



Analysis of the Development Model of Commercial Bank Supply Chain Finance Based on Blockchain Technology

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Abstract. The problem of information asymmetry in the process of crowdfunding restrains the development and growth of product-based crowdfunding under the background of digital economy. Considering that blockchain technology can effectively alleviate the problem of information asymmetry, in this paper, we conducted an innovative modeling and application analysis on the crowdfunding platform's use of blockchain technology to restructure the product crowdfunding business. Specifically, by establishing a crowdfunding data sharing-access model based on alliance chain technology, this paper explores the impact of blockchain technology on the behavior of multiple crowdfunding participants and the balanced financing contract setting by analyzing the game equilibrium of the optimal contract setting of both parties from the perspective of the impact of changing the range of information access on the behavior of participants.

Keywords: reward-based crowdfunding; block-chain; information asymmetry; imitation behavior

1 Introduction

With the gradual revelation of the decentralized features of blockchain, researchers and practitioners are increasingly interested in blockchain research. Blockchain technology enables application participants to conditionally access historical information and securely store it, ensuring evidence preservation and traceability^[1-2]. From a technical perspective, the accessibility of public records of historical transactions enables members of blockchain networks to verify the correctness of database updates during the consensus process^[3]. Through auditing historical data, participants can evaluate the accuracy of transactional data and ascertain whether interacting parties hold legitimate ownership of the transaction objects^[4-5].

The study aims to examine how changes in information accessibility alter the behavioral patterns of key stakeholders (firms and financial institutions) and subsequently influence the equilibrium dynamics of corporate financing markets. By analyzing these

interactions, this research contributes theoretical insights into blockchain-enabled financial systems and provides practical guidance for stakeholders in banking and finance sectors considering technological adoption.

In order to study the behavioral changes brought by different information system configurations (i.e., whether to use blockchain technology) to both parties involved in corporate financing, we build a two-period game model to analyze the game between banks and financing enterprises in the process of corporate financing. Incomplete information exists in the game process. The game process entails banks determining the financing rate for each period, based on their perception of enterprises within the market. Financing enterprises select the degree of effort required to secure bank financing, with such effort yielding a negative utility.

2 The Model

2.1 Research Subject and Problem Definition

Participants: This paper focuses on a two-player game model involving banks and enterprises. The enterprises, which lack initial financing funds, can secure these by borrowing from banks. In return, the banks charge a certain percentage of fees, which serve as their loan benefit.

Participant Behavior: In traditional models, which do not utilize blockchain technology, banks are constrained to charging a uniform rate to financing enterprises based on their average performance. However, in the blockchain model, the implementation of blockchain technology enables banks to categorize enterprises according to their financing performance in preceding periods. Consequently, banks can ascertain the type of financing enterprise and adjust the financing rate accordingly. From the perspective of financing enterprises, the baseline model allows them access to only a fraction of historical project financing information. Conversely, in the blockchain model, enterprises have the opportunity to access the blockchain, enabling less reputable enterprises to potentially mimic the behaviors of more reputable ones to secure a more favorable financing rate in the subsequent phase.

2.2 Analysis of the Types and Behaviors of Financing Enterprises

In the context of bank loan financing, we postulate the existence of two distinct types of enterprises: H and L . Enterprises categorized as type H exhibit superior comprehensive strength, whereas those classified as type L display a weaker comprehensive strength. In this context, the market share of H -type enterprises is denoted as α , while that of L -type enterprises is $1-\alpha$.

The variable α adheres to a uniform distribution within the interval $(0,1)$, symbolically represented as $\alpha \sim U(0,1)$. Assuming that the initial capital of the enterprise at the beginning of each financing stage is 0, and its financing capital demand is 1, if the

financing of each stage is successful, the amount of financing that the enterprise can obtain is R ($R > 1$).

If the financing fails, the return of each enterprise is 0. Regardless of whether the financing activity is successful, the enterprise needs to pay the participation fee of the blockchain at each stage, and the rate is related to the type of enterprise and determined by the bank. For H and L -type enterprises, the likelihood of financing success is $p_i \in (0, 1)$ ($i \in \{H, L\}$), where p represents a monotonically non-decreasing correlation with the degree of effort exerted by the enterprise. Concurrently, there exists a cost linked to the efforts made by the enterprise. In line with preceding research, we employ a quadratic function, denoted as $C_i(p_i) = c_i p_i^2$, to characterize the cost associated with the firm's exertion. In this chapter, the primary distinction between H -type and L -type enterprises lies in the degree of effort realization. Specifically, H -type enterprises exhibit greater skill than L -type enterprises.

