Game Problem and Nash Equilibrium in the Electronic Payment Market with Multi-agent Participation

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Abstract. The rapid development of e-commerce has greatly promoted the popularization of electronic payment methods in China. The electronic payment service of online banking solves the problem of online transaction payment in the early stage of e-commerce development. After the rise of third-party Internet-guaranteed payment services, the problem of mutual trust in online shopping was solved in a breakthrough way, and the electronic payment service model was continuously innovated, and the electronic payment service scene was rapidly expanded and popularized. In this process, the relationship between third-party payment service providers and online banking has evolved from cooperation to competition, and has been developing in the contradiction between competition and cooperation. At the same time, the third-party payment model has brought great challenges to financial supervision. Based on the respective interests of the main participants in the electronic payment market, this paper applies game theory and its Nash equilibrium theory to analyze the optimal strategy choices of the participating entities in the electronic payment market, and gives their respective development strategies.

1. Introduction

According to the 43rd "Statistical Report on the Development of China's Internet Network" released by China Internet Network Information Center (CNNIC), as of December 2018, the number of online shopping users in China reached 610 million, and the number of mobile online shopping users reached 592 million. The number of payment users reached 600 million, and the number of mobile online payment users has reached 583 million. The mobile Internet application has grown rapidly, the dominant position has been strengthened, and the rapid penetration of mobile payment into the offline payment field has greatly enriched the payment scenario. Netizens have further deepened their habits of using mobile phones to pay and settle online stores in subways, buses, supermarkets, convenience stores, etc., which have fundamentally changed people’s daily habits such as consumption, payment, transfer, and payment. The non-cash society is Accelerate to come.

This paper attempts to analyze the main problems among the participating entities in the electronic payment market by using game theory and its Nash equilibrium theory, starting from the respective interests of the main participants in the electronic payment market.
2. Summary of Electronic Payment Research and Theoretical Basis Related to Game Theory

2.1 Related research on electronic payment

Regarding the research on electronic payment, Helen Colinson (1995) first proposed the concept of electronic wallet, and pointed out that electronic payment with electronic wallet as a tool can become a secure payment method on the Internet[1]. Wendy Ming-Yen Teoh, et al. (2013) revealed that interest, self-efficacy, and ease of use had a significant impact on consumer perceptions of electronic payments[2]. Chinese scholar Zhou Huiling et al. (2010) found that people’s doubts about the security and reputation of electronic payment instruments were the main reasons restricting the development of electronic payment tools[3]. Zhao Zhongxin (2012) believed that in order to promote the smooth development of China’s electronic payment market, it should strengthen the electronic payment model in e-commerce, and continuously strengthen the adjustment and improvement of various misconducts[4]. Deng Yao (2017) pointed out that under the impact of third-party payment, online banking should take advantage of its high credit and irreplaceability, learn from the experience of third-party payment, constantly improve yourself, optimize service processes[5].

Hu Juan (2016) summarized three aspects of competition between third-party payment and online banking. First, third-party payment robbed the bank’s intermediary business and formed a conflict of interest. Second, the convenient and fast third-party payment platform transformed bank customers into Non-bank customers have formed a battle for customer groups. Third, the third-party payment platform recorded huge user behavior big data and formed a data dispute[6]. Yang Yanhui (2017) believes that the development of third-party payment has affected the income of bank intermediary business, and the shortcomings of online banking that do not pay attention to user experience have been amplified[7]. Zheng Huiyin (2017) pointed out that while focusing on regulating third-party payments, it is also necessary to promote new developments in third-party payments. Third-party payment can’t just stay in the payment business. It is good at cooperating with the bank, and can develop a new business transaction platform to achieve a win-win situation in cooperation[8].

2.2 Game Theory and Its Nash Equilibrium Theory

There are multiple decision-making bodies in the activities studied by game theory. These subjects are related to each other. Game theory mainly discusses the strategic interaction between them.

