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RESEARCH ARTICLE

Blockchain Enabling Government to Establish a Timely Supervision Mechanism for the Platform Ecosystem

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ABSTRACT Blockchain technology has been applied to the government's supervision mechanism of the platform ecosystem, considering the inaccurate timing of the Chinese government's supervision of the platform ecosystem. This study establishes a game model to study the government's decision-making behavior, total social welfare, and participants in the platform ecosystem. Research suggests that although government regulation can improve overall social welfare, excessive regulation inhibits the development of platform enterprises. Hence, this study further analyzes the government's regulatory interval facing the platform ecosystem, constructs an application scenario of blockchain that enables timely government regulation, and establishes the regulatory interval as the trigger mechanism of smart contracts in the blockchain. The smart contract can send an alarm, and the government can intervene in the platform ecosystem for supervision if the evaluation result is within the regulatory interval. The government will not intervene in the platform ecosystem for regulation (if the government is inside the platform ecosystem at this time, the government will withdraw; if it is not inside the platform ecosystem, it will remain unchanged) if the assessment result exceeds the regulatory range.

INDEX TERMS Blockchain, platform ecosystem, timely supervision mechanism.

I. INTRODUCTION

The digital wave has profoundly changed enterprises' traditional organizational structure and business model. Recently, Uber, JD.com, Apple, Alibaba, and other enterprises quickly established their respective market positions within the platform ecosystem. In January 2022, China's National Development and Reform Commission and nine other departments jointly issued opinions on promoting the platform economy's standardized, healthy, and sustainable development. These opinions emphasized equal attention to development and standardization and established a basic background for the future development of China's platform economy. The platform economy proposed the "establishment of an orderly and open-platform ecosystem" and building a compatible and open ecosystem for the first time. The platform ecosystem develops itself by collecting, sorting, analyzing, and operating massive amounts of user data. It also realizes substantive control of the same industry and cross-industry combination or concentration to strengthen and consolidate its multilateral platform structure of market power [1], [2], [3]. Microsoft, Facebook, Amazon, Netflix, and Google in the United States, and Baidu, Ali, Tencent, JD.com, and TikTok in China are typical representatives of this platform ecosystem. In a platform ecosystem, the impact of platform enterprises on participants is twofold [4]. Conversely, when participants join the ecosystem, the enterprise platform bestows positive externalities upon them. This encourages participants to conduct digital transformation and upgrading [5], [6], such as three squirrels, a handu clothes house, and Taobao-developed brands. In contrast, platform enterprises have brought a huge impact (negative externality) on

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participants [7], prompting participants to face the dilemma of how to rely on the platform for transformation and upgrade without losing their autonomy. For example, convenience store owners in urban communities deeply feel the ''hostility'' from Internet platforms; with huge capital subsidies, agricultural and sideline products as low as a few yuan, or even a few cents, the surge in the help of all kinds of low-cost sales. The original small and microeconomic ecology has been hit hard, and the income of small- and medium-sized operators has been decreasing. Once a platform enterprise obtains a dominant or monopolistic market position owing to its brand-new business model, strong network effect, almost zero marginal cost [8], and other advantages, it firmly controls participants and consumers in its established ecosystem [9]. It uses its advantageous technology and capital to hunt, forms a monopoly, and compromises the public's interests, leading to the phenomenon of ''market failure.''

The platform economy improves economic efficiency, promotes social development, and challenges the traditional government supervision mechanism. Conversely, the openness of the platform and cross-border trends [10] have intensified the information asymmetry challenge of government regulation. In contrast, participants in the platform ecosystem are scattered, diverse, and large-scale [11], making obtaining regulatory decision-making information difficult for governments. More importantly, once social welfare is damaged or platform enterprises are monopolized, the government's supervision can only control platform enterprises. This misses the best supervision opportunity and restricts the development of platform enterprises, seriously impacting the efficiency and accuracy of government supervision.

The core advantage of blockchain technology is decentralization. This decentralization can realize point-to-point transactions, coordination, and cooperation based on decentralized credit in a distributed system where nodes do not need to trust each other using data encryption, timestamps, distributed consensus, and economic incentives. This provides solutions to the problems of high cost, low efficiency, and insecure data storage commonly existing in centralized institutions [12], [13]. Therefore, the blockchain-enabled government supervision mechanism can promote information exchange between platform enterprises and participants and provide participants with a market environment suitable for growth. It can make appropriate adjustments to the actual situation to ultimately achieve free competition and cooperation among various entities of the platform ecosystem. ''Timeliness'' here manifests in that the government enters or exits supervision of the platform ecosystem in time according to external changes of the platform enterprises to the participants. Specifically, when platform enterprises' negative externalities dominate, the government enters the platform ecosystem for supervision. When the negative externalities of platform enterprises to participants no longer dominate, the government will withdraw from the platform ecosystem. Hence the platform ecosystem can continue to maintain free competition and cooperation between platform enterprises and participants.

This study focuses on the dynamic path of blockchain, enabled by the government's timely supervision of the platform ecosystem by constructing a theoretical welfare economics model. Unlike previous literature that unilaterally or qualitatively explored the government's regulation of platform enterprise monopoly, this study combines the government's regulatory policy with the development of the platform ecosystem and examines the following issues:

(1) How should the government regulate the platform ecosystem promptly, that is, when should the government regulate it and when to withdraw it, with the ultimate goal of achieving a balance between competition and cooperation among various entities of the platform ecosystem?

(2) How can blockchain empower the government to conduct timely supervision, which can reduce the negative externality of platform enterprises to participants and enable the government to intelligently enter or exit supervision according to the development of the platform ecosystem?

This study first establishes a game model to analyze the decision-making behavior of platform enterprises, participating enterprises, and consumers in the platform ecosystem in the game process to solve the above problems. Moreover, this study discusses the range of government supervision of the platform ecosystem in this process. Subsequently, it takes the regulatory range as the preset condition of smart contracts and constructs an application scenario for blockchain that enables timely government supervision. Possible innovations in this study include the following three aspects.

(1) This study aims to balance competition and cooperation among the main bodies of the platform ecosystem rather than simply protecting the interests of platform enterprises or participants.

(2) This study examines the optimal timely supervision interval of the government using a quantitative game model.

(3) This study introduced blockchain technology to empower the government to implement a supervision mechanism, providing an implementation path for the benign development of the platform ecosystem.

The remainder of this paper is organized as follows. The second part of the paper covers the literature review, which combs and systematically reviews relevant literature. The third section comprises the research model, including the basic and extended models. The fourth part discusses an application scenario based on blockchain technology. Finally, the fifth part provides a summary.

