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Game theory analysis on credit risk assessment in E-commerce

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ABSTRACT

With the development of network technology and social economy, e-commerce has been widely utilized around the world, while the E-commerce credit has become one of the most important issues. The credit risk in E-commerce is not only the result of game between different sellers, but also the result between online traders and managers. From the perspective of different sellers with same products or services, this paper analyzes and discusses the formation of credit risk in E-commerce based on the game theory, and presents some suggestions for future application of E-commerce credit. In order to reduce the loss caused by E-commerce credit risk, the government should play a macro-control role or participate in the game process as a participant to influence the game result. The government can guide enterprises' game activities through legal and economic levers such as legislation, taxation, to make the results approached to the Pareto optimal solution, and the utility of the entire society will be increased.

Introduction

As the rapid development of E-commerce, on-line trading has been the main way of consumer shopping. In the process of online shopping, merchant credit is one of the main factors in consumers' decision-making. As information asymmetry in EC transactions and many illegal and irregular act such as brushing bills and false evaluation, dishonesty in E-commerce is not uncommon. E-commerce credit has become one of the serious problems to restrict development of E-commerce.

Credit is the trust which allows one party to provide money or resources to another party where that second party does not reimburse the first party immediately (thereby generating a debt), but instead promises either to repay or return those resources (or other materials of equal value) at later date [1]In other words, credit is a method of making reciprocity formal, legally enforceable, and extensible to a large group of unrelated people [2]. Credit risk refers to the risk of default on a debt that may arise from a borrower falling to make required payments [3].

Different models have been proposed by researchers around the world to access and analyze problems related to credit risk. The most popular models can be classified into category: credit scoring models (such as Fair Isaac) [4-6], options-theoretic structural models (such as KMV and Moody's RiskCalc) [7-10] and reduced-form models (such as Credit Risk Plus) [11-14]. A credit scoring method is a risk assessment method of evaluating a loan applicant's financial health by predicting her likelihood of default based on statistics. It employs mathematical models to rank order instances based on data that is combined into a single number that tries to assess risk or credit history. The application of the theory of planned conduct is an adaptation of the concept of behavioral intention, in

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which the appropriate perception occurs spontaneously and the behavioral intention determines intent. The apparent social expectations to conduct or not execute the conduct is referred to as the perceived usefulness [18]. The types of credit risk assessment are when the gap between investment interest rates in addition to risk-free return rates fluctuates, there is credit spread risk, the risk of a company's risk rating being downgraded, and failure to make contractual payments creates default risk of the borrower. These models allow lenders and regulators to develop techniques that rely on portfolio aggregation to measure retail credit risk exposure. Portfolios as well as saving programmed that have been combined into one are called aggregate portfolios. In order to determine performance besides asset allocation, the system combines entire transactions from the underlying portfolios.

Yilmaz [15] has classified credit risk models into three groups: traditional methods, modern methods and credit portfolio risk measurement models. Traditional models include credit risk measurement by appraisal method and artificial neural networks, credit scoring models and credit scoring models with financial data. Modern methods include Merton-Based models, historical default rate approach model and risk-adjusted return on capital (RAROC) model. Credit portfolio risk measurement models include credit metrics, credit risk plus, Moody's KMV, credit portfolio view and credit risk portfolio theory. A debt analysis model that is utilized to determine the credit risk of a company's debt is said to be Merton model. Analysts as well as investors utilize the Merton model to determine a company's ability to satisfy service debt, financial commitments, then assess the likelihood that it would default on its debt. Because default probability as well as migration probabilities are not independent of the economic cycle, credit portfolio view was developed. There is a need to update the 'unconditional' migration matrix to take into account current economic conditions besides business cycle. Due to the fact that the 'unconditional' migration matrix reflects the fact that default probability is lower during boom times, then vice versa, during recessions default probabilities as well as downward migration probabilities are lower than the longer-term average. Based on Moody's KMV model, a simple method for explicitly calculating a firm's credit limit is created. As a result, it is possible to take into consideration factors such as loan maturity date, a balance sheet structure, quality of assets then the needed default likelihood.

Credit scoring models have been widely used by financial institutions to determine if loan customers belong to either a good applicant group or a bad applicant group. The advantages of using credit scoring models can be described as the benefit from reducing the cost of credit analysis enabling faster credit decision, ensuring credit collections, and diminishing possible risk. In order to obtain a satisfied credit scoring model, numerous methods have been proposed. These methods can be classified to parametric statistical methods (e.g. discriminant analysis and logistic regression), non-parametric statistical methods (e.g. k nearest neighbor and decision trees), and soft-computing approaches (e.g. artificial neural network (ANN) and rough sets). While the training information is stored, the model does not learn anything from it until it is time to make a real time forecast. Compared to other algorithms that need training, such as SVM besides linear regression, KNN is significantly quicker. An effort to replicate the network of neurons that comprise the human brain in order for the computer to learn in addition to make choices in a humanlike way is said to be artificial neural network (ANN). It is developed through programming ordinary computers to act like linked brain cells. ANNs are the most popular tool used for credit scoring and has been reported that its accuracy is superior to that of traditional statistical methods in dealing with credit scoring problems, especially in regards to nonlinear patterns. Risk-adjusted return on capital (RAROC) is a modified return on investment figure that takes elements of risk into account [16,17,20,21,23]. Kim et al. [24] developed a theoretical framework describing the trust-based decision-making process a consumer uses and test the proposed model using a Structural Equation Modeling technique on Internet consumer purchasing behavior data collected via a Web survey. Jia et al. [27] analyzes the factors that affects consumers' acceptance of e-commerce consumer credit service by considering situation in China.