This difference is particularly evident in two situations: (i) When production costs are equivalent, the quality level of firm H 's products is superior, denoted as $p_H > p_L$ when $c_H(p_H) = c_L(p_L)$.

(ii) Given identical product quality levels, the production cost incurred by H -type firms is less than that of L -type firms, specifically when $p_H = p_L$, $c_H(p_H) < c_L(p_L)$.

Bank strategy analysis. Prior to initiating each corporate financing project, the bank establishes a financing rate for the company's financing, which serves as its return on investment. Concurrently, the bank incurs a fixed cost F due to factors such as platform construction ($R > F > 1$). Banks must enter into a contract with the financing enterprise prior to initiating each financing activity, stipulating the financing rate. Contrary to traditional financing models where the financing rate remains a constant and is not subject to variation, the blockchain-based financing model offers a distinct advantage. It enables banks, as initiators of the consortium chain, to access information pertaining to the financing enterprises.

Consequently, this facilitates the implementation of differentiated rates by the banks, contingent on the type of enterprise, thereby optimizing potential returns. At the commencement of each period, the bank and the firm enter into a contract for the stipulated interest rate, with the decision variable being the rate r . At the commencement of period 1, the bank possesses no historical data regarding the firms and consequently charges a uniform rate, $r_{(H,L),1}$, for both H -type and L -type firms. After the completion of the initial stage, the bank is able to assess the performance of all enterprises participating in this stage.

Furthermore, it can gather data pertaining to the degree of effort exerted by these enterprises. This information enables the bank to update the categorization of enterprises based on the outcomes observed during the first stage^[6]. In the absence of blockchain technology, the information that each bank possesses about an enterprise remains

incomplete. Consequently, banks can only update the average probability of the enterprise for each type. That is, when a bank has prior information θ about the enterprise type, they use it to conduct a Bayesian belief update on the enterprise's type in the second stage, based on the project financing situation in the first stage. This process yields the posterior probability, which informs their decision regarding the second-stage rate. When blockchain technology is employed, each bank within the blockchain has the ability to access a company's comprehensive historical financing data. This implies that banks can thoroughly understand all the company's financing information thanks to blockchain technology.

Consequently, from the second phase onwards, banks are equipped with the knowledge of the company's full historical data, enabling them to categorize the company (either H or L) and accordingly set the interest rate, $r_{H,2}, r_{L,2}$, for the company's second phase of financing, based on its designation.

3 Equilibrium Analysis

3.1 Decision Objective and Equilibrium Rules

According to the above two subsections, the expected utility function of corporate decision-making $E[\Pi_i]$, $i \in \{H, L\}$ and the expected profit function of banks $E[\Pi_p]$ can be illustrated as the following equations.

$$E[\Pi_i] = \underbrace{p_{i,1}(R - r_1) - C_i(p_{i,1})}_{\text{First stage expectation}} + \underbrace{p_{i,1}(R - E[r_2]) - C_i(p_{i,2})}_{\text{Second stage expectation}}, \quad i \in \{H, L\}.$$

$$E[\Pi_{p,t}^T] = \alpha p_H r_{j,t} + (1 - \alpha) p_L r_{j,t} - f, \quad j \in \{H, L\}, \quad t \in \{1, 2\}.$$

$$E[\Pi_{p,t}^B] = \alpha p_H r_{j,t} + (1 - \alpha) p_L r_{j,t} - f, \quad j \in \{H, L\}, \quad t \in \{1, 2\}.$$

3.2 The Rules of the Game Equilibrium

(1) Given the average success rates p_H, p_L of projects for H -type and L -type enterprises, the bank maximizes its expected profit by setting the rates for the first and second stages.

(2) Given the effort levels of the other firms, each firm chooses its effort level to maximize its expected payoff.

3.3 Bank Equilibrium Analysis

In accordance with the regulations governing the equilibrium of a game between banks and enterprises, banks, given the average success rates p_H and p_L of H -type and L -type

enterprise projects as exogenous variables, endeavor to maximize their anticipated profits. This is achieved by strategically setting the rates in the first and second stages.