II. LITERATURE REVIEW

A. PLATFORM ECOSYSTEM

According to Alibaba Research Institute, a platform is a specific form of market resource integration and business model innovation in the network era. It can guide or facilitate transactions among multiple customers and attract all parties to use it by charging appropriate fees to maximize revenue. A platform ecosystem refers to a business ecosystem composed of a series of closely related stakeholders such as platform enterprises (platform firms or platform owners), their participants (platform participants, suppliers of products or services), and consumers [14]. Platform enterprises and participants are ''producers'' of platform products or services, while ''consumers'' are end users. In the industrial Internet's full and full-link digital scenarios, participants increasingly rely on platform enterprises to promote digital transformation [15]. Conversely, platform enterprises provide channels for traditional enterprises to contact consumers better. Data analysis technology can help traditional enterprises better serve consumers. In contrast, platform enterprises rely on their technological advantages to provide consumers with innovative and alternative products or services, which also occupy the market share of traditional enterprises [16]. The problem of information asymmetry between platform enterprises and participants [17] has strengthened the technological impact on traditional enterprises. The negative externalities generated by the technological impact may completely offset the positive externalities generated by technological spillovers, such that traditional enterprises are squeezed out of the platform ecosystem. While the market dominance of platform enterprises is becoming stronger, they will eventually establish a monopoly in the platform ecosystem [18] and engage in behaviors that are harmful to consumer interests and social welfare.

Prioritizing participants' development in a platform ecosystem is an important gap in existing research. Combining the relevant literature, we find that many studies originate from the perspective of platform subjects [19], [20] and focus on the governance and competition strategies of platform enterprises [21]. Studies from the perspective of ecological participants have increased in recent years [22], [23]. Research from the perspective of the platform's main body mainly focuses on how the platform can break the ''chicken laying egg'' problem, promote participants' innovation input, stimulate the network effect, and achieve ''winner take all'' [24], [25]. Research from this perspective has also focused on the need to consider the interaction between participants and platform enterprises in platform governance [23], [26], [27]. However, generally, the existing research mainly emphasizes how platform owners influence and stimulate the complementary innovation of the participants and do not place participants in a position of ''active subjects.'' Participants are active subjects who compete and interact with platform enterprises [28]. Participants made differentiated decisions based on the evolution of strategic situations. However, because of the weak decision-making of participants in the platform ecosystem, if participants adjust their strategies to regulate ecosystem development, their role is limited. Zhu and Liu [21] examined how Amazon entered the product space of third-party sellers and found that platform enterprises could enter the product space of participants and compete with them. This competition affects the profit growth of the latter on the platform and pushes many participants out of the platform [29]. For example, Netscape and real network complements of Microsoft's Windows platform were eliminated by the competitor's Microsoft applications, Internet Explorer, and Windows Media Player. Apple eliminates some previously essential third-party applications in every new operating system released. Research has shown that a balance of competition and cooperation between platform enterprises and participants drives stable platform ecosystem development [30]. Therefore, if the government can correct this imbalance of competition and cooperation through an appropriate regulatory mechanism, stable development of the platform ecosystem can be promoted.

B. GOVERNANCE OF PLATFORM ECOSYSTEM

Given the rapid development of the ecosystem led by platform core enterprises and the increasing market power of platform enterprises [31], the effective management of the increasingly unbalanced development of the platform ecosystem has become a prime concern in academia and industry. Combining the existing literature, we find that the governance of a platform ecosystem can be divided into two categories: internal and external. Internal governance mainly discusses how platform enterprises coordinate and manage the platform ecosystem through different strategies: This includes technology investment [32], competitive pricing [33], reputation mechanism [Panagopoulos et al., 2017], contract mechanism [34], and platform-specific governance means and governance models [35], all of which belong to the scope of giving play to the self-regulation role of the market mechanism. The platform expands the group of participants as much as possible, maintains openness, and improves innovation efficiency to maximize economic benefits. Given the expansion of the scale of platform enterprises, the risk of platform management and control also increases [36], which may lead to severe legitimacy challenges and even threaten the stability of the platform ecosystem. The pursuit of the goal of maximizing interests by platform enterprises may conflict with public interests and lead to market failure, which increases privacy risks, property rights, and monopoly problems [37] and threatens public interests.

Therefore, scholars have begun exploring ways to coordinate the benign development of platform ecosystems through external governance. External governance mainly refers to the coordination and balance of the platform ecosystem through the government rather than relying solely on the market mechanism's self-regulation. Government regulations aim to protect public social interests and promote the progress of knowledge technology and social welfare by correcting market failure. Government regulation has an important impact on building a good social and economic operational environment, especially in terms of system supply and externality management, which play irreplaceable roles [39]. However, in the digital economy, government regulation faces a dilemma between inclusive innovation and legal regulation. Conversely, platform enterprises have created several business opportunities and made important contributions to national economic and social development through the two-wheel drive of technological and business model innovation. Government regulations must provide policy support and inclusive space to develop platform enterprises [40]. Simultaneously, participants actively participate in innovation and require time and opportunities to learn the advanced business model of platform enterprises. Moreover, the government should help improve the comprehensive strength of the participants [41]. In contrast, monopoly and other problems in the platform ecosystem development also need to be regulated by the government to safeguard the market environment and public interests [42], [43]. Additionally, owing to the distance between government and market practices, the government faces great challenges in the timely and accurate observation of changes, rapid follow-up, and adjustment of regulatory measures. Therefore, considering the regulatory challenges presented by the digital economy, it is difficult to ensure the effectiveness and timeliness of regulation by relying solely on traditional regulatory concepts and models. Limited regulatory resources, backward technical means, and other ‘‘shortcomings’’ cannot support a government's regulatory functions. This results in traditional government regulations no longer meeting the development needs of the new era, inaccurate regulatory timing [44], and vague, repressive, and arbitrary regulation.

C. BLOCKCHAIN ENABLING GOVERNMENT GOVERNANCE

Blockchain is a decentralized, non-tampering, and traceable distributed database technology that can realize point-to-point value transmissions [45]. The 14th Five-Year Plan for Business Development issued by the Ministry of Commerce clearly proposes to ‘‘promote the deep integration of 5G, big data, artificial intelligence, Internet of things, blockchain, and other advanced technologies with business development.’’ As an information ‘‘transportation’’ tool, blockchain's direct role in government regulation alleviates regulatory information asymmetry [46] and compensates for the information shortage. Simultaneously, decentralized trust interaction can build an honest cultural environment, impose accountability on regulators and subjects of the platform ecosystem, enhance the government's management and decision-making ability [47], and improve the efficiency and accuracy of supervision.

Research indicates that blockchain technology has broad applications in many industries, such as energy, finance, medical care, education, and government work, and can greatly improve the efficiency of government governance [48]. Researchers in political science, administrative management, information engineering, and other disciplines have conducted extensive research on blockchain-enabled governance. Qi et al. [49] examined blockchain technology's role, advantages, and paths in building government trust and how blockchain underlying technology can solve data islands, data rights confirmation, and trust problems. The wide application of blockchain in the field of digital platforms [50] has led to the rise of ‘‘blockchain + regulation’’ research [51]. These research results have revealed the significant role of blockchain technology in changing the government governance model and have initially demonstrated the importance of blockchain technology in empowering the transformation of government leadership. The integration of blockchain/smart contract and the game model is a hot topic. The bloqckchain governance game is a new hybrid theoretical model to find best strategies towards preparation for preventing a network malfunction by an attacker [52] and Su et al. [53] propose a contract-based energy blockchain for secure EV charging in SC.

However, relevant research remains in its infancy, with more applied and countermeasure research and less quantitative research.

Overall, the existing literature affirms the considerable role of government in platform governance, but it cannot solve the problem of inaccurate or excessive government regulation. This study builds a theoretical model from the perspective of balancing the positive and negative externalities of platform enterprises with participants combined with blockchain technology, considering the initiative of the platform ecosystem. Moreover, this study proposes a timely government supervision mechanism. It studies how a government that maximizes social welfare should properly govern the platform ecosystem and maintain dynamic competition and cooperation between platform enterprises and participants. It ensures the sound operation of the platform ecosystem and guarantees that the market mechanism can continue to play a regulatory role.

