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Research on the tracing system of technological achievements transformation based on blockchain technology

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Abstract

Low transformation rate of Sci. & Tech achievements and high transaction costs are key issues that urgently need to be solved in the field of Sci. & Tech management in our country. Based on this, this article designs the information storage chain for the full life cycle of Sci. & Tech achievements based on blockchain technology, and realizes the open and transparent, tamper-free, data-sharing and traceability of the research and development, evaluation and transformed information, and reduces the cost of information searching, transaction decision-making and price negotiation, as well as the supervision cost of both parties during the transformation trading, secondary research and development and transformation benefits.

Keywords: Transformation of Sci. & Tech Achievements; Blockchain; Transaction Costs-benefit

1. Introduction

Technological innovation and achievement transformation have emerged as crucial grasp for creating an industrial innovation ecology and overcoming external demand hindrance [1], which made rapid recovery and expansion of the modern economy and society possible. Universities are agglomerations for innovation resources and are crucial to the process of independent innovation and critical technologies to overcome obstacles [2]. However, the transformation of Sci. & Tech achievements in our country is primarily driven by scientific research, and the majority of the model is "emphasis on scientific research, despise transformation", which makes the proportion of patent transfer in universities is quite low [3]. Our nation has gradually completed the transfer of achievements' ownership, the right to disposal and income distribution in recent years [4]. The traditional institutional barriers impeding the transformation have also been dismantled, thus scientific research and industrial development are becoming more closely aligned.

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The exploration of application scenarios of blockchain technology continues to expand, such as supply chain management [5], food safety [6], logistics management [7], power systems [8], electronic health record systems [9], etc. The phenomena of opaque information and high costs on the trading market for the Sci. & Tech achievements limits the transformation of those. The aforementioned issues can be resolved by blockchain technology.

2. Analysis of transaction cost of Sci. & Tech achievements transformation

The process by which patented technology and knowledge application across various industrial subjects and further added to is known as the transformation of Sci. & Tech achievements. The transition from the application of abstract knowledge to general commodities inevitably involves transaction behavior and incurs transaction costs. Each participant of the ecological chain believes that the cost can be offset by additional benefits within the tolerance range under the guidance of value co-creation concept. However, in the extensive market transaction process, some factors, such as supply-demand information asymmetry, price mechanism failure, institutional constraints, patent diffusion risk, and market uncertainty, raise the transaction costs. The likelihood of the outcomes being shelved will exists.

2.1. Cost-benefit analysis of intermediary model

Whether the basis of transaction cost depends on people's behavioral will can be divided into exogenous transaction cost C_0 and endogenous transaction cost C_1. Here we consider the four costs that have the greatest influence on exogenous transaction costs: search cost C_{01}, negotiation cost C_{02}, decision cost C_{03} and supervision cost C_{04}. It is assumed that in the market for the transformation of Sci. & Tech achievements, the provider is also the price recipient, the achievement price P and the market demand q are exogenous variables, and the retention value of the achievements by the supply and demand parties is k and t, which does not change with the market structure.

The intermediary agency shall separately deduct the intermediary service fee $u_1, u_2 (u_1, u_2 > 0)$ to both parties of the transaction. The operating cost of the intermediary itself is C_M, and the participation efficiency is $\theta (0 < \theta < 1)$.

The transaction cost of the provider is:

$$C_T = \theta m_1 \left(\sum_{i=1}^{4} \alpha_i C_{0i} + C_1 \right) + u_1 \tag{1}$$

where $\partial_i (0 < \partial_i < 1)$ is the elasticity coefficient of each cost, and its value depends on the efforts made by the deliverable provider to reduce each transaction cost. m_1 is the cost factor of the provider.