From the angle of economics, this paper studied the external mechanism of e-commerce credit risk formation, and analyzes the influence of different parts of the transaction in e-commerce and the resulting mechanism of virtual market credit risk. This Credit Risk Analysis provides a complete introduction of fundamental ideas and approaches for comprehending credit quality drivers, modelling methods for creditworthiness assessment, and contemporary practice guidelines in management of credit risk methods. Along with credit structure and profitability, risk management is among the three main hazards that all banks must disclose and keep reserve against [19]. Because of the uncertainty of credit status in e-commerce, that is, the extent to trade subjects complied with the market contract is uncertain, this will lead to the loss of the trade subjects. Compared to traditional trading mode, the characteristics of electronic transaction such as inter-region, virtualization and asymmetric information make e-commerce credit risk more difficult and complex to identify, evaluate and control. Consumers and related stakeholders in e-commerce have the characteristics of limited rationality and pursuit of maximum benefit. The type of credit models selected by these stakeholders in e-commerce transactions and the effect of the selected credit models on virtual market both are important source of e-commerce credit risk and the external mechanism of e-commerce credit risk formation. With the growing rise of e-commerce, nevertheless, the issue of credit risk is becoming increasingly noticeable. Credit risk in e-commerce is a complicated structure involving technological, market, managerial, cultural, trade, and human variables, according to the study, which also found that credit risk in e-commerce possesses incredibly features such as self-stability and self-optimization [22]. Which kind of credit models are selected by related stakeholders in e-commerce transaction are affected by many factors, including not only their own credit ethics and credit concepts, but also external factors especially the decision of related stakeholders (such as e-commerce enterprises, online consumers and the government). In essence, it is the game result of relevant stakeholders. The formation of e-commerce credit risk is the result of mutual game between multiple participants. E-commerce credit quality arose as a result of credit issues, and it is a key impediment to the growth of e-commerce. Asymmetric information is a major impediment to every trade, and mutual understanding is an effective method to handle this issue; however, mutual respect is the foundation of good credit between individuals. As a result, in its purest form, e-commerce is a lending market [25]. It includes not only buyers and sellers, but also online traders, managers and third-party platforms. The trustworthiness of online traders depends on the trade-off between the default cost and possible benefits coming after it; managers balance the cost and benefits of supervision when they determine whether or not to supervise online traders and also the supervision over them.

2. Game model for analysis

Game situation refers to the set of parameters that may affect game result, such as competitor, information and market. Due to the complex economic environment in reality, e-commerce enterprises themselves are also varied. One among the requirements of more than one individual must be taken into account is said to be a complex economic environment. At the time of two individuals share a home but have different requirements, they may essential to develop separate care plans. An enterprise ecommerce technology is a promising solution that caters to a large company's complex needs. Enterprise-level systems are tailored to your company's size and expansion plans. A strong infrastructure must be able to satisfy your current needs as well as expand to address expected sales levels. For the convenient of analysis, the following assumptions are introduced for seller's game situation in e-commerce:

(1) There is only one product in the virtual market, and the product can only be provided by just two e-business enterprises.
(2) The two e-business enterprises are both rational economic people and pursue the maximization profits.
(3) The virtual market is still in its early stage of development, and the level of online consumption is extremely low.

**In the process of making strategic decision, the participants do not consider the impact of their decisions on other people. Effective leadership requires the ability to make strategic decisions. The stated term has a tremendous influence on employees, customers, the market as well as eventually the accomplishment of a firm at the time of a leader makes decisions. The 5 characteristics are significant to define the problem, collect information before developing else evaluating possible solutions. Execute as well as monitor your decision after you have chosen the best course of action. Find the appropriate path to victory is the goal of strategy formulation. Making strategic decisions will assist you in formulating a course of action and aligning your short-term objectives with the larger picture. Strategic decision-making differs from day-to-day decisions from the point of view of administration.