III. RESEARCH MODEL

A. BASIC MODEL

Based on the current operation of platform enterprises, the theoretical model of this study assumes that the platform in the market is a bilateral market (e.g., the Didi taxi platform). Consider an industry market D. Before the platform appeared, the products (or services) in the traditional market were provided by Participant 1. For example, a traditional taxi company can provide taxi services for transportation. Platform 2 (platform enterprises) is an advanced technical method based on a digital economy. It is a bilateral market that integrates information interaction, product (service) circulation, and other functions.

Table 1 lists the main parameters and definitions used in this study.

Suppose that the variable cost of the product (or service) provided by participant 1 is the variable cost of the product (or service) provided by participants 1 through 2. There has been owing to the progress of Platform 2 in business models and technical means $k_1 < k_0$. We introduce the positive externality parameter e ($e \in (0, 1)$) to describe the variable cost reduction brought to the enterprise by Platform 2 after it enters the market. Then, after Platform 2 enters the market, the product (or service) variable cost in Market D decreases owing to positive externalities.

When platform 2 enters Market D, consumers (purchasers of products or services) can purchase the products (or services) of participant 1 directly through traditional

TABLE 1. Main parameters.

	Symbol	Definition
Index	U	Utility function
	Q	Demand function
	ω	Consumer preferences
	θ	Supplier preference
	π	Profit function
	CS	Consumer welfare function
	TS	Total social welfare function
	$G(\lambda)$	Cost function of government supervision
Param eters	k	Cost of product (or service)
	e	Positive externality parameter
	s	Substitutability of products (or services)
	μ	Positive externality of Platform 2 to Participant 1
	λ	Government input level
	p	Price of products (or services)
	ρ	Strengthening degree of positive externality of Platform 2 by government regulation

channels or the products (or services) provided by platform 2. Referring to Guo and Zhao [43], consumers' preferences for products (or services) obey a continuous distribution of intervals $[0, \overline{\omega}]$. In this study, the consumer group that directly purchases products (or services) through participant 1 is defined as Group F, and the consumer group that purchases products (or services) through platform 2 is defined as Group O. p_1 and p_O represents the prices paid by consumers to purchase the products (or services) of Participant 1 and the products (or services) provided by platform 2 through traditional channels, respectively. s represents the degree of substitution for these two products (or services). A larger value of s represents stronger substitutability of the two products. $s = 0$ indicates that the two products are completely irreplaceable and $s = 1$ indicates that they are completely homogeneous. In reality, the products (or services) provided by platform 2 may be similar (not completely irreplaceable) to the products (or services) of participant 1, and the products (or services) may be improved owing to the improvement of the platform's business model and technical means. However, they were not completely homogeneous, as assumed in the $s \in (0, 1)$ study.

Numerous studies show that the complementarity of products (or services) provided by participants 1 and 2 is generally higher than their substitutability. In the platform ecosystem, participant 1's development path is a process of gradual growth through dependence and complementarity on platform 2.

According to the theoretical research of Bahar et al. [26], based on consumer preferences, the utility functions of consumers in the two groups are as follows:

$$U_F = \omega - p_1 \tag{1}$$

$$U_O = s\omega - p_O \tag{2}$$

When a consumer does not choose to buy the products (or services) of participant 1 through traditional channels or the products (or services) provided by platform 2, their utility is 0.

There are two types of marginal consumers: the first is that there is no difference in the utility obtained by consumers who choose to purchase the products (or services) of participant 1 through traditional channels. The other is that no difference exists in the utility obtained by consumers who purchase the products (or services) provided by platform 2 and do not consume them. The preferences of these two types of marginal consumers are as follows.

$$\widetilde{\omega}_{1,O} = \frac{p_1 - p_O}{1 - s} \tag{3}$$

$$\widetilde{\omega}_{O,0} = \frac{p_O}{s} \tag{4}$$

The demand functions of the two types of consumers are as follows:

$$Q_1(p_1, p_O) = \overline{\omega} - \widetilde{\omega}_{1,O} = \overline{\omega} - \frac{p_1 - p_O}{1 - s} \tag{5}$$

$$Q_O(p_1, p_O) = \widetilde{\omega}_{1,O} - \widetilde{\omega}_{0,O} = \frac{sp_1 - p_O}{s(1 - s)} \tag{6}$$

Similar to Group O, this study marks the suppliers of products (or services) as Group G. Based on research by [54], preferences for supplied products (or services) θ obey a continuous distribution of intervals $[0, \overline{\theta}]$. The closer the preference is to zero, the more inclined a group is not to supply products (or services), and the closer it is to supply products (or services). Based on the assumption regarding the preference of suppliers for products (or services), the utility of individuals or enterprises in Group O that do not supply products (or services) is 0. The utility of the supplier in Group O is as follows:

$$U_G = p_G - k_1 + \theta \tag{7}$$

p_G refers to the price of products (or services) the supplier provides and k_1 refers to the cost of products (or services) in the platform ecosystem. In a platform ecosystem, because the needs of platform enterprises are non-zero, there is $k_0 < s\overline{\omega}$. When suppliers in Group O have no difference in utility obtained by providing products (or services) and not providing products (or services), they are marginal suppliers. Currently, the preferences are

$$\widetilde{\theta}_{G,0} = p_G - k_0 \tag{8}$$

The supply function of the product (or service) is as follows:

$$Q_G(p_G) = \widetilde{\theta} - 0 = p_G - k_0 \tag{9}$$

Based on the current situation in the platform ecosystem, this study's theoretical model assumes that the platform appears in the form of a bilateral market. Platform 2 is similar to an online ride-hailing platform (e.g., Didi Dache). The unit revenue of platform 2 originates from the difference between the transaction price and cost between each taxi service provider, such as drivers (Group G), and service demanders, such as passengers (Group O). According to research, the profit of the platform is derived from the part of the effective transactions completed, more than just the number of users on the platform. As the providers and purchasers of products or services on bilateral platforms (e.g., drivers and passengers on the Didi Chuxing platform) are often not the same person, the preferences of Groups G and O are independent of each other, and the number of effective transactions on the platform is $Q_1(p_1, p_O) \times Q_G(p_G)$.

Participants 1 and 2 set prices for products (or services) that can maximize their profits in the platform ecosystem. The profit functions of Participants 1 and 2 are:

$$\pi_1 = \left[\mathrm{p}_1 - k_0(1-\mu_0)\right](\varpi - \frac{p_1 - p_o}{1-s}) \tag{10}$$

$$\pi_2 = (p_1 - p_o)(p_G - k_1)\frac{sp_1 - p_o}{s(1-s)} \tag{11}$$

μ_0 is a constant that indicates the positive externality generated by Platform 2 for Participant 1; therefore, $\mu_0 > 0$.