The transaction cost of the demand side is:

$$C_X = \theta m_2 \left(\sum_{i=1}^{4} \beta_i C_{0i} + C_1 \right) + u_2 \tag{2}$$

where $\beta_i (0 < \beta_i < 1)$ is the elastic coefficient of each cost, which is the same with ∂_i. m_2 is the cost coefficient of the demand side. At this point, the provider's net income is:

$$W = P - t - C_T + W' \tag{3}$$

in which $W' = k - C_X - P$ is the increment of added value obtained after the transaction, such as feedback on the application, reputation, etc., that is the income of the demand side.

The following is determined based on the provider's net income $W_2 \geqslant 0$:

$$\sum_{i=1}^{4} \alpha_i C_{0i} + C_1 \leqslant C_B \leqslant \frac{P - t - u_1 + W'}{m_1 \theta} = C_1 \tag{4}$$

The following is determined based on the demander's profit $W_2' \geqslant 0$:

$$\sum_{i=1}^{4} \beta_i C_{0i} + C_1 \leqslant C_B \leqslant \frac{k - u_2 - P}{m_2 \theta} = C_2 \tag{5}$$

Therefore, the transaction cost range of the transformation mode with intermediaries is $C_B \leqslant \min\{C_1, C_2\}$.

The provider's payoff increment is $L = H + C + L'$, in which H is the revenue increment after unit achievement transformation. C is the cost reduction relative to direct transformation; L' is the increment of added value obtained by the provider. The more the cost increment of the provider for technology accumulation, product function development, technology upgrading, etc., the greater L' is.

The demanders' profit increment is $U = U(C) - U'$, in which $U(C)$ is the profit generated after achievements are put into use, which is measured by the value increment brought by the cost increment C of the provider; U' is the cost increment on the demand side.

2.2. Income distribution analysis of joint innovation center model

Based on the principle of "investment risk sharing and income sharing", the supply and demand sides of Sci. & Tech achievements can achieve long-term cooperation by jointly constructing laboratories, research centers, or forging alliances between upstream and downstream members of the industrial chain, which will significantly lower transaction costs. Now, each subject needs to consider the amount of investment (I), the risk coefficient (γ), the gains (R), the proportion of profit distribution (φ) and the contribution coefficient (j).

The total cost of colleges and universities is:

$$C_x = C_{x0} + C_{x1} + \lambda_1 (v_1 e_1)^2 \tag{6}$$

where C_{x0} is the productive cost; C_{x1} is the fixed cost of scientific research; v_1 is the R&D cost coefficient; e_1 is the additional input quantity; λ_1 is the coefficient of additional input.

The total cost of the enterprise is:

$$C_q = C_{q0} + C_{q1} + \lambda_2 (v_2 e_2)^2 \tag{7}$$

where C_{q0} is the production and operation cost of the enterprise; C_{q1} is the fixed cost of R&D invested by the enterprise; v_2 is the R&D cost coefficient; e_2 is the additional input quantity; λ_2 is the extra input factor.

The total revenue R from cooperation is:

$$R = \lambda_3 [j_1 E(e_1) + j_2 E(e_2)]^2 + [j_1 E(e_1) + j_2 E(e_2)] + R_0 + \delta \tag{8}$$

where λ_3 is the value input coefficient; j_1, j_2 are contribution coefficients; $E(e_1), E(e_2)$ are the value of the additional input of both schools and enterprises after transformation; R_0 is a constant; δ is the external comprehensive coefficient that affects the output of cooperative R&D between the university and the enterprise.

The net income of the university is:

$$R_x = \gamma_x (\varphi_x R - C_x) - I_x \tag{9}$$

The net income of the enterprise is:

$$R_q = \gamma_q [(1 - \varphi_x) R - C_q] - I_q \tag{10}$$

If n cooperative agents are involved in the transformation, the profit distribution ratio φ_i of the i-th cooperative agent is regarded as a function of I_i and γ_i, that is, $\varphi_i(I_i,\gamma_i), i=1,2\cdots n$. The payoff of the cooperative agent increases with the growth of risk and investment amount, that is, φ_i is an increasing function. According to the sharing principle, the revenue of each principal is:

$$R_i = \frac{I_i\gamma_i}{\sum_{i=1}^{n} I_i\gamma_i} j_i R, i=1,2,\cdots n \tag{11}$$

where $\gamma_i \in (0,1)$ includes risks of R&D, policy and market failure; j_i is the value contribution coefficient of each participating subject.