(1) The information of both sides in the market is complete, that is, both sides have an accurate understanding of their characteristics, payment function and strategic space.
(2) Under the same credit mode or trading strategy, both sides have the same product price, unit cost and random cost variable. Price gouging, day playing, impulse trade, trading strategies, and position trading are the five basic trading strategies available to technical traders.
(3) The transaction decision of both sides can be abstracted in two cases: integrity (providing quality products or actual products consistent with description) and fraud (providing inferior products or actual products and description). The two sides are asymmetric in information and independent in the whole decision-making process. Before making any decisions, they do not know each other's strategies. The game between the two sides is static game. By looking at the link between the e-retailer and the platforms from a macro perspective. That's an assessment for individuals; it has significant statistically significant results to aid both parties' decision-making processes. The method to solving games given stable, full information is using Nash equilibrium to determine feasible solutions. Backward inference is indeed the resolution notion in dynamical conflicts with comprehensive information, as it excludes non-credible accusations as feasible strategy for participants.
(4) Demands of the whole virtual market for the product are limited and fixed, and demands of products under different credit modes are not the same with each other.

Based on the above assumptions, considering profit of two sides is ϕ, price of the product is p, sales volume is q, unit cost is c, random cost viable is V, and the probability of random cost increase is λ. Then the profit model can be written as

$$\phi = p \times q - c \times q - \lambda \times V \tag{1}$$

For the sake of convenience, the following description uses 1 to represent one enterprise A, and 2 to represent another enterprise B. From hypothesis (6), we have

$$p_{1h} = p_{2h} = p_h \tag{2}$$

$$p_{1c} = p_{2c} = p_c \tag{3}$$

$$V_{1c} = V_{2c} = V_c \tag{4}$$

$$V_{1h} = V_{2h} = V_h \tag{5}$$

where p_{1h}, p_{2h}, p_{1c}, p_{2c}, represent price of products under model of integrity and fraudulent. p_h, p_c are price under mode of honesty and fraud. V_{1h}, V_{2h}, V_{1c}, V_{2c} are increase of random cost under mode of honesty and fraud, the increment of the random cost under fraudulent mode are mainly from the legal action caused by fraud, administrative penalty and the loss of reputation, etc. This means places like soliciting money or gratuities, mishandling confidential information, improprieties, and fraudulent bidding. Fraud is a problem that can affect any company, regardless of size, business, or location. Fraud may be undertaken in high-profile scams if the organization contains expensive property.

Generally,

$$p_h \geq \ p_c \tag{6}$$

Introducing hypothesis (7) and (8),

$$q_{1h} + q_{2h} = q_h \tag{7}$$

$$q_{1c} + q_{2c} = q_c \tag{8}$$

$$q_h < q_{1h} + q_{2c} < q_c \tag{9}$$

$$q_h < q_{1c} + q_{2h} < q_c \tag{10}$$

In this way, the game model for selection of credit modes in two e-commerce enterprises' can be established and we can obtain Table 1. where $\Phi(1\text{h}, 2\text{h})$ and$\Phi(2\text{h}, 1\text{h})$ are profits of enterprise 1 and 2 when integrity models are selected by two sides, and $\Phi(1\text{h}, 2\text{c})$, $\Phi(2\text{c}, 1\text{h}), \Phi(1\text{c}, 2\text{h}), \Phi(2\text{h}, 1\text{c}), \Phi\ (1\text{c}, 2\text{c})$ and $\Phi\,(2\text{c}, 1\text{c})$ have the similar explanation.

To ensure that information objects in a system remain legitimate when they move from one system state towards another, an integrity policy specifies how they should be handled. According to the model, principals deployed in the system have certain powers. it also lays out certification besides enforcement criteria. Analytical fraud detection relies on identifying probable predictors of fraud linked with well-known criminals in addition to their prior behavior. All of the most sophisticated fraud models (as well as most powerful consumer response models) are based on the foundation of historical information.

3. Analysis of game model

The following analysis are based on the introducing the profit function. The profit function of an e-commerce distribution network is computed by taking the price level and estimated maximum volume under specific portfolio as decision-making factors, and the predicted value of random pricing variables as the establishing total sales.

$$\Phi(\text{h}) > \Phi(\text{c}) \tag{11}$$

which can be expanded as follows:

$$\begin{aligned} &\Phi(1\text{h}, 2\text{h}) > \Phi(1\text{c}, 2\text{h}) \\ &\Phi(1\text{h}, 2\text{c}) > \Phi(1\text{c}, 2\text{c}) \\ &\Phi(2\text{h}, 1\text{h}) > \Phi(2\text{c}, 1\text{h}) \\ &\Phi(2\text{h}, 1\text{c}) > \Phi(2\text{c}, 1\text{c}) \end{aligned}$$

Substituting Eq. (1) into Eq. (11) and we have

$$(p_h - \text{c}) \times q_h - (p_c - \text{c}) \times q_c > \lambda_h \times V_h - \lambda_c \times V_c \tag{12}$$

where λ_h and λ_c are the increment probability of random cost under integrity and fraud models.

