Attention Markets of Blockchain-Based Decentralized Autonomous Organizations

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***Abstract*—The attention is a scarce resource in decentralized autonomous organizations (DAOs), as their self-governance relies heavily on the attention-intensive decision-making process of "proposal and voting". To prevent the negative effects of proposers' attention-capturing strategies that contribute to the "tragedy of the commons" and ensure an efficient distribution of attention among multiple proposals, it is necessary to establish a market-driven allocation scheme for DAOs' attention. First, the Harberger tax-based attention markets are designed to facilitate its allocation via continuous and automated trading, where the individualized Harberger tax rate (HTR) determined by the proposers' reputation is adopted. Then, the Stackelberg game model is formulated in these markets, casting attention to owners in the role of leaders and other competitive proposers as followers. Its equilibrium trading strategies are also discussed to unravel the intricate dynamics of attention pricing. Moreover, utilizing the single-round Stackelberg game as an illustrative example, the existence of Nash equilibrium trading strategies is demonstrated. Finally, the impact of individualized HTR on trading strategies is investigated, and results suggest that it has a negative correlation with leaders' self-accessed prices and ownership duration, but its effect on their revenues varies under different conditions. This study is expected to provide valuable insights into leveraging attention resources to improve DAOs' governance and decision-making process.**

***Index Terms*—Attention, decentralized autonomous organizations, Harberger tax, Stackelberg game.**

I. Introduction

As an emerging technology that can revolutionize various industries, blockchain has been gaining increasing attention in recent years [1]−[3]. One of the most typical applications of blockchain is decentralized autonomous organizations (DAOs), which are organizations that operate without a central authority [4], [5], using smart contracts to facilitate decentralized decision-making and automate administrative tasks [6], [7]. DAOs are self-governing entities that enable members to collaborate and make collective decisions in a transparent and secure manner [8]−[10] leveraging the immutability and consensus mechanisms of the blockchain [11], [12]. The development of DAOs has broadened the definition of assets to encompass not only traditional economic tokens but also knowledge, trust, and attention [13], [14], as well as further innovating the way they are generated, traded, and valued in the decentralized economy [15], [16]. Among them, we put special focus on DAO members' attention, considering that the decision-making pattern of "proposal and voting" commonly used by DAOs is attention intensive [17]. In the context of DAOs, attention refers to the focus and engagement that members or participants dedicate to the activities, discussions, and decision-making processes within the organization [18], [19]. DAOs are by nature distributed and decentralized communities that rely on consensus among their members to produce governance decisions [20], [21], and the outcomes depend greatly on members' attention allocated to various proposals and the resulting voting choices [22], [23].

However, the allocation of attention in DAOs is not always straightforward. Due to the decentralized nature of DAOs [24], [25], members may have varying levels of incentives and interests while their attention spans are limited [26]. This opens up new opportunities for creating decentralized attention markets where DAO members can buy and sell their attention in a transparent and secure manner. However, the decentralization of attention also poses challenges of unequal allocation of attention, where certain proposals receive more attention than others, potentially leading to imbalanced decision-making [27]. Just as an "uncongested toll-free highway" is considered a public good, while a "congested toll-free highway" is considered a common good, attention in DAOs can also shift between being a public good and a common good, depending on the scale of demand. As the number of proposals increases, the competition for members' attention intensifies, causing attention to the transition from a public good to a common good. DAO members' average attention span decreases due to the constant barrage of information and distractions [28], leading to the development of new strategies

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aimed at capturing and retaining attention, e.g., some proposers resort to using attention-grabbing titles to draw members' attention to meaningless proposals. This could lead to the "tragedy of the commons" [29], [30], where valuable proposals with more straightforward titles may be neglected. This trend could lead to the entire DAO community resorting to attention-grabbing titles, further depleting attention quickly and wastefully. The mismatch between the value of proposals and the attention they get can impede the growth of DAOs.

Traditional solutions to address the "tragedy of the commons" have primarily involved privatized markets and administrative management [29], [31]. However, these solutions are not applicable to the attention economy of DAOs, and may even go against the principles and spirits of DAOs. On the one hand, DAOs are decentralized networks comprised of individuals with common goals and values, where individuals exhibit the traditional market behaviors of pursuing self-interests independently as well as autonomous and coordinated behaviors that involve mutual adaptation [32], [33]. Even if members are also owners and governors of a DAO, they cannot act solely in their self-interest. On the other hand, DAOs embody free will that is not controlled by centralized governance, relying instead on technology and incentives in a trustless environment to build collaborative relationships and address the problems of information asymmetry and its associated inefficiency losses [34]. Therefore, it is crucial to find a customized governance solution to address the "tragedy of the commons" of DAOs' attention as well as realize their effective allocation.

A feasible solution is to stimulate and accelerate the flow of social value and achieve a good allocation schedule for DAOs' attention in the market manner [35]. The first priority of such a solution is to clarify their property rights [36]. Along with the private and public property rights corresponding to the traditional solutions, there should be partial common property rights in DAOs, also known as partial common ownership (PCO) [37]. For the implementation of PCO in DAOs, the radical market (RM) approach offers a novel idea through the establishment of continuous trading [38]. It means attention can remain in a state of constant property rights claim and exchange, preventing permanent ownership by any member. Aiming to facilitate RM for achieving this continuous trading, proper monetary mechanisms and pricing methods for DAOs' attention need to be employed. However, the most commonly used auction-based pricing methods, such as the Vickrey Commons [39] are not applicable due to the following reasons. Traditionally, attention in the digital economy is controlled by centralized entities, such as social media platforms and advertising networks. These entities use algorithms and auction mechanisms to match the supply and demand of attention [40]–[42], but the process is often opaque and vulnerable to manipulation. In contrast, attention in DAOs can be completely controlled by the individuals who generate it. This has given rise to the decentralized attention allocation pattern that requires the auction to be conducted in a many-to-many manner, making it challenging to maintain fairness and efficiency as the DAO community expands. Besides, the generation of attention in DAOs is inherently an infinite game, where both proposers continuously submit multiple bids to reach a deal, making it difficult to guarantee efficient trading [43], [44]. Moreover, the dynamic conversion of public and private property in the open Web3 network results in high liquidity of attention.