Nash equilibrium was proposed by Nash in 1950 and is the basis of game theory. Nash Equilibrium is a combination of strategies \( s^*=(s_1^*, s_n^*) \), which meets two requirements:

- For each player \( i \in N \), can be expected to adopt a combination of strategies \( s_i^* \);
- For each player \( i \), \( s_i^* \) is his best strategy for coping with \( s_{-i}^* \).

If \( G=< N, S_1, S_2, \ldots, S_n, u_1, u_2, \ldots, u_N > \) is a strategic game model with complete information, the strategy combination \( s^*=(s_1^*, s_n^*) \), \( s_i^* \in S_i, s_{-i}^* \in S_{-i} \) is a Nash equilibrium of \( G \). If for \( \forall i \in N, s_i^* \) is the opponent strategy combination of \( i \) under \( s_{-i} = s_{-i}^* \) conditions, the optimal reflection strategy of the player \( i \) is \( u_i(s_i^*, s_{-i}^*) = \max_{s_i \in S_i} u_i(s_i, s_{-i}^*) \) or \( u_i(s_i^*, s_{-i}^*) \geq u_i(s_i, s_{-i}^*) \), \( \forall s_i \in S_i \), if the inequality pair \( s_i \neq s_i^* \) is strictly established, the \( s_i^* \) is the strict Nash equilibrium of \( G \). Game theory believes that the player with rational choice behavior \( i \) will choose the strategy combination \( s_i^* \) in the Nash equilibrium because he can expect the opponent to choose \( s_{-i}^* \), and \( s_i^* \) is the optimal response to \( s_{-i}^* \). If the player \( i \) chooses \( s_i^* \) and the opponent does not choose \( s_{-i}^* \), it may reduce the opponent's payment. So each participant will choose the strategy combination \( s_i^* \) \((i=1, 2, \ldots, n)\), and the result will show the Nash equilibrium ending \( s^*=(s_1^*, s_n^*) \). Therefore, in the complete information static game, the Nash equilibrium can be used to predict the strategy combination of each participant, and then predict the various game outcomes that the analyst is concerned about.

3. Safe and convenient game analysis of online banking and third party payment

Among them, \( N=\{ \text{Online Banking, Third Party Payment} \} \), the limited policy set of online banking is \( S_1=\{ \alpha_1=\text{Security}, \alpha_2=\text{Convenient} \} \), and the limited policy set of third party payment is
S2=\{\beta_1=\text{Security}, \beta_2=\text{Convenient}\}.

The payment of the person in the game = harvest - pay. Harvest: electronic payment, market share, number of customers, growth rate, profit. Pay: technical costs, service costs.

Thus, the payment matrix is obtained, and the game model is constructed as shown in Table 1.

In order to solve the Nash equilibrium of the above game model, the hypothesis is proposed:

- (1) When the payment of the online bank is \(a_{11}\), and the payment of the third party payment is \(b_{11}\), the thresholds for their use are relatively high. However, due to the high credit level of online banking, its market share and number of customers will be more than third-party payment.
- (2) When the payment of the online bank is \(a_{12}\), and the payment of the third party payment is \(b_{12}\), it improves the user experience in electronic payment on the premise of ensuring certain security. Therefore, third-party payment will gain a larger market share, and a larger number of customers. Comprehensive (1) (2) can be obtained: \(b_{11} < b_{12}\).
- (3) When the payment of the online bank is \(a_{21}\), and the payment of the third party payment is \(b_{21}\), online banking will gain a larger market share and a larger number of customers. Comprehensive (1) (3), because at this time the online bank's original credit is higher than the third party, and also adopts a convenient strategy, so \(a_{21} > a_{11}\).
- (4) When the payment of the online bank is \(a_{22}\), and the payment of the third party payment is \(b_{22}\), both parties are likely to obtain a large number of customers, which may equalize the market share. Comprehensive (3) (4) can be obtained: \(b_{21} < b_{22}\). Comprehensive (2) (4) It can be seen that when online banking adopts a convenient strategy in a third party, it can only obtain more benefits when it adopts a convenient strategy, so it can be known that \(a_{22} > a_{12}\).

| online banking | Third Party Payment |
|----------------|---------------------|
| \(\alpha_1=\text{Security}\) | \(\beta_1=\text{Security}\) |
| \(\alpha_2=\text{Convenient}\) | \(\beta_2=\text{Convenient}\) |

Using the scribing method, the Nash equilibrium of the above-mentioned game model shown in Table 1. Therefore, the Nash equilibrium of this model is \(S^* = \{\alpha_2^*, \beta_2^*\} = \{\text{convenient, convenient}\}\).