Find the first derivative of (10) and (11), and let the first derivative be 0, so that the equilibrium price of the product (or service) of participant 1 and the equilibrium price of the demand and supply sides of the platform 2 is:

$$\mathrm{p}_1^* = \frac{3(1-s)\varpi + k_1 + 3k_0(1-\mu_0)}{2(3-s)} \tag{12}$$

$$\mathrm{p}_\mathrm{o}^* = \frac{s(1-s)\varpi + k_1 + sk_0(1-\mu_0)}{3-s} \tag{13}$$

$$\mathrm{p}_\mathrm{G}^* = \frac{\mathrm{s}(1-s)\varpi + (4-s)k_1 + sk_0(1-\mu_0)}{2(3-s)} \tag{14}$$

Upon substituting the equilibrium prices of (12)-(14) into (10) and (11), the equilibrium profits of participants 1 and 2 can be obtained as follows:

$$\pi_1^* = \frac{[3(1-s)\varpi + k_1 - k_0(3-2s)(1-\mu_0)]^2}{4(1-s)(3-s)^2} \tag{15}$$

$$\pi_2^* = \frac{[\mathrm{s}(1-s)\varpi - (2-s)k_1 + sk_0(1-\mu_0)]^3}{8s(1-s)(3-s)^3} \tag{16}$$

Proposition 1: The condition for free competition between platforms 2 and 1 is that platform 2 meets the positive externality of participant 1: $e \in (e_{\min}, e_{\max})$. Additionally, the market demand for platform 2 was zero, and the demand for Participant 1 was 0. $e_{min} = 1 - \frac{3\varpi(1-s)+k_1}{sk_0(2-s)}$, $e_{\max} = 1 + \frac{s\varpi(1-s)-k(2-s)}{sk_0}$.

Proposal 1 was the condition for coexistence and competition between Platforms 2 and 1. When $e > e_{\max}$, the positive externality of Platform 2 to Participant 1 was too large. Participant 1 rapidly improved in learning about the advanced technology and business model of platform 2 and formed a leading edge. Hence, Platform 2 withdrew from the market, and Participant 1 monopolized the market. When $e < e_{\min}$, the positive externality of Platform 2 to Participant 1 is too small. Platform 2 monopolizes the market because of its leading edge in advanced technology and business models, and participant 1 is pushed out of the market. Only if the positive externality of platform 2 to Participant 1 is maintained at an appropriate level, when $e \in (e_{\min}, e_{\max})$, can platforms 2 and 1 compete freely in the market.

CS^*, CS_1, and CS_2 represent consumer welfare when participants 1 and 2 coexist in the market; participant 1 monopolizes the market. TS^*, TS_1, and TS_2 represent the total social welfare when participants 1 and 2 coexist in the market, participant 1 monopolizes the market, and platform 2 monopolizes the market.

When participant 1 or platform 2 monopolizes the market, their profit functions are:

$$\pi_1 = (p_1 - k_0)(\omega - p_1) \tag{17}$$

$$\pi_2 = (p_o - p_G)(\varpi - \frac{p_o}{s})(p_G - k_1) \tag{18}$$

Find the first derivative of $\mathrm{p}_1, \mathrm{p}_o, \mathrm{p}_G$ and obtain the optimal price when participant 1 or platform 2 monopolizes the market to maximize profits.

$$p_1 = \frac{\varpi + k_0}{2}; \quad p_o = \frac{2s\varpi + k_1}{3}; \quad p_G = \frac{s\varpi + 2k_1}{3} \tag{19}$$

Substituting (19) into (17) and (18), the maximum profit when participant 1 or platform 2 monopolizes the market is

$$\pi_1^0 = \frac{(\varpi - k_0)^2}{4}; \pi_2^0 = \frac{(s\varpi - k_1)^3}{27s} \tag{20}$$

Upon substituting (19) into the consumer welfare function, the consumer welfare when participant 1 or platform 2 monopolizes the market can be obtained as follows:

$$CS_1^0 = \int_0^{\varpi} (\omega - p_1)d\omega = \frac{(\varpi - k_0)}{8} \tag{21}$$

$$CS_2^0 = \int_0^{\varpi} (s\omega - p_o)d\omega + \int_0^F (F - k_1)dF = \frac{(1+s)(s\varpi - k_1)^2}{18s} \tag{22}$$

Additionally, when participants 1 and 2 coexist in the market, substituting (12)-(14) into the consumer welfare function, consumer welfare at this time can be obtained in (23), as shown at the bottom of the next page.

Therefore, the total social welfare in the three cases of participant 1 monopolizes the market, platform 2 monopolizes the market, and participants 1 and 2 coexist.

$$TS_1^0 = CS_1^0 + \pi_1^0; \; TS_2^0 = CS_2^0 + \pi_2^0; \; TS^* = CS^* + \pi_1^* + \pi_2^* \tag{24}$$

Proposition 2: Comparing consumer welfare in the three cases, we find $\mathrm{k}_0 > \mathrm{k}_1$ and $CS^* > \max\{CS_1, CS_2\}$. Comparing total social welfare under the three conditions, we find $TS_2 > TS_1$.

Compared with when participants 1 and 2 monopolize the market, participant 1 and platform 2 can always improve consumer welfare when they coexist in the market. As for total social welfare, when platform 2 monopolizes the market, total social welfare is higher than when participant 1 monopolizes the market. This also explains why platform 2 can enter the market and why the improvement in technology and business models by platform 2 can improve social welfare. However, if further improving overall social welfare is the goal, the cost gap between participants 1 and 2 must be narrowed, and competition must be freed. Conversely, if participant 1 cannot narrow the cost gap with platform 2 to improve overall social welfare, platform 2 should eliminate participant 1 from the market, allowing platform 2 to monopolize the market. This also shows that when participants 1 and 2 coexist in the market, if there are factors beyond market forces (e.g., government supervision) that narrow the gap between Participants 1 and 2 to allow free competition and cooperation, the overall social welfare can be maintained at a relatively good level.

Therefore, the government's input level for implementing the coordinated policy was λ. Government regulation aims to alleviate the negative externalities of platform 2 with advanced technology and business models for participant 1 in the platform ecosystem. It aims to strengthen the positive externalities between them, place the platform ecosystem in a state of free competition and cooperation between platform 2 and participant 1, maintain the welfare level of consumers, and maintain the benign operation of the platform ecosystem. Therefore, after government regulation, the positive externalities of Platform 2 to Participant 1 changed with the level of government regulation, $\mu = \mu(\lambda)$. Giving $\lambda > 0$, then $\mu(\lambda) > \mu(0) = \mu_0$. As government supervision strengthens the positive externality of platform 2 to participant 1, the operating cost of Participant 1 is reduced from $k_0(1-\mu_0)$ to $k_0\left[1-\mu(\lambda)\right]$. However, this means that Participant 1 must pay non-zero operating costs. Simultaneously, the government's regulatory cost function is assumed to be $G(\lambda)$. According to [Nilsen et al. 2022], this is expressed as $G(\lambda) = \alpha\lambda^2/2$, of which α is a constant and $\alpha > 0$.

Consider a three-stage game between the government, participant 1, platform 2, and consumers. In the first stage, the government supervises and dynamically adjusts the level of supervision to maximize total social welfare. In the second stage, participants 1 and 2 engaged in price competition in the second stage after observing the government's coordinated policies to maximize profits. In the third stage, consumers in the platform ecosystem make purchase decisions after observing the prices of participants 1 and 2.