In probability theory, a Nash Equilibrium is a set of management practices, in each participant in a multiplayer group, where switching schemes has no advantage for just about any participant. In this case, all of the game's players are pleased with the selections at the very same time, and the situation looks balanced [26]. In this situation, game has the only Nash equilibrium (Integrity, Integrity), which is the result of cooperate game, it not only increases the profits of e-commerce enterprises, but also increases performance of whole society and improves the welfare of whole society.

$$\Phi(\text{h}) < \Phi(\text{c}) \tag{13}$$

which can also be expanded as follows:

$$\begin{aligned} &\Phi(1\text{h}, 2\text{h}) > \Phi(1\text{c}, 2\text{h}) \\ &\Phi(1\text{h}, 2\text{c}) > \Phi(1\text{c}, 2\text{c}) \\ &\Phi(2\text{h}, 1\text{h}) > \Phi(2\text{c}, 1\text{h}) \\ &\Phi(2\text{h}, 1\text{c}) > \Phi(2\text{c}, 1\text{c}) \end{aligned}$$

Substituting Eq. (1) into Eq. (13) and we have

$$(p_h - \text{c}) \times q_h - (p_c - \text{c}) \times q_c < \lambda_h \times V_h - \lambda_c \times V_c \tag{14}$$

Table 1
Profits of two enterprises with two different models.

Enterprise2 Enterprise1	Integrity model	Fraud model
Integrity model	$\Phi(1\text{h}, 2\text{h}), \Phi(2\text{h}, 1\text{h})$	$\Phi(1\text{h}, 2\text{c}), \Phi(2\text{c}, 1\text{h})$
Fraud model	$\Phi(1\text{c}, 2\text{h}), \Phi(2\text{h}, 1\text{c})$	$\Phi(1\text{c}, 2\text{c}), \Phi(2\text{c}, 1\text{c})$

In this situation, the best game strategy of both enterprises is the fraudulent credit model. So there is only one Nash equilibrium (Fraud, Fraud) can be chosen. A game theory idea which states that the best result of a game is where there is no incentive to stray from their original analysis is said to be Nash equilibrium. Individuals can get no additional benefit from modifying their actions if the other participants' tactics stay unchanged. To illustrate why two rational persons might not collaborate, even when it appears to be in their best interests to do so, game theory utilizes the prisoner's dilemma as an example. In the absence of any means of communication, every prisoner is kept in solitary confinement without any contact from the other. In the prisoner's dilemma, two parties who are separated as well as unable to communicate must decide whether else not to cooperate with each other. It is up to every bank robber whether else not to collaborate with his accomplice besides kept silent, else to defect from the gang and testify against his gangmates. In this case, two enterprises are trapped in the "prisoner's dilemma", which reduces the welfare and benefit of whole society.

(1) $\Phi(\mathrm{h})$ and $\Phi(\mathrm{c})$ are unknown functions.

There are 14 cases in total, which can be classified to 4 situations in Table 2.

For situation ①, the solutions are (integrity, integrity) or (fraud, fraud), (integrity, integrity) is Pareto's optimal solution; under solution (fraud, fraud), the utility of the whole society is the worst, we don't consider this situation. Parametrically ideal outcomes are those that cannot be dominated through other outcomes. For instance, if a pareto outcome has been chosen, it is obvious that no alternative result will be better for entire participants than pareto. A way to compare economic outcomes, pareto efficiency can help. A pareto improvement is a policy else activity that improves the lives of at least one person without harming anybody else.

For situation ②, the solution is depended on composition structures of consumers, we don't consider this situation neither.

Thus, the situations ③ and ④ are analyzed as following, we will take one case in each situation as an example.

Situation ③:

$$\Phi(1\mathrm{h},2\mathrm{h}) > \Phi(1\mathrm{c},2\mathrm{h})(15.1)\Phi(1\mathrm{h},2\mathrm{c}) < \Phi(1\mathrm{c},2\mathrm{c}) \tag{15.2}$$

$$\Phi(2\mathrm{h},1\mathrm{h}) < \Phi(2\mathrm{c},1\mathrm{h}) \tag{15.3}$$

$$\Phi(2\mathrm{h},1\mathrm{c}) > \Phi(2\mathrm{c},1\mathrm{c}) \tag{15.4}$$

First, assuming enterprise 1 makes decision and chooses integrity model, we have

$$\Phi(2\mathrm{h},1\mathrm{h}) < \Phi(2\mathrm{c},1\mathrm{h}) \tag{16}$$

which means the profit of fraud model is greater than that of integrity mode for enterprise 2, so the optimal decision for enterprise 2 is fraud, then, we have

$$\Phi(1\mathrm{h},2\mathrm{c}) < \Phi(1\mathrm{c},2\mathrm{c}) \tag{17}$$

which means the profit under fraud model is greater than that under integrity model for enterprise 1, so the optimal decision for enterprise 1 is also fraud model. In this circumstance, the decision goes back to its initial point.

Then, if enterprise 1 makes decision first and chooses fraud model instead, we have

$$\Phi(2\mathrm{h},1\mathrm{c}) > \Phi(2\mathrm{c},1\mathrm{c}) \tag{18}$$

which means profit of integrity model is greater than that of fraud model for enterprise 2, so the optimal decision for enterprise 2 will be integrity. Then, for enterprise 1, we have

$$\Phi(1\mathrm{h},2\mathrm{h}) > \Phi(1\mathrm{c},2\mathrm{h}) \tag{19}$$

which means profit of integrity model is greater than that of fraud mode for enterprise 1, so the optimal decision for enterprise 1 is also integrity model, the decision also goes back to original decision point.