### 4. Game Analysis of Competition Cooperation between Online Banking and Third Party Payment

Similarly, build a game model as shown in Table 2. In order to solve the Nash equilibrium of the above game model, the hypothesis is proposed:

- (1) When the payment of the online bank is \(a_{11}\), and the payment of the third party payment is \(b_{11}\). Third-party payment is just to increase the business volume of e-commerce. Online banking has gained passenger traffic and gained a lot of revenue. Therefore, it can be judged that the income obtained by the online bank is greater than the third party payment: \(a_{11} > b_{11}\).
- (2) When the payment of the online bank is \(a_{12}\), and the payment of the third party payment is \(b_{12}\). The competitive advantage of third-party payment comes from the extremely low cost and threshold, which is quickly recognized by consumers, and the rapid increase in consumers using Alipay and bank cards, the gains from third-party payments are greatly increased. Comprehensive (1) (2) are available: \(b_{12} > b_{11}\). Due to the surge in consumers using fast payment, the amount of payment through the bank card has also increased, so it can be judged: \(a_{12} > a_{11}\).
- (3) When the payment of the online bank is \(a_{21}\), and the payment of the third party is \(b_{21}\), that is, Online banking greatly enhances convenience and limits Alipay quotas and increases rates. Third-party payment is only developed to start online banking functions or to conduct business only in areas such as micropayments. Comprehensive (1) (3) can know: online bank payment \(a_{21} > a_{11}\) under this combination of strategies.
• (4) When the payment of the online bank is \( a_{22} \), and the income of the third party payment is \( b_{22} \), third-party payment is more convenient for consumers without improving security, so \( b_{22} < a_{22} \). Comprehensive (2) (4) can be judged: under the strategy of competition by third parties, the convenience of not reducing security is deeply rooted in the hearts of the people, so its customers and capital flow are huge. At this time, the income from the online banking adopting the cooperation strategy is greater than that from the competition strategy, that is, \( a_{12} > a_{22} \). Comprehensive (3) (4) available: payment by third party payment \( b_{22} > b_{21} \).

### Table 2 Nash Equilibrium of the Game Model of Cooperation and Competition between Internet Banking and Third Party Payment.

|                | \( \beta_1 \) = Cooperation | \( \beta_2 \) = Competition |
|----------------|-----------------------------|-----------------------------|
| \( \alpha_1 = \text{Cooperation} \) | \( (a_{11}, b_{11}) \)        | \( (a_{12}, b_{12}) \)        |
| \( \alpha_2 = \text{competition} \) | \( (a_{21}, b_{21}) \)         | \( (a_{22}, b_{22}) \)         |

Using the scribing method, the Nash equilibrium of the above-mentioned game model shown in Table 2. Therefore, the Nash equilibrium of this model is \( S^* = \{\alpha_1, \beta_2\} = \{\text{cooperation, competition}\} \).

5. Game Analysis of Innovation Supervision between Financial Supervision and Third Party Payment

Similarly, build a game model as shown in Table 3. In order to solve the Nash equilibrium of the above game model, the hypothesis is proposed:

• (1) When the financial regulator’s payment is \( a_{11} \), and the third party’s payment is \( b_{11} \), the innovative investment in third-party payments will not be rewarded. It can be judged that: \( b_{11} \) is small (innovative investment, no additional income), and \( a_{11} \) growth is slow.

• (2) When the financial regulator’s payment is \( a_{12} \), and the third party’s payment is \( b_{12} \), such as prohibiting most innovations, third-party payments will tend to be non-innovative. Comprehensive (1) (2) can be judged: \( b_{12} < a_{12} \) (no innovation input, no additional income).