Currently, the profit functions of Participant 1 and Platform 2 are:

$$\widehat{\pi}_1^* = \max_{p_1} \prod\nolimits_1 (p_1, p_o) = \left\{p_1 - k_0\left[1-\mu(\lambda)\right]\right\} \cdot \left(\varpi - \frac{p_1 - p_o}{1-s}\right) \tag{25}$$

$$\widehat{\pi}_2^* = \max_{p_o,p_p} \prod\nolimits_2 (p_1, p_o, p_p) = \left(p_o - p_p\right) \cdot \frac{sp_1 - p_o}{s(1-s)} \left(p_p - k\right) \tag{26}$$

Upon deriving (25) and (26) from p_o, p_1, and p_p, the product equilibrium price of participant 1 and the product equilibrium price of both the supply and demand sides of platform 2 can be obtained as follows:

$$\begin{aligned} \widehat{p}_1^* &= \frac{3(1-s)\overline{\omega} + k_1 + 3k_0\left[1-\mu(\lambda)\right]}{2(3-s)} \\ \widehat{p}_p^* &= \frac{s(1-s)\overline{\omega} + (4-s)k_1 + sk_0\left[1-\mu(\lambda)\right]}{2(3-s)} \\ \widehat{p}_o^* &= \frac{s(1-s)\overline{\omega} + k_1 + sk_0\left[1-\mu(\lambda)\right]}{3-s} \end{aligned} \tag{27}$$

Proposition 3: After government supervision, the product prices of traditional and platform enterprises on both sides of the supply and demand decrease. Moreover, the decline in product prices of traditional enterprises is greater than that of platform enterprises. The decline in platform enterprises' product prices on the supply side is greater than that on the demand side.

This shows that government regulation impacts the prices of products (or services) of traditional enterprises and platform enterprises and has a greater impact on the prices of products (or services) of traditional enterprises. Specifically, the government's coordination policy has strengthened the positive externalities of platform enterprises. Traditional enterprises have reduced their operating costs and alleviated cost pressure using advanced business models of platform enterprises for reference. The price of products (or services) has also decreased, leading some consumers to turn to traditional channels to obtain products (or services). To compete with traditional enterprises, platform enterprises have correspondingly lowered the prices of products (or services) on both supply and demand sides. As platform enterprises reduce the price of products (or services) on the supply side, the supply motivation of platform suppliers weakens, and the supply of products (or services) on the platform decreases. The coordination policy can weaken the impact of platform enterprises on traditional enterprises from both the supply and demand sides and provide the necessary coordination environment for traditional enterprises to complete transformation and upgrading.

Substituting the three equilibrium prices in (17) into (25) and (26), the equilibrium profits of participants 1 and 2 can

$$\begin{aligned} CS^* &= \frac{[3\overline{\omega}(1-s) + k_1 - k_0(3-2s)(1-e)]\,[\overline{\omega}(1-s)(3+2s) - k_1(3-2s) - k_0(3-4s)(1-e)]}{8(1-s)^2(3-s)^2} \\ &\quad + \frac{[s\overline{\omega}(1-s) - k_1(2-s) + sk_0(1-e)]^2}{8(1-s)^2(3-s)^2} + \frac{[s\overline{\omega}(1-s) - k_1(2-s) + sk_0(1-e)]^2}{8(3-s)^2} \end{aligned} \tag{23}$$

be obtained as follows:

$$\widehat{\pi}_1^* = \frac{\left[3(1-s)\overline{\varpi} + k_1 - (3-2s)k_0\left[1-\mu(\lambda)\right]\right]^2}{4(1-s)(3-s)^2} \tag{28}$$

$$\widehat{\pi}_2^* = \frac{\left[s(1-s)\overline{\varpi} - (2-s)k_0 + sk_0\left[1-\mu(\lambda)\right]\right]^3}{8s(1-s)(3-s)^3} \tag{29}$$

Proposition 4: The condition for platform 2 to compete freely with participant 1 is that platform 2 satisfies the positive externality of participant 1: $e \in \left(e'_{\min}, e'_{\max}\right)$. When $e > e'_{\max}$, the market demand for platform 2 is 0, and when $e < e'_{\min}$, the demand for participant 1 is 0. $e'_{min} = \lambda^{-1}\left(1 - \frac{3(1-s)\overline{\varpi}+k_0}{sk_0(2-s)}\right)$, $e'_{\max} = \lambda^{-1}\left(1 + \frac{s(1-s)\overline{\varpi}-(2-s)k_0}{sk_0}\right)$。

Comparing Proposition 4 with Proposition 3, $e'_{min} > e_{min}$, and $e'_{max} > e_{max}$. This shows that government regulation can strengthen the positive externality of platform enterprises to traditional enterprises, increase the free competition range between traditional and platform enterprises and reduce the risk of Platform 2 pushing participant 1 out of the market.

Proposition 5: Government regulations should prevent overinvestment and inhibit the development of platform enterprises. Formulating the maximum coordination space E according to the situation of different industries and ensuring that the actual coordination space brought about by government regulations does not exceed the maximum coordination space E is necessary. Namely, $e'_{\max} - e'_{\min} \le E$.

The welfare of consumer groups F, O, and G is represented by CS_F, CS_o, CS_G. Then: (30)-(32), as shown at the bottom of the next page.

The key to government regulation is to formulate the optimal investment level, which enables participants 1 and 2 to coexist and maximizes total social welfare. Therefore, combined with the equilibrium profit functions (27), (28), and (30)-(32) of participants 1 and 2, the optimal government input can be described as follows:

$$\begin{aligned} &\max TS(\lambda) = \widehat{\pi}_1^*\left[\mu(\lambda)\right] + \widehat{\pi}_2^*\left[\mu(\lambda)\right] + CS_F\left[\mu(\lambda)\right] \\ &\quad + CS_o\left[\mu(\lambda)\right] + CS_G\left[\mu(\lambda)\right] - G(\lambda) \\ &s.t.\ \widehat{\pi}_1^*\left[\mu(\lambda)\right] > 0, \widehat{\pi}_2^*\left[\mu(\lambda)\right] > 0 \end{aligned} \tag{33}$$

The objective function of formula (33) is the social welfare of government regulation, and the constraint condition indicates that government regulation aims for free competition and cooperation between participants 1 and 2. Referring to the literature [17] and others, the externality generated by platform 2 on participant 1 is set as a linear function: $\mu(\lambda) = \mu_0 + \rho \cdot \mu$. Here, $\mu_0 > 0$ means that even if the government does not intervene, Platform 2 generates positive externalities for Participant 1(μ_0). $\rho > 0$ refers to the degree to which government regulation strengthens the positive externality of platform 2. From the constraint conditions of (33), the upper limits of government input levels $\lambda_{\max}$, and $\lambda_{\min}$ can be obtained when Participants 1 and 2 coexist. The upper (λ^*_{high}) and lower limits (λ^*_{low}) of the government's optimal input level can be solved using the objective function of (23).