In the blockchain technology-based model, during the second stage, banks are able to access blockchain data to ascertain the type information of enterprises, based on their financing performance in the first stage. Consequently, they can establish enterprise type-related rates (denoted as $r_{H,2}$ and $r_{L,2}$) for different enterprise types (H, L). Thus, the objective function of the bank in the second stage can be expressed by the following formula $E[\Pi_{p,2}^B] = \alpha(p_H r_{H,2} - f) + (1 - \alpha)(p_L r_{L,2} - f)$.

Based on the equilibrium condition, the optimal rate for H and L enterprises in the second stage can be formulated as:

$$r_{H,2}^* = \begin{cases} \frac{f}{p_H}, & \text{if } p_H \geq \frac{f}{R}, \\ \infty, & \text{if } p_H < \frac{f}{R}. \end{cases}$$

$$r_{L,2}^* = \begin{cases} \frac{f}{p_L}, & \text{if } p_L \geq \frac{f}{R}, \\ \infty, & \text{if } p_L < \frac{f}{R}. \end{cases}$$

The meaning of ∞ in the formula is that the bank and the enterprise do not sign a contract, that is, the game equilibrium does not exist.

During the initial stage, all financing enterprises enter the market. Given the absence of historical data, banks must rely solely on prior information to determine the financing rates. Considering that the ratio of H-type enterprises is denoted as θ , and their success rate is p_H , while the ratio of L-type enterprises is $1 - \theta$ with a success rate of p_L , the objective function of the bank in the initial stage can be formulated as:

$$E[\Pi_{p,1}^B] = (\alpha p_H + (1 - \alpha) p_L) r_1 - f.$$

The optimal financing rate for the initial stage can be articulated, in accordance with the bank linear equilibrium condition, as follows:

$$r_1 = \begin{cases} \frac{f}{\alpha p_H + (1-\alpha)p_L}, & \text{if } \alpha p_H + (1-\alpha)p_L \geq \frac{f}{R}, \\ \infty, & \text{if } \alpha p_H + (1-\alpha)p_L < \frac{f}{R}. \end{cases}$$

In accordance with the equilibrium principle, each firm determines its effort levels at two financing stages, $p_{i,1}, p_{i,2}$, with the aim of maximizing its anticipated payoffs, given the effort levels of other firms. According to formula (5.3), the objective function of the financing enterprise decision-making is:

$$E[\Pi_i] = \underbrace{p_{i,1}(R - r_1^*) - c_i p_{i,1}^2}_{\text{First stage expectation}} + \underbrace{p_{i,2}(R - r_{i,2}^*) - c_i p_{i,2}^2}_{\text{Second stage expectation}}, \quad i \in \{H, L\}.$$

In the equation, $\Delta R = r_2(F) - r_2(S)$ denotes the preferential treatment accorded to the second-stage financing rate in light of the successful completion of the initial stage. As per the first-order optimality conditions, the optimal effort level of the enterprise can be articulated through the subsequent equation:

$$p_{i,1}^* = \frac{R - r_1^*}{2c_i}, \quad p_{i,2}^* = \frac{R - r_{i,2}^*}{2c_i}.$$

Theorem 1: The effort level of H-type firms in equilibrium is higher than that of L-type firms, that is, $p_{H,t}^* > p_{L,t}^*, \forall t \in \{1, 2\}$. The effort level of H-type firms in the second stage is higher than that in the first stage, while the effort level of L-type firms in the second stage is lower than that in the first stage, i.e., $p_{H,2}^* \geq p_{H,1}^*, p_{L,2}^* \leq p_{L,1}^*$.

Financing Enterprise Imitation Behavior and Equilibrium Analysis. As established in the preceding chapter, our model demonstrates that within a blockchain-based framework, every enterprise can secure authorization. This is achieved by initially submitting a data access request to enterprises that have finalized their financing, subsequently gaining access to the project details of these financed enterprises within the consortium blockchain database. Therefore, in the first phase, enterprises might emulate another enterprise type to obscure their true classification, aiming to secure more favorable terms in the subsequent phase. In this chapter, the term $-i$ represents the antithesis of the enterprise type i -type ($i \in \{H, L\}$). This means that while the true nature of a particular enterprise is type i , its exertion level in the initial phase is $p_{-i,1}$. This

discrepancy misleads the platform at the commencement of the second stage, causing it to incorrectly classify the enterprise as i -type and assign it an equilibrium rate of $r_{-i,2}^*$. Thus, for i , $i \in \{H, L\}$ firms, its two-stage expected utility function can be represented by

$$E[\Pi_i^I] = \underbrace{p_{-i,1}(R - r_1^*) - c_i p_{-i,1}^2}_{\text{First stage expected utility}} + \underbrace{p_{i,2}(R - r_{-i,2}^*) - c_i p_{i,2}^2}_{\text{Second stage expected utility}}.$$