• (3) When the financial regulator’s payment is \( a_{21} \) (such as allowing most innovations), but there are certain restrictions (such as limits) to prevent third-party payment innovations from impacting traditional financial institutions. On the other hand, the third party’s payment is \( b_{21} \), and innovation will continue to bring prosperity to Internet finance, and also bring traffic to traditional financial institutions such as online banking and commercial banks. Therefore, comprehensive (1) (3) can be judged: \( b_{21} < b_{11} \), \( a_{21} > a_{11} \).

• (4) When the financial regulator’s payment is \( a_{22} \) and the third party’s payment is \( b_{22} \), there is a certain regulatory cost, which will not bring financial risks, but the development of electronic payment will become slow. Comprehensive (3) (4) can be judged: \( b_{22} > b_{21} \). Comprehensive (2) (4) can be known: \( a_{12} < a_{22} \).

• (5) When the financial regulator’s payment is \( a_{31} \) (not regulated), and the third party’s payment is \( b_{31} \), innovation will achieve unprecedented prosperity, but may lead to Systemic financial risks arise. Comprehensive (3) (5) can be judged: \( a_{31} < a_{21} \).

• (6) When the financial regulator’s payment is \( a_{32} \) (not regulated), while the third party’s payment is \( b_{32} \), the supervision cost will decrease, and the electronic payment market is orderly, but the development of electronic payment is slow, which is not conducive to social development. Comprehensive (5) (6) can be judged: \( b_{32} > b_{31} \). Comprehensive (4) (6) can be known: \( a_{32} > a_{22} \).

### Table 3 Nash Equilibrium of the Game Model of Innovation and Supervision by Third-Party Payment and Financial Supervisors.

|                | \( \beta_1 \) = innovative | \( \beta_2 \) = No innovation |
|----------------|-----------------------------|-----------------------------|
| \( \alpha_1 = \text{strict supervision} \) | \( (a_{11}, b_{11}) \)        | \( (a_{12}, b_{12}) \)        |
| \( \alpha_2 = \text{moderate supervision} \) | \( (a_{21}, b_{21}) \)         | \( (a_{22}, b_{22}) \)         |
| \( \alpha_3 = \text{loose supervision} \) | \( (a_{31}, b_{31}) \)         | \( (a_{32}, b_{32}) \)         |
Using the scribing method, the Nash equilibrium of the above-mentioned game model shown in Table 3. That is, the Nash equilibrium of this model is \( S=\{\alpha_2, \beta_1\} = \{ \text{moderate regulation, innovation} \} \).

6. conclusion

With the conclusion of the integrated security and convenience game model and the competition and cooperation game model, Online banking should choose a convenient and cooperative development strategy, that is, to simplify and optimize the operation process as much as possible while maintaining its own security advantages. On the other hand, online banking should continue to cooperate with third-party electronic payment service providers to strengthen big data analysis, achieve complementary advantages, and achieve win-win cooperation.

Based on the conclusions of the three models, the optimal strategy for third-party electronic payment service providers is continuous and convenient strategies, competitive strategies and innovative strategies. That is to say, third-party electronic payment companies continue to innovate on the premise of ensuring security to bring more convenient and perfect payment experience to users. In addition, when dealing with the bank, third-party electronic payment companies should maintain a certain cooperative relationship with online banking, while maintaining a competitive attitude and maintaining competitiveness in the electronic payment market through continuous innovation.

From the conclusions of the innovation and supervision model, it is concluded that the optimal strategy of financial regulators is moderate supervision, and it is very important to grasp the supervision. Moderate regulation, that is, financial regulators should allow for compliance innovations that encourage third-party electronic payment service providers. For example, when supervising Alipay, WeChat payment and other third-party payment service providers that are already in the world's leading level, they should be given a moderately loose regulatory policy and regulatory recognition. In order to maintain the leading and promoting of the leading enterprises in the electronic payment market innovation.

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