When the government supervises, there are $\lambda^*_{\text{high}} > \lambda_{\max} > \lambda^*_{\text{low}} > \lambda_{\min}$. Upon solving $TS''(\lambda)$ in (33), it is negative based on the first-order optimal solution, which indicates that the optimal government input level maximizes social welfare by making participant 1 and platform 2 coexist in the market $\lambda^* \in \left(\lambda^*_{low}, \lambda^*_{\max}\right)$. Hence, the optimal input level of the government is not unchangeable. When the operating cost of participant 1 is lower than that of platform 2, with the increase of government input (λ^*), the market demand of participant 1 increases, and the operating vitality of Platform 2 is weakened, resulting in the adverse consequences of excessive government input. When the operating cost of participant 1 is higher than that of platform 2, the market demand of participant 1 will decrease, and the demand for Platform 2 will increase significantly with the decrease of the government input level (λ^*). Simultaneously, the government should increase input. Therefore, the government's optimal input level λ^*needs to be dynamically adjusted according to the actual situation of the market. Moreover, the relative operating costs of participant 1 and Platform 2 ($k_0\left[1-\mu(\lambda)\right]/k_1$) should be controlled within a reasonable range through the adjustment.

B. EXTENTED MODEL

Consider a situation wherein participants 1 and 2 can coexist in the market and compete. The government has implemented the coordination policy, and Platform 3, a potential competitor of platform 2, enters the market and competes with platform 2. After Platform 3 enters the market, if platform 2 charges a higher commission to participant 1, Participant 1 will turn to platform 3 [27]. For Platform 3, the entry strategy is feasible if the profit obtained from entering the market is sufficient to compensate for the cost.

Assuming that the cost of platform 3 entering the market is I_0, the optimization problem of platform 2 can be expressed as follows:

$$\begin{aligned} &\max \pi_2(p_1, p_o, p_G) \\ &s.t. \pi_2^E(p_o^E, p_G^E) \le I_o \end{aligned} \tag{34}$$

$\pi_2(p_1, p_o, p_G)$ is given by formula (11), $\pi_2^E(p_o^E, p_G^E)$ represents the profit of platform 3, and p_o^E and p_G^E represent the prices on the demand and supply sides of platform 3. As platform 3 enters the market after platform 2, p_o^E and p_G^E are functions of p_o and p_G, respectively. Moreover, in pricing to maximize profits, platform 2 will also consider the profits that platform 3 may obtain after entering the market and formulate a price that can effectively restrain platform 3 from entering the market. Therefore, the product prices of platform 3 and platform 2 are positively correlated, that is $p_o^{E*}(p_o) > 0, p_G^{E*}(p_G) > 0$.

Proposition 6: When there are potential competitors (Platform 3) in the market, the equilibrium prices on both the demand and supply sides of Platform 2 decrease.

Proof: Construct Lagrangian function:

$$\mathrm{L}(\mathrm{p},\lambda) = \pi_2(p_1, p_o, p_G) + \lambda \left[I_o - \pi_2^E(p_o^E, p_G^E) \right] \tag{35}$$

Let the first derivative be 0:

$$\begin{aligned} \frac{\partial \mathrm{L}(\mathrm{p},\lambda)}{\partial p_o} &= \frac{\partial \pi_2(p_1, p_o, p_G)}{\partial p_o} - \lambda \left[\frac{I_o}{\partial p_o} \cdot \frac{\lambda \pi_2^E(p_o^E, p_G^E)}{\partial p_o} \right] \\ &= 0 \\ \frac{\partial \mathrm{L}(\mathrm{p},\lambda)}{\partial p_G} &= \frac{\partial \pi_2(p_1, p_o, p_G)}{\partial p_G} - \lambda \left[\frac{I_o}{\partial p_G} \cdot \frac{\lambda \pi_2^E(p_o^E, p_G^E)}{\partial p_G} \right] \\ &= 0 \end{aligned} \tag{36}$$

When potential competitors (Platform 3) do not exist, there are:

$$\begin{aligned} \frac{\partial \pi_2(p_1, p_o, p_G)}{\partial p_o} \Big|_{p_o = p_o^*} &= 0 \\ \frac{\partial \pi_2(p_1, p_o, p_G)}{\partial p_G} \Big|_{p_G = p_G^*} &= 0 \end{aligned} \tag{37}$$

Substituting formula (37) into formula (36), we can obtain:

$$\begin{aligned} -\lambda \left[\frac{\lambda I_o}{\partial p_o} - \frac{\lambda \pi_2^E(p_o^E, p_G^E)}{\partial p_o} \right] &< 0 \\ -\lambda \left[\frac{\lambda I_o}{\partial p_G} - \frac{\lambda \pi_2^E(p_o^E, p_G^E)}{\partial p_G} \right] &< 0 \end{aligned} \tag{38}$$

Therefore, when potential competitors (platform 3) exist in the market, equilibrium prices on both the demand and supply sides of platform 2 will not be higher than those in the absence of potential competitors.

Moreover, when there are potential competitors (platform 3) in the market, platform 3 exerts certain competitive pressure on platform 2, prompting platform 2 to raise the market access threshold by reducing product prices. Additionally, the input of government regulations is related to the entry cost of platform 3 (I_0). The smaller the I_0, the easier it is for platform 3 to enter the market; thus, platform 2 can reduce product prices, achieving the same goal as government regulation. Currently, this can be achieved by introducing a competition mechanism; hence, the input of government regulations should be reduced. Conversely, the government should increase its input. However, for $I_0 > 0$ and $\lambda \neq 0$, the government still needs to implement coordinated policies.

IV. GOVERNMENT COORDINATION MECHANISM BASED ON BLOCKCHAIN

In recent years, in the development of China's platform economy, there have also been many problems, such as the squeezing of profits of operators within the platform, mutual prohibition between platforms, and the inability to effectively protect the legitimate rights and interests of workers in the new employment form. This has restricted the healthy development of the platform economy to a certain extent. A blockchain is a shared distributed ledger technology. It is a new application technology based on distributed data storage, point-to-point transmission, consensus mechanisms, encryption algorithms, and other computer technologies [45], [46], [47]. The advantages of decentralized blockchain technology-transparent transactions, open consensus, non-tampering, and traceability-rebuild trust between the government and the platform ecosystem and construct a collaborative regulatory framework.

The concept of applying blockchain technology to the government supervision mechanism proposed in this study is as follows.

(1) Blockchain technology helps overcome the problem of ''information islands''.

The platform ecosystem has formed the problem of ''information isolated islands'' centered on platform enterprises. First, there are information barriers between platform enterprises and their participants. Platform enterprises occupy a central position and have absolute control over information, hindering information flow. The resulting information asymmetry also creates a high level of information barriers. Second, closed-loop activities between platform ecosystems make it difficult to unify the implementation standards and regulatory standards of each platform ecosystem unable to be unified, hindering the development of the platform economy.

