise price war status

The way of competition between firms includes price and non-price competition, but is dominated by price competition. Many scholars at home and abroad focus their research on the field of price competition in a certain industry or a certain type of product. With the increasingly fierce competition in the e-commerce market in recent years, price war has become a common means for major e-commerce platforms to compete for the market [3].

In China, for example, e-commerce platforms such as Taobao, Jingdong, and Pinduoduo often launch large-scale discounts, seconds, full reductions, and other promotional activities during shopping festivals such as Double Eleven and 618, and the intensity of the price war has been escalating. Some small and medium-sized e-commerce firms also have to participate in the price war in order to survive in the competition, which leads to the price level of the whole market is constantly suppressed. A similar situation exists not only in China, but also in e-commerce markets in other parts of the world. For example, Amazon has been pulling down prices in the US market through its Prime membership programme and various promotions, prompting other competitors to follow suit [15].

In the e-commerce environment, the mechanism of price wars is different from that of traditional industries. E-commerce platforms, due to their openness and global nature, make price information more transparent, which exacerbates the extent of price wars. According to the basic models in game theory, price wars can be described by different game models, such as the Berchard model, the Gounod model and the Stackelberg model [16]. In this case, firms may choose to avoid the negative impact of price wars through price collusion or

differentiated pricing strategies to avoid vicious competition [1]. In addition, with the intensification of market competition, some e-commerce firms may also introduce third-party platforms or enhance their market control by monopolizing the market, so as to gain an advantage in the price war [16].

2.4 Reasons for choosing game theory analysis

From the consumer side, it will have a negative impact on consumer psychology and their behaviour, as it will strengthen people's holdout mentality, which may cause market development to stagnate and corporate inventories to surge, which is detrimental to the development of the company and the industry, and ultimately makes the product and brand image damaged to a certain extent [17, 18].

Under such a dilemma, it is important to study how enterprises should use price competition strategies to avoid the negative impacts of excessive price competition. Game theory, as a theoretical method to study the decision-making behaviour of rational decision-makers under the condition of mutual influence of strategies of all parties, can be an effective tool (table 1).

Table 1. Brief classification of static game models

Type of game	Definition	Specificities
zero-sum game	Participant's total return is constant zero	What one party gains is what the other party loses
constant-sum game	Participant's total return is fixed	Co-operation can change the distribution of benefits
non-zero-sum game	Participants' total return is variable	Can win or lose together, strategy interaction is critical
Perfect information game	All participants have full knowledge of the rules of the game, the set of strategies, and the payoffs	Strategy choice is based on complete information
Imperfect information game	At least one party has incomplete knowledge of the other party's information	Information asymmetry must be taken into account

3 Application of game models to price wars

3.1 Application of static game models to price wars

3.1.1 Bertrand model

The Bertrand model provides a framework for gaining insights into how firms compete for market share through pricing strategies [19]. The model assumes that there are two or more competitors in the market for a homogeneous good, and that consumers have immediately access to price information from all merchants and always tend to buy the lowest priced good [19]. This setting is suitable for analyzing plots where product differentiation is not obvious and consumers make purchase decisions mainly based on price, which fits precisely with certain characteristics in the e-commerce environment [20]. Any small difference in price among merchants will directly translate into a change in market share, which triggers intense price competition until the price equals the marginal cost, theoretically reaching a Nash equilibrium [21].

Through the concept of Nash equilibrium, Bertrand's model portrays the e-commerce firms setting prices to maximize their profits under the condition of complete information. In

this equilibrium, no firm alone will increase its profit by changing its price strategy, so all firms have an incentive to maintain their current prices.

3.1.2 Analysis of Nash equilibrium theory

In the strategy analysis framework of e-commerce price wars, the Nash equilibrium theory plays an important role, which provides us with a powerful tool for predicting the rational decision-making process of market participants under conditions of complete information and the steady state they eventually reach [22].

There is usually a negative correlation between price and demand. In this model, assume that there are two e-commerce firms, A and B, which can choose different pricing strategies to gain market share. As price rises, market demand shows a decreasing trend. When setting prices, firms A and B should not only consider sales revenue, but also assess the potential response of their rivals and its impact on their market share.

Through Nash equilibrium analysis, it is assumed that each enterprise has two strategies: low price high price strategy. If both firms adopt a low-price strategy, they can attract a large number of customers and form a large market share, although their profit margins are compressed in the short term [23]; conversely, if both firms adopt a high price strategy, they may lose market share as price-sensitive consumers switch to rivals [24]. Additionally, if one firm chooses low prices, the other faces the choice of following the trend of price reduction to maintain market share or maintaining high prices to protect profits [25].