The formula delineates the utility of the imitation behavior exhibited by enterprise i . Specifically, it suggests that by accessing the blockchain model, enterprise i can scrutinize the informational outputs of two distinct types of enterprises. Consequently, this observation enables enterprise i to strategically select an optimal effort level, denoted as $p_{-i,1}$, during the initial stage.

This calculated move is anticipated to yield a financing rate, $r_{-i,2}^*$, in the subsequent second stage. However, if the imitative behavior does not result in the anticipated increase in utility for enterprise i , it will not opt to imitate another type of enterprise in the initial phase. Thus, assuming it chooses to imitate, this subsection first computes the utility derived from its imitation, and subsequently compares it with non-imitation behavior to assess the impact of its imitative actions.

By utilizing optimality conditions to solve the formula, one can determine the equilibrium solution $p_{i,2}^{I*}$, which represents the optimal financing rate for type i enterprises in the second stage. This occurs after the selection of imitation behavior in the first stage, as illustrated in the subsequent equation.

$$p_{i,2}^{I*} = \frac{R - r_{-i,2}^*}{2c_i}.$$

Upon comparing the equilibrium under standard conditions with that in which imitation behavior is present, we can derive the following theorem.

Theorem 2: Compared to the absence of imitation behavior, the optimal effort level of H-type enterprises in the second stage with imitation behavior is reduced, that is, $p_{H,2}^{I*} < p_{H,2}^*$. In the L-type enterprise imitating behavior, the optimal effort in the

second stage increases, that is, $p_{L,2}^{I*} > p_{L,2}^*$.

Theorem 2 presents the impact of the imitation behavior of H/L type enterprises on their second-stage effort level, analyzed from the perspective of expected profit. The imitation behavior of H type enterprises in the first stage, that is, choosing the optimal effort level value of L type enterprises, causes them to suffer a utility loss in the first

stage, as they do not choose the optimal value. At the same time, their first-stage imitation behavior leads the enterprise to misjudge itself as an L type enterprise, charging a higher rate in the second stage, thus causing it to suffer a utility loss in the second stage. Therefore, for the H-type enterprise, it has no motivation to imitate the L-type enterprise in the first stage. On the contrary, although the L-type enterprise suffers a utility loss in the first stage by imitating the H-type enterprise, the optimal rate it obtains in the second stage results in an increase in utility.

4 Summary

This paper employs blockchain technology in the context of bank loan financing, scrutinizing alterations in the information acquisition scope for both banks and financing parties resultant from its utilization. By means of modeling and analysis, it theoretically infers the influence of blockchain on the optimal contract between banks and financing enterprises.

Reference

1. Zheng, Z., Xie, S., Dai, H., Chen, X. and Wang, H. June. An overview of blockchain technology: Architecture, consensus, and future trends. In *2017 IEEE international congress on big data*, 2017: 557-564.
2. Gadekallu, T. R., Huynh-The, T., Wang, W., Yenduri, G., Ranaweera, P., Pham, Q. V., ... & Liyanage, M., 2022, "Blockchain for the metaverse: A review", arXiv preprint arXiv:2203.09738.
3. Sharma, V., Kero, A., Sharma, H. C., & Semwal, P. A study on security of Iot: problems solving using MI and block chain[J]. *Journal of Pharmaceutical Negative Results*, 2023: 1311-1323.
4. Catalini, C., & J. S. Gans, 2016, "Some simple economics of the blockchain", National Bureau of Economic Research, Working Paper 22952.
5. Gualandris, J., Longoni, A., Luzzini, D. and Pagell, M. The association between supply chain structure and transparency: A large-scale empirical study[J]. *Journal of Operations Management*, 2021, 67(7): 803-827.
6. Yuan, Y. and Wang, F. Development status and prospect of blockchain technology[J]. *Acta Automatica Sinica*, 2016, 42(4): 481-494.

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