To solve these problems, the government should first break the original one-way transmission of information through point-to-point transmission and distributed ledger technology and establish a channel for information networking and exchange. First, the information uploaded by each ecosystem and subject is collected through distributed ledger technology. The information was recorded and stored in a distributed manner to realize information interaction, and each subject received information passively. Second, the interaction

$$\begin{aligned} CS_F &= \int_{\widetilde{\omega}}^{\overline{\omega}} U_F \mathrm{d}\omega \\ &= \frac{\left[3(1-s)\overline{\omega} + k_1 - k_0(3-2s)\left[1-\mu(\lambda)\right]\right]\left[(1-s)(3+2s)\overline{\omega} - k_1(3-2s) - k_0(3-4s)\left[1-\mu(\lambda)\right]\right]}{8(1-s)^2(3-s)^2} \end{aligned} \tag{30}$$

$$CS_o = \int_{\widetilde{\omega}}^{\overline{\omega}} U_o \mathrm{d}\omega = \frac{\left[s(1-s)\overline{\omega} - k_1(2-s) + sk_0\left[1-\mu(\lambda)\right]\right]^2}{8s(1-s)^2(3-s)^2} \tag{31}$$

$$\text{and} \quad CS_G = \int_0^{\widetilde{\theta}} U_G \mathrm{d}\omega = \frac{\left[s(1-s)\overline{\omega} - k_1(2-s) + sk_0\left[1-\mu(\lambda)\right]\right]^2}{8(3-s)^2} \tag{32}$$

of information allows each ecosystem and subject to share information, breaking the ''information island'' problem formed by the original information barrier. Third, the main bodies of the ecosystem establish contacts through point-to-point transmission and distributed ledger technology, form networked information exchanges, consolidate trust relationships between the main bodies, and open the information channel for supply and demand forecasting. Fourth, the single-chain and closed-loop constraints of the original platform ecosystem can be broken to form a networked, information-based industrial alliance with an effective regulatory system, expanding the market scale and introducing competition to platform enterprises. For the participants, this increased the number of cross-ecosystem links and expanded the resource network. For the government, improving the regulatory standards and establishing a unified regulatory system not only improves the efficiency of platform ecosystem activities but also strengthens supervision, reduces internal risks, and improves the ability to resist external risks jointly.

(2) Blockchain technology assists the government in providing timely supervision.

Excessive government intervention has caused excessive suppression of platform enterprises and restrained the development of platform ecosystems, which has led to excessive suppression of platform participants and the interest of participants and consumers. Therefore, the government's timely supervision mechanism is a practical problem that needs to be solved in platform ecosystem supervision.

A. APPLICATION SCENARIO

Smart contract technology in the blockchain can assist the government in timely regulation. Platform ecosystems conduct information interactions based on products or services. When market information is constantly updated, the government evaluates the transaction information. The smart contract is triggered based on the condition that the information evaluation result is within the regulatory range. If the evaluation result is within the regulatory range, the smart contract will send an alarm, and the government will intervene in the platform ecosystem for supervision. The government will not intervene in the platform ecosystem for regulation (if the government is now inside the platform ecosystem, the government will withdraw, and if not inside the platform ecosystem, it will remain unchanged) if the assessment result exceeds the regulatory range.

Blockchain technology can empower the government to solve the problem of the timely supervision of the platform ecosystem. In this process, we must rely on a reasonable government layout. From a risk management perspective, in-depth research should be conducted on information protection, technical specifications, data security, and other blockchain aspects. The government should strengthen the information disclosure of all subjects in the ecosystem platform system from the aspects of the development of the underlying core technology of the blockchain. The application of middle logic, the management, and control of upper information, building a sound smart contract and consensus mechanism, forming a regulatory system, and improving relevant legal work to ensure and protect the smooth application of blockchain technology in the platform ecosystem.

B. MECHANISM DESIGN

If government regulation is certain, then too much regulation leads to excessive regulation, the cost of government regulation is too high, and the development of platform enterprises is inhibited. In contrast, too low regulation leads to insufficient regulation, and markets cannot coexist freely. When the government regulation does not match the market competition, the social welfare level is reduced. Therefore, this paper establishes an intelligent contract mechanism to enable the government to supervise the platform ecosystem in time, which can make the government supervise the platform ecosystem reasonably and help promote information flow within the platform ecosystem, realizing the free competition and cooperation of the internal subject.

Smart contracts deployed in the blockchain enable the government to implement a timely regulatory process, and those smart contracts enabling the government to implement the regulatory platform ecosystem are shown in Figure 2. Platform enterprises and participants in the platform ecosystem in the blockchain network have their own databases, which are managed and stored in a distributed manner The government, platform enterprises and participants are playing games in the platform ecosystem, adjusting their competing strategies. The identity management contract (IMC) confirms and manages identity of the main body of the ecosystem through preset corresponding rules. A timely supervision contract (DSIC) dynamically adjusts the level of government regulatory input based on the positive externalities between the platforms and participants that choose different competing strategies and iterates according to preset triggers and corresponding rules to adjust government regulation to its best level and promote the free competition in the platform ecosystem.

First, each main body enters the platform ecosystem to carry out identity authentication. The IMC divides the principals into the customer user and the platform user and manages their identity certificates based on the type of principals in the platform ecosystem; then, calling the RSIC, according to the positive externality of the platform for participants, the government dynamically adjusts the level of supervision input. The IMC records the username user ID, the user attribute set role, and the associated smart contract RSIC. In the RSIC, government regulatory revenue S, regulatory cost C and global variables va*riable*[] are deployed. S includes externality income and welfare income, which correspond to the positive externality of the platform ecosystem and total social welfare, respectively; C includes supervise cost, which corresponds to the level of government supervision input λ. va*riable*[] is a variable that needs dynamic maintenance and includes mainly the number of platform ecosystem agents and game stage i.

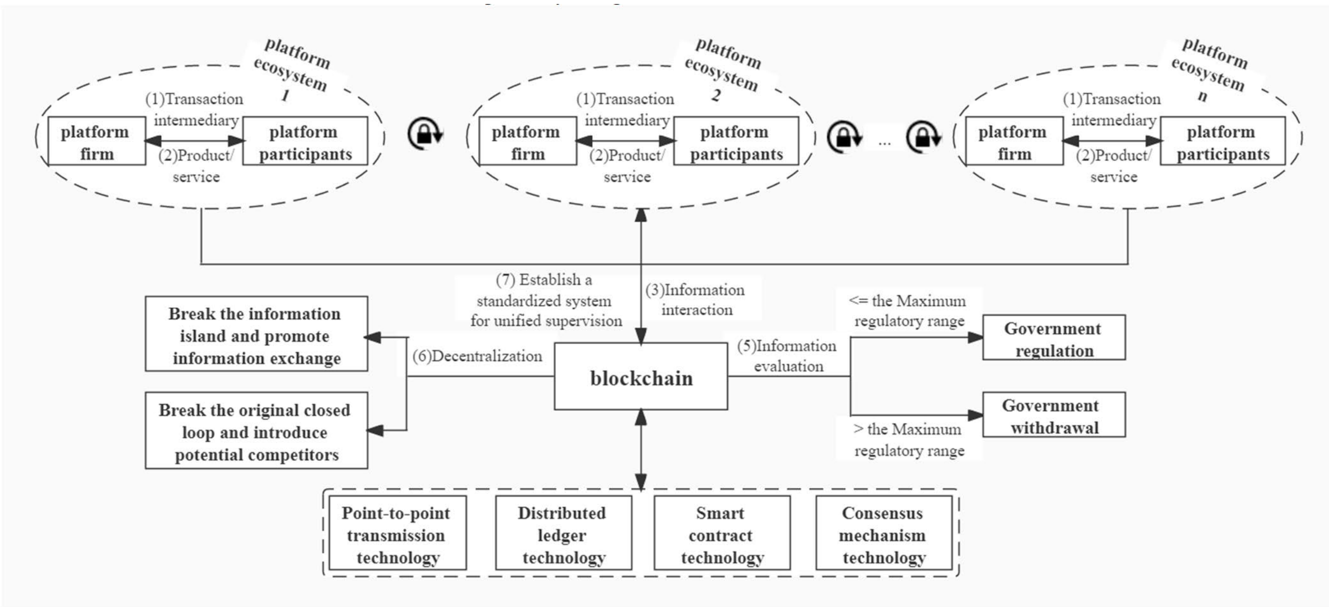

FIGURE 1. Application scenario of blockchain enabling government regulation.