In this simplified binary strategy space, if both parties choose a low-price strategy and this combination of strategies forms a Nash equilibrium, then any attempt by either party to raise prices on its own will result in a significant decline in its market share, which will not be compensated by a price increasing, and will ultimately force it to return to its original strategy. This analytical framework explains why, even though price wars may compress profit margins, firms may still prefer to maintain a low-price strategy to secure market position under certain conditions.

3.1.3 Amazon and the eBook marketplace example analysis

Amazon launched the Kindle and subsequently priced a large number of e-books at \$9.99 each, well below the average selling price of physical books [26]. The main purpose of this strategy was to boost sales of the Kindle reader and attract consumers to digital reading through low-priced e-books.

This strategy has rapidly increased the market penetration of Kindle and helped to cultivate the habit of purchasing and reading e-books, which is conducive to binding long-term stable customers.

There are two main types of its competitors: publishers, who are concerned about Amazon's low-price strategy as it compresses profit margins and could disrupt the pricing structure of the physical book market; and other e-book retailers such as Barnes & Noble and Apple, who have also launched their own e-reading devices and platforms, and have been forced to adopt a similar low-pricing strategy to compete for market share [26].

With competition from Amazon and other retailers, the average price in the e-book market generally declined. Consumers began to expect lower e-book prices and adjusted their purchasing behaviour. The market eventually reaches a new Nash equilibrium in which each retailer sells e-books at a lower price level, a price level that balances market demand and retailers' profit needs [27]. Amazon's low-price strategy not only successfully promoted the Kindle and e-books, but also led to a major restructuring of e-book production, distribution and pricing across the publishing industry [28].

3.1.4 Jingdong, Alibaba Pinduoduo price war

The participants are Jing Dong, Alibaba, and Pinduoduo, three e-commerce giants. The available strategies include maintaining existing prices, competing with price reductions, or adopting non-price competition strategies (e.g., increasing service quality, fast logistics, etc.) and are assumed to be a complete information game, i.e., the participants are able to observe each other's prices and strategies [29].

In 2019, the 618 e-commerce festival, Pinduoduo 'tens of billions of subsidies' officially online, which caused Jing Dong's trigger strategy, on 2 March 2023, Jing Dong 10 billion subsidy channel has been online part of the new products, which corresponds to Pinduoduo's 10 billion subsidies to steal the market from Jing Dong four years ago.

The core logic of Pinduoduo's low price is that low price can achieve incremental volume and create new demand, and its biggest harm is Jing Dong, because Jing Dong's traditional advantage category lies in high unit price digital products, mainly standard products. If Jing Dong's price is lower than Pinduoduo's, but also maintain consistent, that is, at the same time to take the price competition and non-price competition strategy can hope to be able to snatch a large number of old customers from Pinduoduo.

Ali also stressed the concept of 'price power', whose focus is obviously different from Jing Dong, the on-line Tao factory, the goal is to point to the source of the good, to enhance their corresponding voice in the face of the supply chain, rather than direct price cuts pay more attention to non-price competition strategy [30]. That is because Ali's advantageous categories are clothing, mainly non-standard products.

Therefore, although the price reduction strategy may attract consumers and increase market share in the short term, but in the long term, companies need to consider how to gain a competitive advantage through innovation and optimisation of services.

3.2 Dynamic game analysis in e-commerce price wars

3.2.1 Repeated game

Interactions between e-commerce platforms in the context of long-term price competition have been analysed in depth through the repeated games framework, which reveals how firms navigate the edges of cooperation and competition in search of optimal market strategies [31]. The essence of repeated games is that participants' current decisions not only consider immediate gains, but also weigh the long-term impact on future interactions, which provides a theoretical basis for the dynamic adjustment and complexity of strategies [32].

Incentive compatibility is key to ensure that co-operative strategies are sustained. On e-commerce platforms, this may manifest itself in price coordination mechanisms to avoid excessive price wars and jointly maintain market profit levels [33]. For example, by establishing price alliances or implicit agreements, platforms may maintain a relatively stable price range [34].

Reputation is the cornerstone for cooperation to be sustained in repeated games. A platform that consistently demonstrates a propensity to co-operate, even at the expense of some benefits in the short term, can accumulate reputation capital in the long term, prompting other platforms to respond in order to co-operate [35]. For this reason, designing effective punishment mechanisms is crucial to curb opportunistic behaviour. When a platform violates the co-operation agreement, other platforms impose penalties by increasing prices and reducing advertising co-operation in order to restore the balance [36].

3.2.2 Stochastic game

In the complex and changing environment of e-commerce price wars, stochastic games introduce the uncertainty factor, which is closer to the actual e-commerce market situation. The stochastic game model takes into account the incompleteness of information and the randomness of the environment in the decision-making process, allowing participants to continuously adjust their strategies based on new information.