Based on the above analysis, it is concluded that the transaction cost of the joint innovation center model is relatively high and has a limited range of applications. There are still large intermediate costs and reputation risk, even though agencies can cut the transaction cost to some extent. Blockchain technology can be used in this issue to lower transaction costs because of its properties of decentralization, non-tampering, whole-process trace, and traceability.

2.3. Transaction Cost Analysis based on Blockchain

1. Reduce the costs of information search, evaluation and due diligence.

When the blockchain technology is used for transformation, achievements' information, such as patent documents, appearance images, research team, etc., is recorded in the distribution block of the basic layer. Due to its traceability and non-tampering, it can be used to establish a traceability evaluation mechanism for achievements, in order to break down the data island between achievement holders, demand-side, and TLOs, solve the information asymmetry issue in the transformation process, and further lower the cost of searching C_{01}, which covers the price of professional due diligence spent finding supply and demand data, analyzing the transaction item, and finding a match.

2. Reduce transaction decision costs.

The integrity constraint of the research and demand sides can be realized by using blockchain 's data tamper-evident features. This allows the two sides to make the best decisions possible regarding the method of transformation, the relationship between property rights and benefit allocation, and further reduces the cost of transaction decision-making C_{03}. Meanwhile, the market information and transfer of these achievements is fed back to the R&D personnel to support the overall process of technical services and optimization of Sci. & Tech achievements.

3. Reduce supervision costs

The consensus mechanism of blockchain provides a platform for information sharing and effective communication between research and demand parties. Through the full chain tracking and comprehensive sharing of the whole life cycle information of achievements, such as info of capital flow, investment, and property rights, the participants can be urged to track the applying process and provide technical services in time to prevent them from violating the contract or even cheating. As a result, the transformation supervision cost C_{04} caused by unpredictability of process, industry policy uncertainty, market risk and "opportunism" is reduced. Also, it can prevent fake trading arbitrage behavior, which is also a guarantee for the construction of market demand-oriented technology innovation market.

4. Reduce negotiation costs

Smart contract technology records the entire process of transaction information of Sci. & Tech achievements, including transaction time, transaction price, supply and demand side information, value evaluation, government funding and financial loans, property rights, profit distribution, and other content, in order for the main body in the alliance chain to share all transaction information of each achievement honestly and accurately. Therefore, it can realize the traceability in multiple transformation, address the issues of rights confirmation and transaction trust, reduce the transaction price negotiation cost C_{02} brought on by the disparity of value judgment between the supply and demand sides, and enable both parties obtain more additional value while reaching the benefit balance point.

As a result, the use of blockchain technology in the transformation of Sci. & Tech achievements can lower the exogenous transaction costs C_{01}~C_{04} from various levels. Table 1 is a summary of the three patterns.

Table 1. Comparison between traditional transaction mode and the mode based on blockchain.

Model	Cost	Information traceability	Full-service accessibility	Applicability	Profit	Central-ization	Feedback
Intermediary	High	Relatively complete, large forgery risk	The R&D side provides poor technical services	Wide	Original value, guaranteed risk	Yes	Relatively many
Joint innovation center	High	More comprehensive, none public information	Late technical service accessibility is poor	Small, large high-tech enterprises	Original value, risk sharing	No	Many, temporary
Based on blockchain	Low	Open and comprehensive, non-tampering, traceable	Strong	Wide, precise matching	Original value+ increment of added value	No	Record chronologically persistence

As observed in Table 1, the Sci. & Tech achievements transformation method based on blockchain technology has advantages over the traditional transaction modes in terms of transaction costs, scope of application, benefits, etc. Based on this, this article goes on to design a blockchain-based traceability system for Sci. & Tech achievements.