The decision tree can be expressed as in Fig. 1:

It can be seen from Fig. 1 that there is no pure Nash equilibrium in the game, which can be classified to mixed strategy decision problem with complete information. Assuming the model has an optimal mixing strategy, we can solve the Nash equilibrium for the mixed strategic decision model.

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Table 2
Solution for different situation.

Situation	Solution
①	(integrity, integrity) or (fraud, fraud) . (Two enterprises have same credit model)
②	(integrity, fraud) or (fraud, integrity). (Two enterprises have different credit model. Both credit models are determined and independent)
③	Credit models for two enterprises are uncertain and interactive.
④	Two enterprises have different credit model. The credit model for one enterprise is determined, and the other enterprise's credit model is on this premise

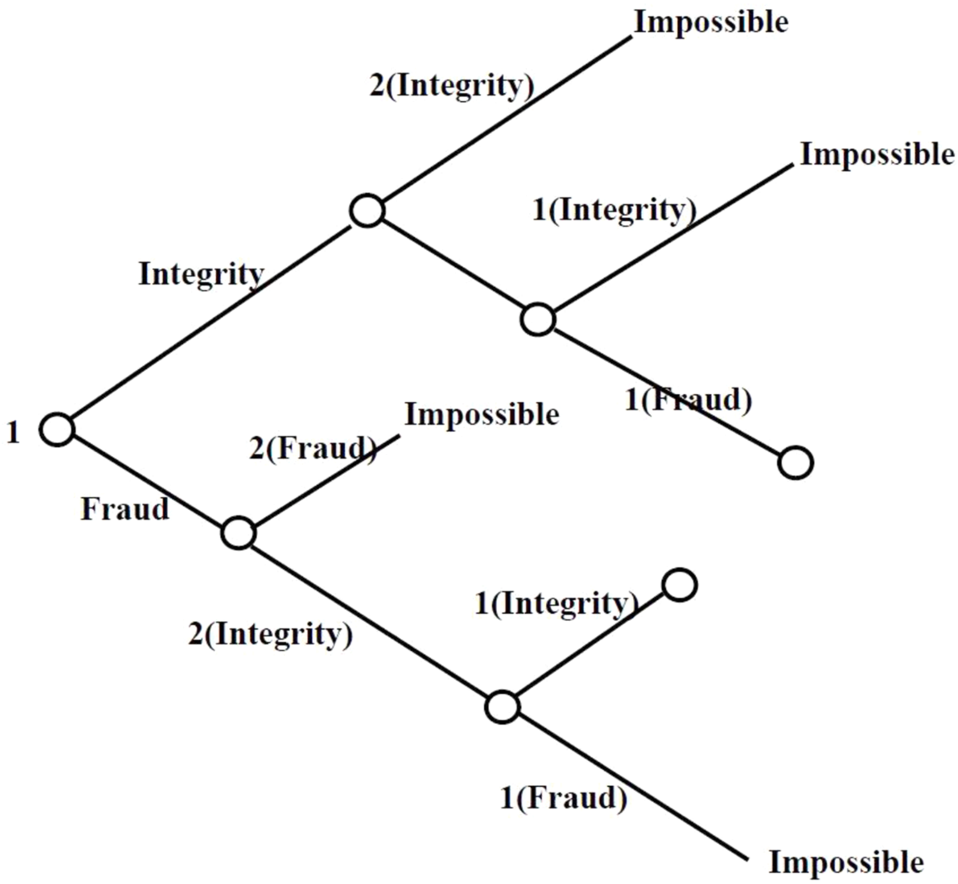

Fig. 1. Decision tree for situation ③.

tampered with in any manner by an unauthorized person is referred to as the authenticity paradigm. From the previous assumptions, α_1, α_2 are the probabilities of enterprise 1 and enterprise 2 choosing integrity model, then the mixed strategy for enterprise 1 is (α_1, 1-α_1) , which means the integrity model will be selected with the probability α_1 and the probability of fraud is (1-α_1). The mixed strategy for enterprise 2 is (α_2, 1-α_2), which means the integrity model will be selected with the probability of α_2 and the probability of fraud is (1-α_2).

