The Prisoner's Dilemma in Price Wars: A Game Analysis Based on Competition in a Duopoly Market

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Abstract. In a duopoly market, price wars between firms often lead to a "prisoner's dilemma" due to non-cooperative game dynamics, creating a conflict between individual and collective rationality. Based on game theory, this paper constructs static and dynamic game models to analyze the strategic choices and equilibrium outcomes of duopolistic firms in price competition. The study finds that under complete-information static games, both firms tend to adopt price-cutting strategies to gain market share, resulting in a Nash equilibrium of "low-price competition." However, this equilibrium deviates from Pareto optimality, leading to mutual profit losses and revealing the prisoner's dilemma nature of price wars. Under an infinitely repeated game framework, firms may overcome short-term profit constraints through trigger strategies or reputation mechanisms, achieving long-term cooperation and mutual benefits. Furthermore, through case studies, the paper explores how market transparency, regulatory policies, and strategic rule design can mitigate this dilemma, proposing feasible approaches such as signaling mechanisms and punishment schemes to foster cooperative competition. This research provides a theoretical foundation for understanding pricing strategies and offers practical insights for optimizing market competition and antitrust policy formulation.

Keywords: Prisoner's dilemma, duopoly competition, price war, nash equilibrium, repeated game.

1. Introduction

A duopoly market, dominated by two major firms, has long been a key subject in economics. The Cournot and Bertrand models systematically analyze firm competition from output and pricing perspectives, respectively, while the Stackelberg model examines the dynamic relationship between leaders and followers. Duopoly competition resembles the "prisoner's dilemma," where firms pursuing self-interest may fall into a non-cooperative equilibrium, harming collective welfare. Building on these theoretical models, this paper investigates competitive strategies in duopoly markets, analyzes the trade-off between cooperation and competition, and discusses the impact of policy intervention and technological innovation on market equilibrium.

In duopoly markets, price wars frequently occur, leading to reduced profits and market instability. Such competitive behavior often exhibits prisoner's dilemma characteristics, where firms prioritizing short-term gains result in a non-cooperative equilibrium, undermining industry-wide sustainability. Game theory, including the Cournot model, Bertrand model, and repeated game theory, provides a crucial theoretical framework for analyzing firm competition [1].

This study enhances the understanding of the prisoner's dilemma in duopoly markets, enriches the application of game theory in firm competition, and contributes to theoretical advancements. Additionally, the findings offer guidance for firms in formulating pricing strategies and establishing cooperative mechanisms, while aiding policymakers in optimizing market regulation to promote healthy and orderly market development.

The research first constructs static and dynamic game models to analyze the strategic choices and equilibrium outcomes of duopolistic firms in price competition. Then, through case studies, it examines firm behavior and its implications under different competitive strategies. Finally, it

proposes solutions to mitigate the prisoner's dilemma, such as optimizing market rules, strengthening cooperation mechanisms, and policy interventions, aiming to foster long-term mutual benefits.

2. Theoretical Models

2.1. Static Game Model

In a market with two firms, A and B, each faces a choice between a high-price (H) or low-price (L) strategy. The payoff matrix is as follows (Table 1), where the numbers 2, 3, 5, and 8 represent the payoffs for Firms A or B, with only high-price or low-price options available.

Table 1. Payoff Matrix

	FirmB: Hign-price (H)	FirmB: Low-price (L)
FirmA: Hign-price (H)	(5, 5)	(2, 8)
FirmA: Low-price (L)	(8, 2)	(3, 3)

From Table 1, when both firms choose high-price strategies, they maximize profits with payoffs (5, 5). If one firm defects to a low-price strategy while the other maintains a high price, the defector gains a higher payoff (8) at the expense of the cooperator (2). When both choose low-price strategies, profits drop to the lowest level (3, 3). In this static game, the Nash equilibrium occurs when both firms select low-price (L) strategies. A Nash equilibrium is defined as a strategy profile where no player can improve their payoff by unilaterally changing their strategy, given the other player's strategy. Thus, in equilibrium, each firm's strategy is the best response to the other's.

2.2. Repeated Game Model: The Logic of Cooperation

In the complex dynamics of market competition, repeated game models provide a dynamic perspective on firm strategy. In infinitely repeated games, firms face high-price or low-price decisions in each round, profoundly influencing cooperative or competitive behavior [2].

The trigger strategy is central to this model. Initially, firms cooperate by setting high prices to establish long-term mutual benefits, as seen in the static game's (5, 5) payoff under cooperation. However, cooperation is conditional: if one firm detects betrayal (i.e., a low-price strategy), it triggers a permanent punitive shift to low prices. While betrayal yields short-term gains (e.g., a payoff of 8 when one defects and the other cooperates), it disrupts cooperation, leading to reduced payoffs (3, 3) when both defect.

The reputation mechanism is equally vital, serving as an invisible bond for cooperation. Firms maintaining cooperative strategies build trust, encouraging cooperation and sustaining high profits. Conversely, betrayal damages reputation, erodes trust, and perpetuates a low-profit competitive cycle.

Cooperation requires strict conditions. The discount factor (δ) measures how much firms value future payoffs—higher δ means greater emphasis on long-term gains, incentivizing cooperation. If δ is low, firms are more likely to betray for short-term benefits. Additionally, cooperation must yield higher long-term cumulative payoffs than short-term betrayals. While sustained cooperation offers stable but modest per-period payoffs (e.g., (5, 5)), its total payoff exceeds the long-term losses from defection-induced price wars. The repeated game model reveals that to maximize long-term profits, firms must balance short- and long-term gains, uphold their reputation, and carefully choose between cooperation and competition [3, 4].