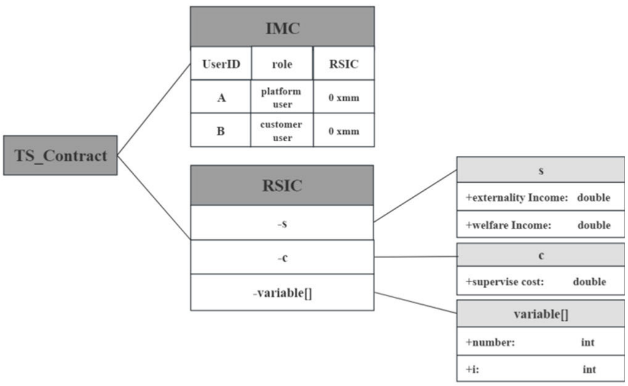

FIGURE 2. Smart contract of the platform ecosystem timely supervised by the government.

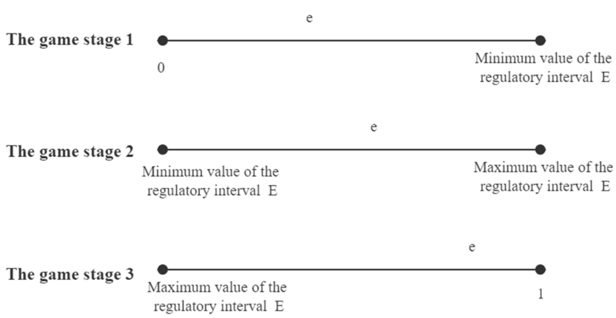

FIGURE 3. Governmental supervision process for the platform ecosystem.

C. MECHANISM REALIZATION

At the beginning of the game (Stage 1), in the platform ecosystem, players interact with platform enterprises in a competitive way, and the platform produces positive externality income for players. The total benefits also increase. As there is increasing competition between participants and the platform enterprise, externality income is increasing. When positive externality e is greater than the minimum value of regulatory interval E, the game enters Stage 2, regulatory contract RSIC is triggered in time, and the government enters platform ecosystem regulation. The dynamic iteration adjusts the government input level λ, and causes the social welfare level to be maintained at the optimized level. Until positive externality e increases to the maximum of regulatory range E, the game enters Stage 3, the regulatory contract RSIC is closed in time, the government withdraws from the platform ecosystem, and participants and platform enterprises compete and cooperate freely.

The algorithms needed for the platform ecosystem to invoke the IMC and RSIC are shown below.

Input: e
Output: λ, i
function
role= getUserType();
while (1)
{
if ($e < E_{\min}$)
λ =0;
$i = 1$;
continue;
else
if ($E_{\max} < e \leq E_{\min}$)
λ = getValue(welfare Income)
$i = 2$;
continue;
else
$\lambda = 0$;
$i = 3$;
continue;
}
Endfunction

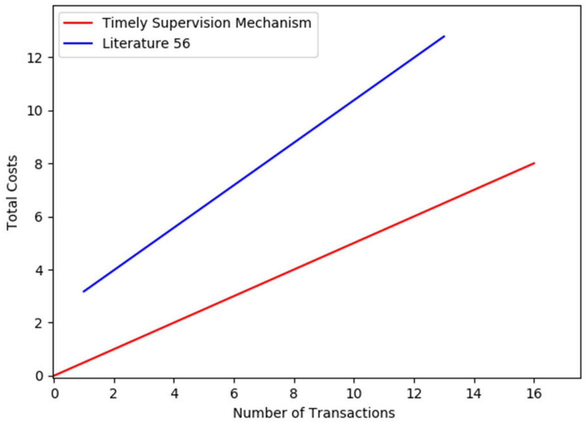

FIGURE 4. Comparison results of regulatory cost between timely supervision mechanism and literature [56].

V. SIMULATION EXPERIMENT

In this section, we evaluate whether the above timely regulation can meet the requirements of lower cost, timely supervision and the smooth system operation.

On a computer configured with a 2.3 GHz CPU, 16.0 GB of running memory, and a 64-bit operating system, the article uses MATLAB R2018a to call a Python program to simulate the government's process through the blockchain supervision platform ecosystem. Simulation and testing are conducted using Z-ledger based on the Hyperledger Fabric kernel as the deployment platform, comparing it with traditional trading platforms such as Ethereum. The permission management function accompanying this platform can well meet market entry needs. The network bandwidth is set to 100Mb/s, block size is set to 1Mb, and amount of data collected in one simulation is 32 bytes. To evaluate the timely supervision mechanism of this article, a comparison is made with the systems in references 56 in terms of regulatory cost and regulatory duration. The transaction scenario is set as follows: the number of network nodes is set to 1000, and 20 simulated transactions are conducted on the model in reference 56 and the timely supervision mechanism of this article. Regulatory cost is defined as the total number of node packets. The comparison results of regulatory cost is shown in Figures 4.

From Figure 4, it can be seen that the timely supervision mechanism in this article has reduced the total cost of the regulatory mechanism compared to literature [56]. Moreover, the timely supervision mechanism ensures that the total cost will not significantly increase with increasing blockchain network size, further verifying the availability of the timely supervision mechanism.

VI. CONCLUSION

Based on the game model of the decision-making behavior of the government and the participants in the platform ecosystem, this study examines the dynamic path of the government to promote the sound development of the ecosystem platform. It further analyzes the government's regulatory interval facing the platform ecosystem from the perspective of timely regulation and constructs an application scenario of blockchain enabling timely government regulation. Research shows:

(1) The market pattern of dynamic competition and cooperation in the platform ecosystem can achieve the goal of maximizing social welfare. Therefore, To ensure dynamic competition and cooperation in the platform ecosystem, the government should intervene for supervision when platform enterprises' has a significant negative impact. We have proved that there is an optimal interval for government regulation to maximize social welfare.

(2) The extended model shows that introducing competition can appropriately reduce pressure on government regulations. However, government supervision remains necessary if a platform ecosystem has an entry threshold that the introduction of competition may become difficult.

(3) Blockchain technology can empower the government to solve the problem of the timely supervision of platform ecosystems. The government regulation interval was established as a trigger mechanism for blockchain smart contracts. When the results of government information evaluation coincide with the trigger mechanism, the government intervenes in the platform ecosystem to supervise it. This mechanism avoids excessive supervision by the government.

In this critical period of economic transformation and development, the policy implication of this study is mainly to prevent the risk of platform enterprises monopolizing the market by virtue of their technological advantages. The timely regulatory policy proposed in this study is not to blindly protect platform participants with relatively backward technology. It is to appropriately regulate the market to maintain the market competition order and maximize social welfare, ultimately achieving dynamic competition and cooperation within the platform ecosystem. Therefore, regardless of whether the platform participants have completed the transformation and upgrading during the government's supervision period, they will eventually face free competition with platform enterprises, and the fittest will survive.

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