3. Design of traceability system for transformation of Sci. & Tech achievements based on blockchain

3.1. Full lifecycle information storage chain construction

In order to achieve full life cycle traceability of information throughout the entire transforming process of Sci. & Tech achievements, a full life cycle information storage chain of achievement creation, integration, ripening, evaluation, and implementation is established on the basis of blockchain (see Fig. 1). Included in experimental indicators, information of researchers, patent information, state funding, ownership of intellectual property rights, information of supply and demand parties, economic benefits of production and feedback on problems, etc. Therefore, it is possible to implement an efficient transformation, and the value quantity may be accurately appraised. This reduces the need for recollection during "secondary innovation" and saves time and money on search expenses.

The data is traceable and unchangeable throughout the whole life cycle. In order to prevent the supply and demand parties from losing resources when gathering the achievements, the relevant subjects of the transaction can accurately access and query relative information according to the information usage appeals and access rights, and further analyze and filter the information in depth. To safeguard the technology secrets in the course of a successful transaction, the technology secret block is encrypted using hash algorithm and fully backed up during the transaction [10].

The achievements at each stage necessitate the transfer of value, and the consensus process maintains the consistency and accuracy of all accounting nodes at each stage. The R&D information, patent papers, policy fund support, and other ownership data will be recorded in the block once they are matured. This block will then be thoroughly verified and cross-managed by universities and research institutions, the CNIPA, innovation centers, so as to realize the connection and checks and balances between the government's oversight and the market circulation. In addition, after being verified and bound by the image, other data such as product performance and functional parameters, market demand are also recorded in the block. This minimizes illegal behaviors like data manipulation and node falsification, allowing each subject can assess the value of the achievements in a reliable and fair way.

Smart contracts hold all the data necessary for the transactions, enabling trusted transactions without the need for third parties to monitor them. The system performs comprehensive intelligent credit management, which includes determining whether the transformation is trustworthy into the credit score system. It achieves automatic contract fulfillment by completing the process management, automatic monitoring, cross-verification, and credit evaluation of the required subjects for both supply and demand parties, the government, financial institutions, and others.

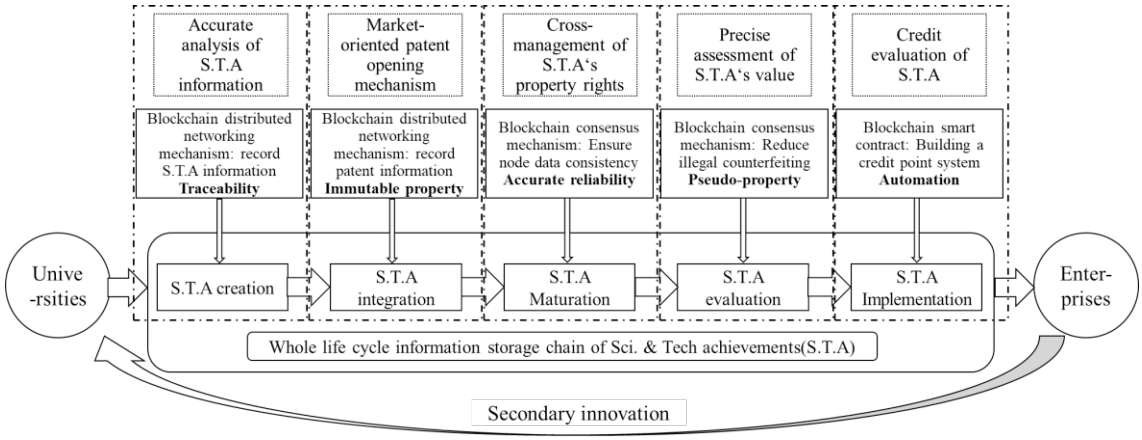

Fig. 1. The model diagram of the application of blockchain technology in the transformation of Sci. & Tech achievements.