Assuming u_1 and u_2 are the expected utility functions for enterprise 1 and enterprise 2, then

$$u_1 = \alpha_1 \times [\alpha_2 \times \phi(1h, 2h) + (1-\alpha_2) \times \phi(1h, 2c)] + (1-\alpha_1) \times [\alpha_2 \times \phi(1c, 2h) + (1-\alpha_2) \times \phi(1c, 2c)] \tag{20.1}$$

$$u_2 = \alpha_2 \times [\alpha_1 \times \phi(2h, 1h) + (1-\alpha_1) \times \phi(2h, 1c)] + (1-\alpha_2) \times [\alpha_1 \times \phi(2c, 1h) + (1-\alpha_1) \times \phi(2c, 1c)] \tag{20.2}$$

An idealized human who behaves rationally in addition with complete information in order to maximize personal value else satisfaction is termed as rational economic man. Many economic theories assume the presence of an economic man. According to the assumptions of rational economic man, both enterprises will pursue the maximization of utility. Then we have

The first derivative of α_1 in u_1 is zero, that is

$$\frac{\partial u_1}{\partial \alpha_1} = 0 \tag{21.1}$$

The first derivative of α_2 in u_2 is zero, that is

$$\frac{\partial u_2}{\partial \alpha_2} = 0 \tag{21.2}$$

By solving and simplifying Eqs. (21), we can get the optimization first order condition of mode selection for enterprise 1:

$$\alpha_2^* = \frac{\Phi(1c, 2c) - \Phi(1h, 2c)}{\Phi(1h, 2h) - \Phi(1h, 2c) - \Phi(1c, 2h) + \Phi(1c, 2c)} \tag{22.1}$$

$$\alpha_1^* = \frac{\Phi(2c,1c) - \Phi(2h,c)}{\Phi(2h,1h) - \Phi(2h,1c) - \Phi(2c,1h) + \Phi(2c,1c)} \tag{22.2}$$

When the strategy for enterprise 2 is given as(α_2, 1-α_2), the reaction functions of enterprise 1 are showed in Table 3:

The Table 3 shows that A will choose fraud model if $\alpha_2 < \alpha_2^*$ and A will choose integrity model if $\alpha_2 > \alpha_2^*$. In other words, if enterprise 1 found that the proportion of enterprises selecting integrity model is more than α_2^*, then enterprise 1 will probably choose integrity model.

When the strategy for enterprise 1 is given as(α_2, 1-α_2), the reaction functions of enterprise 2 are showed in Table 4.

Table 4 also shows that enterprise 2 will choose fraud model if $\alpha_1 < \alpha_1^*$ and enterprise 2 will choose integrity model if $\alpha_1 > \alpha_1^*$. If enterprise 2 found that the proportion of enterprises selecting integrity model is more than α_1^*, then enterprise 2 will probably choose integrity model, which means, in the case of equilibrium, enterprise 1 will choose integrity model with probability α_2^* , and choose fraud model with probability $(1-\alpha_2^*)$, enterprise 2 will choose integrity model with probability α_1^*, and choose fraud model with probability $(1-\alpha_1^*)$.

Situation ④ :

$$\Phi(1h,2h) > \Phi(1c,2h) \tag{23.1}$$

$$\Phi(1h,2c) > \Phi(1c,2c) \tag{23.2}$$

$$\Phi(2h,1h) < \Phi(2c,1h) \tag{23.3}$$

$$\Phi(2h,1c) > \Phi(2c,1c) \tag{23.4}$$

From Eqs. (23), it can be seen that no matter what credit models were chosen by enterprise 2, the profit under integrity model for enterprise 1 is greater than that under fraud model, so the optimal decision for enterprise 1 is integrity model. In this situation, the profit under fraud model for enterprise 2 is higher than that under integrity model, so the optimal decision for enterprise 2 will be fraud model. The decision tree can be expressed as in Fig. 2.

It can be seen from Fig. 2 that the solution of this game model will be (Integrity, Fraud), and this solution is unstable since Pareto optimization is not achieved. With the development of economy and technology, enterprise 2 will gradually adjust its strategy and choose integrity model by realizing that it will obtain profits under integrity model through constantly studying and learning. Therefore, with the change of game situation and external conditions, the solution (Integrity, Fraud) will gradually come close to Pareto's optimal solution (Integrity, Integrity). The Pareto optimum solution is one where the no target can be improved without deteriorating at minimum each other's. When no result can be Pareto controlled by it, it would seem to be Pareto optimal. To be more explicit about selecting a Pareto outcome, it is self-evident that no alternative outcome will prove to be superior for all stakeholders.

4. Conclusions

The problem of credit risk of e-commence is discussed by using the game theory in this paper. Game theory is an enthralling topic. It is used in a variety of educational disciplines, including as economics and finance. The goal of probability theory is to resolve issues and control risks. The connection between probability theory, strategic thinking, and financial reporting is examined in this paper. To identify any potential that a firm can convert a hazard into a possibility, game theory is integrated with risk assessment concept. For large amounts of data, behavioural economics is simply another lens through which to examine the problem-solving procedure. Through the above analysis, we can get following conclusions:

(1) In order to avoid utility reduction of whole society caused by enterprises only considering short-term benefits, the government should play the macro-control role to influence game result, or the government can participate in the game process as a participant.
(2) From Eq. (1), under integrity model, profit ϕ can be increased by more quantity q and less random cost increase and less probability. As to increase output, the quality standard of online products can be set up to improve entry threshold of online product, and output can also be increased by price subsidies to credit enterprises to improve their marginal profit ratio. The increase in random cost and the probability can be reduced by tax incentives and some favorable government policies.

Table 3
Reaction function of enterprise 1.