3. Case Study

China Mobile and China Unicom have long competed in the field of tariff packages and service prices, and during this period, the industry has been volatile due to price wars [5]. In the initial stage of the static game, both sides adopt the price reduction strategy to compete for users, thus forming a fierce price competition situation, which leads to the profit margin of both sides being greatly

compressed, and the service quality is also affected to a certain extent, which can be constructed as the price war stage in the static game model [2].

3.1. Model Assumptions

In this game scenario, the participants are China Mobile (Player 1) and China Unicom (Player 2), and the strategy space of both parties covers the price reduction strategy (represented by L) and the maintenance of the original price strategy (represented by H).

3.2. Benefit Matrix

As can be seen from Table 2, there are three scenarios in terms of benefit interpretation. If both parties choose the price reduction strategy, the user growth is limited, and the profit margin is compressed, resulting in a negative total return, specifically (-5, -5); If only one party chooses the price reduction strategy and the other party maintains the original price, the price reduction party can attract the opponent's users with the low price strategy, to achieve an increase in revenue in the short term (up to 10), while the opponent suffers a loss due to user loss (the profit is -10); If both parties choose to maintain the original price strategy, the market share will remain stable and the profit level will be normal, with the specific benefit of (5, 5).

Table 2. Earnings matrix

China Mobile \ China Unicom	Price Reduction(L)	Maintain Original Price (H)
Price Reduction(L)	(-5, -5)	(10, -10)
Maintain Original Price (H)	(-10, 10)	(5, 5)

3.3. Nash Equilibrium Analysis

In the game scenario of price competition, the price reduction strategy (L) is regarded as the optimal choice for each participant, regardless of the strategy chosen by the other party, because from the perspective of returns, the loss of -5 is greater than the loss of -10 (when both parties reduce the price), and the gain of 10 is greater than the gain of 5 (when the price is unilaterally reduced), but this choice leads both parties to fall into an inefficient Nash equilibrium state (L, L), and the corresponding return is (-5, -5), which coincides with the situation of the "prisoner's dilemma". To avoid this vicious competition, the two sides have gradually begun to explore differentiated competition paths, such as optimizing 5G services, improving user experience, etc., and actively responding to national policy guidance to gradually reduce unreasonable price competition.

4. Dynamic Game Model

In the differentiated competition stage of a dynamic game, the model is extended to a long-term competition scenario of an infinite repetitive game, participants need to adjust their strategies and introduce differentiated services (such as 5G quality and user experience) to cope with competition, and at the same time, they need to consider the external factors of national policies restricting vicious price wars (such as stipulating minimum tariffs), and in terms of revenue function correction, it is assumed that differentiated competition needs to invest in fixed costs (C=3), but it can improve user stickiness, and if both parties adopt differentiated strategies (D, D), the long-term benefits will increase. The original income (5, 5) becomes (7, 7); If one party is differentiated, the other party continues to fight the price (D, L), the short-term income of the differentiating party decreases to 4 due to the increase in costs, but the long-term user retention is higher, the short-term income of the price war party is 6, in order to maintain cooperation, the trigger strategy (Grim Trigger Strategy) is introduced, and the two parties commit to differentiated competition (D), if one party defaults and lowers the price (L), the other party will permanently return to the price war (L), the discount factor is δ used to measure the importance of future returns, the greater the δ, the more important the participants pay to the long-term returns, The present value of cooperation income V

cooperation=7+7δ+7δ²+…=7/(1-δ), the present value of default income (one party reduces the price) V default=6+(-5) δ+(-5) δ²+…=(6-5δ)/(1-δ), and the sustainable conditions of cooperation are 7/(1-δ)≥(6-5δ)/(1-δ)⇒δ≥1/2, that is, when the δ≥ is 0.5, the two sides have the incentive to maintain differentiated cooperation, and the impact of the national policy is that after the government intervenes, by setting the lower price limit, the minimum return of the price war (L) is forcibly constrained, so that the price war income is lower than the differentiated income, and at the same time subsidizing differentiated input, reducing the cost of differentiation (C from 3→1), increasing the cooperation income to (8, 8), and setting up a punishment mechanism to fine the vicious price reduction enterprise (income -2), so as to revise the income matrix [4].

5. Conclusion

The static game model shows that enterprises tend to choose low-price strategies in order to compete for market share, forming a Nash equilibrium (L, L), but this equilibrium deviates from the Pareto optimal (H, H), resulting in the joint shrinkage of profits of both parties, such as the vicious price war between China Mobile and China Unicom in the early days, which directly compresses profits to (3, 3) and triggers a decline in service quality. For example, Coca-Cola and PepsiCo achieve long-term cooperation through product differentiation and tacit pricing, the core of which is that when the discount factor is δ high enough, the present value of cooperative returns (e.g., 7/(1-δ)) will exceed the short-term betrayal returns (e.g., 6-5δ/(1-δ)) and promote the equilibrium migration to Pareto improvement. Policy intervention plays a key role in this process, such as China's communications industry through policies such as setting a lower tariff limit and jointly building and sharing 5G base stations, restricting the space for low-price competition, and at the same time reducing differentiated costs with technological innovation subsidies to promote enterprises to turn to service optimization; Enterprises can also take the initiative to reshape the rules of the game through signaling (e.g., open cost structure), differentiated competition (e.g., China Unicom's "smart home" ecosystem), and industry self-regulatory alliances. Future research needs to be extended to the impact of multi-oligopoly markets, incomplete information games, and digital algorithmic pricing to more comprehensively analyze the competitive dynamics. In general, the healthy competition of the duopoly market depends on the synergy of dynamic game cooperation mechanism, precise policy intervention and corporate strategic innovation to achieve a balance between efficiency and fairness.

Authors Contribution

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

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