3.2. Management mechanism to reduce transaction costs

1. **Basic layer**: Blockchain technology provides security guarantee for Sci. & Tech achievements data information.

The basic layer is distributed database and encrypted shared ledger. By block packaging, each stage from creation to implementation is permanently recorded and is fully shared by all nodes. Each block is connected chronologically and cannot be altered thanks to the time stamp and hash algorithm [11]. The trading system's security is ensured by the asymmetric encryption process. All knowledge nodes in the distributed network identify the validity of one specific knowledge service in order to guard against manipulation and node fraud, make the information accurate, dependable, and authoritative, and further steer clear of "free riding" and conflicts over intellectual property ownership and infringement [12]. After writing is complete, smart contract is sent to all nodes, enabling the information storage chain to operate in a programmable, data-transparent, and permanent manner throughout the entire life cycle.

2. **Business layer**: Blockchain provides accurate process management for the transformation of achievements.

The information chain about Sci. & Tech achievements throughout their entire life cycle can efficiently carry out intellectual property tracking and evaluation as well as assess the economic efficiency, environmental friendliness and feasibility based on detailed data like patent information, property attributes, and value. The efficiency of evaluation methods used in traditional transaction modes is weak when it comes to issues like missing or false evaluation information that are frequently encountered in the transformation. However, blockchain technology's traceability and immutability can effectively address these issues and boost the effectiveness of the transformation.

A unique identifying number for one transformation can be created using public and private keys in asymmetric encryption technology [13]. According to their requirements, the supply and demand parties seek for relative information through the public chain, and the consult transaction account through the private chain. Public-private links facilitate the precise matching. To achieve high security, manageable risks, openness and transparency, all processes are subject to the oversight of all nodes. In order to lower the risk of illegal trading and provide an open, transparent, trustworthy basis for the "secondary innovation", the smart contract is used to write the performance evaluation rules and credit feedback rules into the program and execute them automatically, which is not restricted by the ability of evaluators. When requiring re-innovation, the initial transaction records are unavailable in the traditional transaction mode since the majority of those information is lost within the first transformation. The blockchain system stores the transaction information of each achievement in a timely and orderly manner (see Fig. 2), so as to realize the traceability of multiple transaction records and the management ability of accurate transformation.

The management data about whole transformed processes will be kept in the system, which is controlled by both public chain and individual private chain, thereby removing the intermediate link in the management of the trading and circulation. If additional improvements are required due to things like changing market demand, shifting policies, and technical flaws after being used or produced on a wide scale, smart contracts can be used for traceability [14].

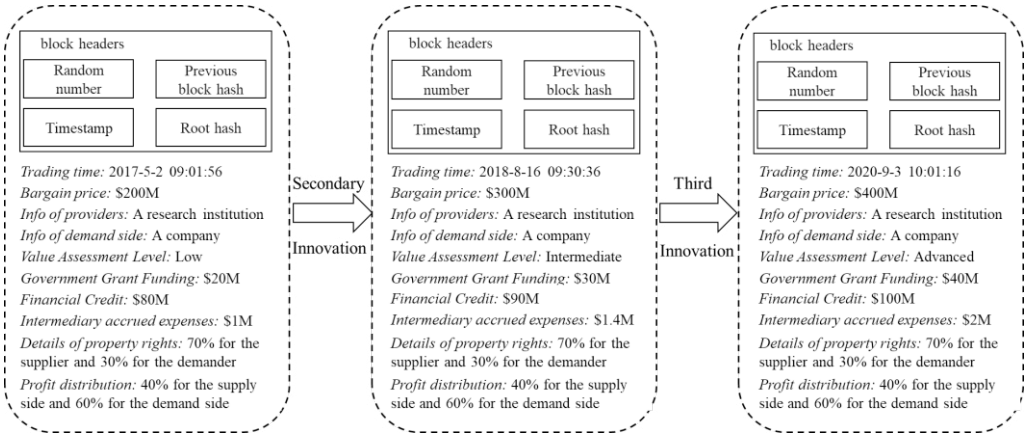

Fig. 2. The data block of Sci. & Tech achievements trading information storage chain

3. **Management layer**: Blockchain creates a new ecology of accurate and effective transformation.