α_1	Conditions
0	$\alpha_2 < \frac{\Phi(1c,2c) - \Phi(1h,2c)}{\Phi(1h,2h) - \Phi(1h,2c) - \Phi(1c,2h) + \Phi(1c,2c)}$
[0, 1]	$\alpha_2 = \frac{\Phi(1c,2c) - \Phi(1h,2c)}{\Phi(1h,2h) - \Phi(1h,2c) - \Phi(1c,2h) + \Phi(1c,2c)}$
1	$\alpha_2 > \frac{\Phi(1c,2c) - \Phi(1h,2c)}{\Phi(1h,2h) - \Phi(1h,2c) - \Phi(1c,2h) + \Phi(1c,2c)}$

Table 4
Reaction function of enterprise 2.

α_2	Conditions
0	$\alpha_1 < \frac{\Phi(2c,1c)-\Phi(2h,c)}{\Phi(2h,1h)-\Phi(2h,1c)-\Phi(2c,1h)+\Phi(2c,1c)}$
[0, 1]	$\alpha_1 = \frac{\Phi(2c,1c)-\Phi(2h,c)}{\Phi(2h,1h)-\Phi(2h,1c)-\Phi(2c,1h)+\Phi(2c,1c)}$
1	$\alpha_1 > \frac{\Phi(2c,1c)-\Phi(2h,c)}{\Phi(2h,1h)-\Phi(2h,1c)-\Phi(2c,1h)+\Phi(2c,1c)}$

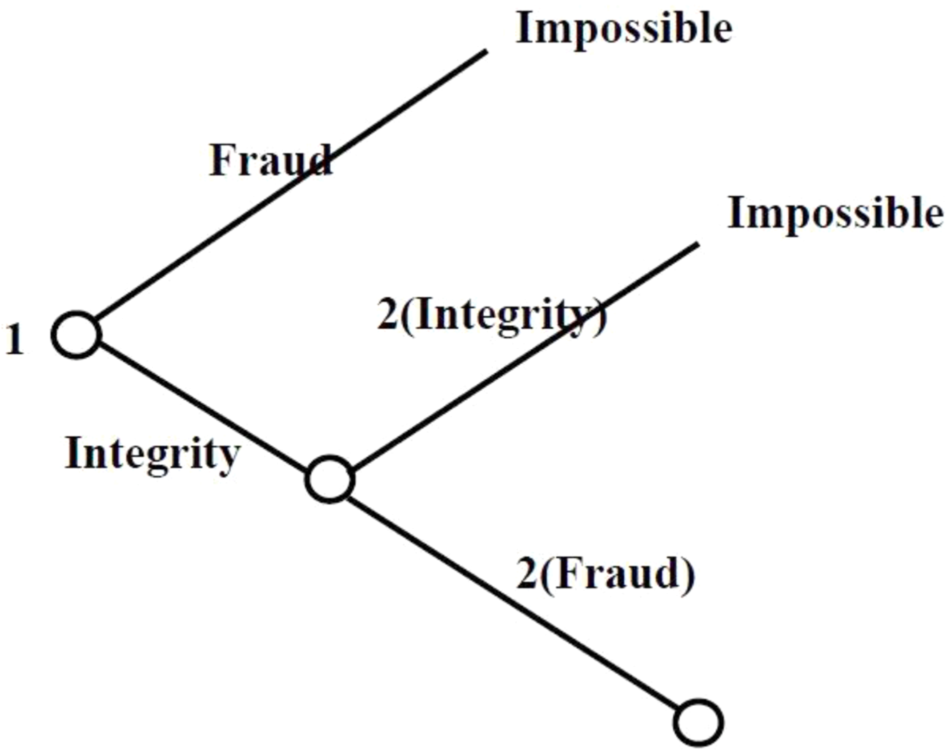

Fig. 2. Decision tree for situation ④.

(3) Under fraudulent model, profit ϕ can be decreased by lower quantity q and more $\lambda \times$ V, for example, strengthening management of virtual market, improving fraud exposure probability and the punishment to fraudulent enterprises.

CRediT authorship contribution statement

Zhang Nana: Conceptualization, Methodology, Writing – original draft. **Wei Xiujian:** Visualization, Investigation, Writing – review & editing. **Zhang Zhongqiu:** Software, Validation, Data curation, Methodology.

