Physica A 432 (2015) 9–15

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

A research on service quality decision-making of Chinese communications industry based on quantum game

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HIGHLIGHTS

- We obtain a superior solution than the classic game.
- The optimal service quality decreases in entanglement operator.
- The optimal customer perceived utility increases in entanglement operator.

ARTICLE INFO

Article history:
Received 8 May 2014
Received in revised form 8 December 2014
Available online 18 March 2015

Keywords:
Service quality
Quantum game
Nash equilibrium
Quantum entanglement
Customer perceived utility

ABSTRACT

In recent years, Chinese service industry is developing rapidly. Compared with developed countries, service quality should be the bottleneck for Chinese service industry. On the background of three major telecommunications service providers in China, the functions of customer perceived utilities are established. With the goal of consumer's perceived utility maximization, the classic Nash equilibrium solution and quantum equilibrium solution are obtained. Then a numerical example is studied and the changing trend of service quality and customer perceived utility is further analyzed by the influence of the entanglement operator. Finally, it is proved that quantum game solution is better than Nash equilibrium solution.

1. Introduction

1.1. Service quality decision-making

In recent years, Chinese service industry has developed very quickly. In Chinese communications industry, the mobile phone users have reached 116.96 million and will reach 1.22911 billion at the end of this year in which 401.61 million will be 4G mobile phone users. Telephone penetration rate reached 110.5 cell phones per hundred persons. These specific data are released from Chinese national bureau of statistics and the national economic and social development statistical bulletin in 2013. Hence, communication service industry will occupy more and more important position in national economy.

A number of information science researchers manifest that service quality is an important variable and affects the successful operation of service enterprise [1–8]. The foreign scholars have attached great importance to service quality and have studied service quality for a long time. Zeithaml et al. successively published two articles to explain the famous SERVQUAL scale about the service quality in 1985 and 1988 [9]. Although the SERVQUAL scale is controversial, it is still widely used in measuring service quality [10,11]. In recent years, service quality is still a hot issue among the researches of some scholars [6,7]. A modified version of the SERVQUAL scale was assessed to determine how effectively it measures service

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http://dx.doi.org/10.1016/j.physa.2015.03.011
0378-4371/

quality in the field of the information service industry [12]. It is shown that service-level quality is a non-monotone function of the inaccuracy rate and service-level quality goes up to an IRI level and subsequently declines, through the invention and establishment of the (Q, R) model [13]. Sandmann establishes a model of perceived service quality including customer satisfaction and the impact of fairness to study the service quality in queues [7]. Zehendner et al. propose a mixed integer linear programming model to effectively handle capacity in the service quality of inland transport modes [8]. In the logistics service supply chain (LSSC), service quality supervision and coordination are the important variables to decide whether the firms can attract more customers. Liu et al. assume service quality with the exponential distribution and establish an objective integral function [14]. Li et al. apply game theory to optimize service quality under different market structures [15].

There are few literatures on service quality decision in supply chain. The existed works generally can better measure the service quality with the SERVQUAL scale or its modified version. The recent literatures establish some objective functions by using the mixed integer linear programming model, the exponential distribution or integral model under various market structures. Most researches are based on the classical probability theory in service supply chain. However, quantum mechanics has a bigger probability space than the classical probability theory. Hence, we can apply quantum game to obtain the optimal solutions.

1.2. Quantum game

Quantum game is the combination of quantum information theory and game theory [16–20]. Today quantum information theory has increasingly become a hot topic in academic area [21,22]. Compared with the classical probability theory, quantum information theory can quickly permeate many other fields and produce a new interdiscipline. Meyer studies the strategies using quantum game and the results show the great power of quantum game than classical game theory [23]. Then Eisert et al. apply quantum game strategies into the prisoner's dilemma model and use the quantum entanglement to eliminate the dilemma [24]. Since then, quantum game theory attracts more attention of many scholars and obtains a lot of new research achievements. Some questions applying quantum game theory can obtain a better optimal solution than classical equilibrium solution, such as Battle of Sexes game [25–27], duopoly model [28–32], noisy quantum games [33] and other interesting aspects [34,35].

Because quantum mechanics has bigger strategy space than the classical probability theory, quantum game can often achieve a better solution. For example, in light of double slit diffraction experiment:

$$|\psi|^2 = |ab\psi(1) + b\psi(2)|^2 = |a\psi(1)|^2 + |b\psi(2)|^2 + a^*b\psi(1)^*\psi(2) + ab^*\psi(1)\psi(2)^*, \tag{1}$$

where a^*, b^* are the conjugate complex of a, b. $\psi(1)^*$, $\psi(2)^*$ are the dual vector of $\psi(1)$, $\psi(2)$. The probability of quantum superposition state is not only equal to the sum of the probability which through the up joint $|a\psi(1)|^2$ and the down joint $|b\psi(2)|^2$, but it also needs to add the probability of the interference term, namely, $a^*b\psi(1)^*\psi(2) + ab^*\psi(1)\psi(2)^*$. Through this experiment, the differences between quantum game theory and classical probability theory can be shown explicitly.

The above analysis shows that quantum game is only applied in simple game models, such as Battle of Sexes game, and duopoly model. Hence, we intend to introduce quantum game into service supply chain field for the first time. At the same time, service quality and quantum both have the characteristics of superposition and entanglement, which will affect the optimal solution studied by the previous scholars. To sum up, the research on the service quality decision-making based on quantum game is feasible, reasonable, creative and scientific.

The content of the paper is as follows. Section 2 introduces problem description and assumptions, including some basic model. Section 3 establishes the objective function models on service quality and consumer's actual perceived utility. To maximize the consumer's actual perceived utility, quantum equilibrium and Nash equilibrium are applied. Then the two results are simply analyzed and compared. In Section 4, a numerical simulation experiment based on the actual data is studied to evaluate the superiority of the solution by quantum game. Afterwards the changing trend of the optimal solution on entanglement operator is analyzed. Section 5 concludes the paper.

2. Problem description and assumptions

The paper assumes that the three companies in the market have the monopoly right for their products. The three major telecommunications service providers are China Mobile, China Unicom and China Telecom in China. Simultaneously, they provide the same service products, such as 4G network communications services. For convenience, j is used to represent the different firms, $j = 1, 2, 3$.

The average of service quality in the market is

$$\overline{q} = \frac{1}{n}\sum q_j. \tag{2}$$

In order to facilitate the research of service quality, the models assume that service quality can be standardized by certain method, such as SERVOUAL scale which was mentioned above. When the telecommunications service providers intend to set up a level of service quality, they just need to choose certain standardization of service quality. q_j denotes the quality service of the participant or firm j.