The traceability, non-tampering, and sharing properties of the intellectual property data in the blockchain enable the pre-storage and in-process control of property rights supervision. Electronic vouchers are given legal advantages by smart contracts, which can achieve post-event accountability and prevent the issue of severing the evidentiary chain of previous transactions and use. The blockchain system consists of the government's public chain and private chain into a collaborative sharing network, and CNIPA, intellectual property rights holders and implementors and other subjects form a collaborative ecology of intellectual property protection services.

A data sharing and linkage mechanism is established for the government, universities and scientific research institutions, financial institutions, enterprises, and technology intermediaries, which uses the basic data information to intelligently analyze the transformation environment, application fields, capital needs, innovation level, etc. The establishment of a punishment mechanism will protect the legitimate rights and interests of each subject while the credit score management system manages the performance of the contract uniformly [15]. Information about the subject of the contract breach will also be shared simultaneously with public security and financial institutions.

The all-aspects information of achievements permanently recorded on the block can make the technology cost sharing of each subject well documented in the "secondary innovation" from businesses to universities, and further a large number of precipitation technical potential of universities can be excavated. It avoids the issues of technology shelving and the lack of motivation of "secondary innovation" in colleges and universities in the traditional primary transformation, so as to build an innovation ecosystem for stepwise transformation of Sci. & Tech achievements.

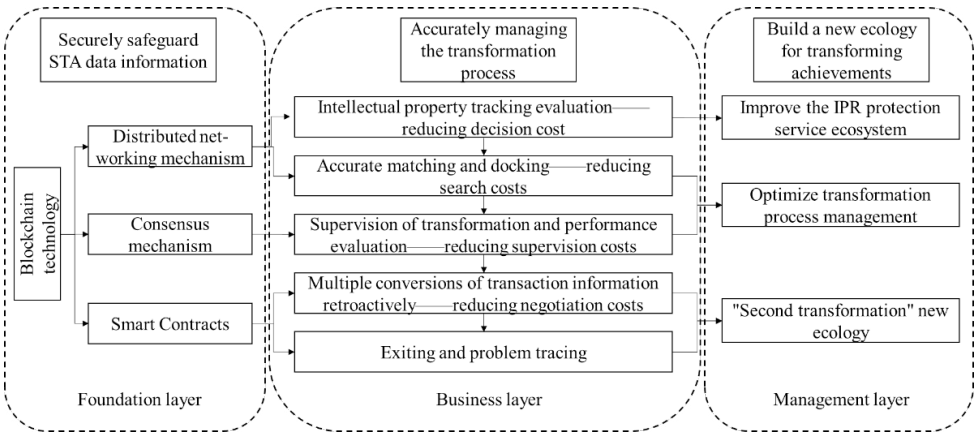

Fig. 3. (a) first picture; (b) second picture.

4. Conclusion

This paper primarily analyzes the current modes of Sci. & Tech achievements transformation from the standpoint of transaction costs and benefits, and proposes a traceability system for Sci. & Tech achievements transformation based on blockchain technology. This paper is mainly innovative from the perspective of research, since transaction cost-benefit model can serve as a guide for the transaction parties in estimating the cost and income amount. And further creatively applying blockchain technology to the transformation to promote the sound of intellectual property protection service ecology, optimize transaction chain management, and aid in the creation of a new ecosystem for such transformation.

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