The application of stochastic game models reveals the possibility of dynamic competition and co-operation in the price decision-making process. For example, when a firm lowers its price to attract more consumers, its competitors may adopt corresponding strategies to maintain market share, e.g., through lower prices or improved service quality [37]. Such strategic interactions form a stochastic game process in which each firm's strategic choices are not only dependent on the current state, but also influenced by the probability distribution of possible future states [38].

Further, stochastic game models emphasize the importance of decision interactions over time series for strategy choice [39]. In this setting, firms need to assess the potential impact of their current strategies on the future state of competition in the market. This includes taking into account how rivals interpret and react to current strategic moves and how these reactions affect the competitive landscape of the market as a whole [40]. Thus, stochastic game modelling not only helps firms to understand current market dynamics, but also provides them with a way to predict future market changes and formulate strategies accordingly [40].

However, the application of stochastic game models to the analysis of e-commerce price wars also faces many challenges. One of them is the challenge of accurately quantifying, for example, uncertainty in the market and its specific impact on firms' strategic choices [40]. In addition, the complexity of the models often requires advanced mathematical skills and computational resources, which may be a barrier for some firms.

4 Strategies and Recommendations

4.1 Pricing strategies for e-commerce platforms

In e-commerce platforms, the choice of pricing strategy is directly related to the competitiveness and market performance of the platform. E-commerce platforms need to consider several factors when developing pricing strategies, including consumers' price sensitivity, competitors' responses, and the supply and demand situation in the market [19], for example, differentiated pricing strategy: companies set different prices based on factors such as consumers' ability to pay to attract consumers at different levels in order to expand their advantage in the price war [1, 8]; bundled sales strategy: selling multiple products in combination to attract consumers at a lower total price than buying them individually, while avoiding the risk of a price war [9]; dynamic pricing strategy: adjust prices in real time based on market supply and demand, competitor behaviour and consumer purchase history to maximize profits while suppressing competitors' price wars [19, 40], which requires platforms to have strong data analysis capabilities and also need to continuously monitor market dynamics in order to quickly respond to changes in the competitive environment [8, 9].

4.2 Future research direction of E-commerce price war

In an e-commerce environment, buyers and sellers often face information asymmetry, especially in price wars, where the information gap between merchants and consumers may

affect pricing strategies and competitive dynamics. Future research can explore in greater depth how firms can achieve competitive advantage through price competition under such information asymmetry conditions. In particular, the application of technologies such as big data and artificial intelligence, and how firms can design more effective pricing strategies through data analysis. In addition, information asymmetry also provides a theoretical basis for imperfectly competitive markets and price discrimination, and it could be explored how these factors exacerbate or mitigate price wars.

Price wars are not only a game between firms, but are also deeply influenced by consumer behaviour. Studying the decision-making process and preference mechanisms of consumers in the face of different price promotions, discounts and market competition will help to understand the effectiveness of price wars. Future research directions could focus on how different consumer groups respond to price fluctuations, as well as micro-mechanisms such as consumers' price sensitivity, brand loyalty, and purchasing habits. In addition, from the perspective of behavioural economics, it is important to analyse how psychological factors such as 'loss aversion' and 'framing effect' affect consumer decision-making behaviour in e-commerce price wars.

In e-commerce price wars, competitors' reactions often determine the duration and intensity of the price war. By studying competitors' reactions, competitors' strategic choices could be better predicted under different market conditions. Future research can analyse in depth the coping strategies of different firms in the face of price wars, such as follow-the-leader pricing, price matching, and differentiation strategies, to help identify the triggers of price wars in the market and how to avoid vicious price competition, and to explore how firms can dynamically adjust their own strategy combinations to stay competitive in price competition.

There is often a 'race to the bottom' among enterprises in e-commerce markets, i.e. competition and cooperation at the same time. Future research could explore how, in the context of price wars, enterprises can avoid over-consumption of resources and reduce the negative impact of price wars by cooperating in order to achieve a 'win-win' situation while enhancing competitiveness.

5 Conclusion

In summary, price wars in e-commerce are more complex in their manifestations and mechanisms, and enterprises need to develop rational pricing strategies in the fierce market competition. Game theory provides businesses with theoretical tools to analyze price wars and help to make more rational decisions in competition. Through the study, it is found that the static game model can explain the mechanism and principle of the e-commerce price war, and the dynamic game model can help to understand and grasp the ever-changing market situation, so that they can adopt favorable strategies in the e-commerce price war. Future research can further explore how e-commerce enterprises can avoid the negative impacts of price wars by optimizing their pricing strategies in different market environments and achieve sustainable development.

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