References

[1] Credit (def. 2c), Merriam Webster Online, 2015.
[2] Simkovic, M. (2016). What can we learn from credit markets?. In *Proceedings of the 93rd Annual Meeting of the American Law Institute*.
[3] Principles for the Management of Credit Risk-final document. (2000). *Basel Committee on Banking Supervision.* BIS.
[4] Avery, R. B., Raphael, W. B., Paul, S. C., & Glenn, B. C. (1996). Credit risk, credit scoring and the performance of home mortgages. *Federal Reserve Bulletin, 82*, 621–648.
[5] Fair, I. (1997). Low to moderate income and high minority area case studies, Fair, Isaac and Company, Inc. Discussion Paper (October 4, 1996). *Federal Reserve Bulletin,* A68.
[6] Hansell, S. (1995). Need a Loan? Ask the Computer: ‘Credit Scoring’ Changes Small-Business Lending. *New York Times*.
[7] Falkenstein, E. G., Boral, A., & Carty, L. V. (2000). Risk calc for Private Companies: Moody's Default Model. *Global Credit Research*. May.
[8] D. Dwyer, K. Ahmet and S. Roger, The Moody's KMV Risk Calc v3.1 Model: Next Generation Technology for Predicting Private Firm Credit Risk. Moody's KMV, 2004.
[9] Crosbie, P. J., & Bohn, R. (2003). *Modeling Default Risk*. San Francisco: Moody's KMV.
[10] Lohmann, C., & Ohliger, T. (2019). Using Accounting-based Information on Young Firms to Predict Bankruptcy. *Journal of Forecasting, 38*(8), 803–819.
[11] Stephen, Z., Kwame, O. D., Ilan, A., & Bersant, H. (2018). Credit Risk Research: Review and Agenda. *Emerging Markets Finance and Trade, 54*(4), 811–835.

[12] Robert, A. J., & Philip, P. (2015). Structural versus Reduced-Form Models: A New Information-Based Perspective. *the Credit Market Handbook*, 118–131.
[13] Molins, J., & Vives, E. (2016). Model risk on credit risk. *Risk and Decision Analysis, 6*(1), 65–78.
[14] Bakshi, G., Madan, D. B., & Zhang, F. (2001). *Recovery in Default Risk Modeling: Theoretical Foundations and Empirical Applications*. Washington, DC, USA: Division of Research & Statistics and Monetary Affairs, Federal Reserve Board.
[15] Yılmaz, Songül (2011). *Ticari Bankalarda Kredi Portföyü ve Kredi Riski Yönetimi – Bankacılık Sektöründe Bir Uygulama, Yayınlanmamış Yüksek Lisans Tezi*. Kadir Has Üniversitesi SBE.
[16] Asarnow, E., & Marker, J. (1995). Historical performance of the U.S. corporate loan market: 1988-1993. *The Journal of Commercial Lending, 10*(2), 13–32.
[17] E.I. Altman, B. Brady, A. Resti and A. Sironi, The link between default and recovery rates (September 2003). NYU Working Paper No. S-CDM-04-07, Available at SSRN: https://ssrn.com/abstract=1295760.
[18] Tarazona, G. M., Pelayo, B. C., Sanjua;n, O., & Rodriguez, L. A. (2014). E-Commerce Metamodel Based on MDA. *IEEE Latin America Transactions, 12*(4), 699–705. https://doi.org/10.1109/tla.2014.6868872
[19] Kumar, G., Saha, R., Buchanan, W. J., Geetha, G., Thomas, R., Rai, M. K., & Alazab, M. (2020). Decentralized accessibility of e-commerce products through blockchain technology. *Sustainable Cities and Society, 62*, Article 102361. https://doi.org/10.1016/j.scs.2020.102361
[20] Anja, G., & Frank, R. (2001). Performance-Based compensation in banks: The Use of RAROC and Related Measures. *Homo Oeconomicus, Institute of Socio Economics, 17*, 489–513.
[21] Bannier, C. E., Bofinger, Y., & Rock, B. (2021). Corporate social responsibility and credit risk. *Finance Research Letters*. , Article 102052. https://doi.org/10.1016/j.frl.2021.102052
[22] Zong, K., Yuan, Y., Montenegro-Marin, C. E., & Kadry, S. N. (2021). Or-Based Intelligent Decision Support System for E-Commerce. *Journal of Theoretical and Applied Electronic Commerce Research, 16*(4), 1150–1164. https://doi.org/10.3390/jtaer16040065
[23] Bhattachary, M., Inekwe, J. N., & Valenzuela, M. R. (2020). Credit risk and financial integration: An application of network analysis. *International Review of Financial Analysis, 72*, Article 101588.
[24] Kim, D. J., Ferrin, D. L., & Rao, H. R. (2008). A trust-based consumer decision-making model in electronic commerce: The role of trust, perceived risk, and their antecedents. *Decision Support Systems, 44*(2), 544–564.
[25] Kaur, Kuljeet, et al. (2015). A Novel Resource Reservation Scheme for Mobile PHEVs in V2G Environment Using Game Theoretical Approach. *IEEE Transactions on Vehicular Technology, 64*(12), 5653–5666. https://doi.org/10.1109/tvt.2015.2482462
[26] Parimala, M., Priya, R. M., Reddy, M. P., Chowdhary, C. L., Poluru, R. K., & Khan, S. (2020). Spatiotemporal-based sentiment analysis on tweets for risk assessment of event using deep learning approach. *Software: Practice and Experience, 51*(3), 550–570. https://doi.org/10.1002/spe.2851
[27] Jia, L., Xue, G., & Xu, L.j. (2018). Factors affecting consumers' acceptance of e-commerce consumer credit service. *International Journal of Information Management, 40*, 103–110.