In RM, the self-assessed pricing mechanism can be utilized to address the problems discussed above, since it advocates compensating the previous owner for facilitating the attention trading. However, proposers may not tend to clarify their true values on DAOs' attention to create the information asymmetry [45]. To tackle this challenge, the Harberger tax (HT) is introduced as the self-assessed pricing method that offers a more precise way to build a strong relationship between the price and value [38], [46]. The basic principles of HT boil down that the owner of a good or asset must periodically announce its market price and pay the tax accordingly as long as he owns it, and any interested buyer can purchase it at that price [47]. HT is seen as a means of ensuring that the market price of attention is close to its true value, because a high price will lead to a high tax while a low price will make the ownership of attention acquired by others [48]. Besides, the employment of HT can eliminate the private monopoly and promote market transactions, thereby increasing the efficiency of allocating the ownership of DAOs' attention. As such, it is in favor of maintaining the dynamic and fair attention markets of DAOs. In turn, DAOs also provide a feasible environment to implement HT, since all related information is recorded in blockchain in a secure, transparent, real-time fashion, and smart contracts are used to automate the tax collection and ownership transfer [49]–[51]. In addition, the decentralized governance structure of DAOs minimizes the concentration of power and reduces the risk of tax abuse, thereby promoting fairness in setting rules concerning tax and trading [52], [53].

The key to establishing a successful market for DAOs' attention is to determine an appropriate Harberger tax rate (HTR). In general, HTR is a constant depending on the weighing of the investment and allocation. When the asset value strongly depends on the owner's investment, the HTR should be low and close to the observable turnover rate, while when the monopoly problem is severe, the HTR should be high regardless of the asset turnover rate [54]. Therefore, it is not feasible for DAOs' attention markets to employ a relatively low HTR, as the only consideration is to optimize the allocation and prevent monopoly but not an investment. In terms of traditional assets, it has been advocated to disregard overly granular HTR and instead adopt coarse-grained rates for a small number of easily distinguishable property classes, such like natural resources, and real estate [48].

Although there are considerations of different tax rates for different classes of properties, the differences in the social values resulting from the ownership of the same property held by different people are seldom investigated. However, this is exactly what should be viewed highly in DAOs. Because the benefits brought by different proposals' access to attention have remarkable differences, e.g., the attention devoted to meaningful proposals is more valuable to the whole DAO community than evil or speculative ones, and the changes in attention allocation may significantly alter the landscape of various proposals and then have a profound impact on the development of DAO community. Considering that the proposers' reputation can be regarded as a prerequisite for evaluating proposals' values and impacts [55], [56], and blockchain provides a new way to define and quantify proposers' reputation via the performance of their previous proposals and votes, we are motivated to adopt the individualized HTR based on each proposer's reputation in these markets [57], [58].

After establishing the DAOs' attention markets based on individualized HT, the pricing strategies in trading attention will also be discussed. Each proposer needs to compete for limited attention resources, resulting in the inability to independently determine the self-assessed price of attention when he is the owner or the offering price when he wants to be the owner. Therefore, the game model should be used to study proposers' optimal strategies concerning attention ownership and trading. According to the rules of HT, the Stackelberg game model of DAOs' attention markets is formulated, where the owner is regarded as a leader employing the strategy of announcing the appropriate price while other competitive proposers are regarded as followers having strategies of submitting the appropriate offers. Our study starts with establishing the Stackelberg game to capture the dynamic nature of DAOs' attention trading, for which the solution process of the equilibrium strategy profile is given. Then, the single-round Stackelberg game is taken as an example to more directly demonstrate the existence of attention trading equilibrium as well as investigate the impact of individualized HTR on attention pricing.

The major contributions of this study include: 1) The new insights into the governance of DAOs' attention is provided by designing the HT-based attention markets, where the individualized HTR is employed to highlight the importance of distinguishing the values that different proposals can generate to the DAO community in terms of investing attention; 2) The Stackelberg game model is established and analyzed in the formulated attention markets to explore how attention is priced via proposers' competitive responses.

The remaining part of the paper proceeds as follows: Section II presents DAOs' attention markets based on Harberger tax; Section III formulates the Stackelberg game model of DAOs' attention markets; Section IV analyzes proposers' equilibrium trading strategies; Section V makes a brief discussion of this study and points out potential directions for future research; Section VI summarizes this paper.

II. DAOs' Attention Markets Based on Harberger Tax

In a DAO, any member can create a proposal that is submitted for discussion on the platform or forum. Feedback is provided by others to address potential issues and refine the proposal before it goes to the vote. Generally, the voting takes place using predetermined modes like token-based or reputation-based voting.

To promote the adoption of their proposals, proposers strive to capture the attention of voters. To facilitate the attention allocation, the economic policy of HT is implemented to trade attention and design DAOs' attention markets, that is, each attention owner should pledge HT to maintain the ownership of attention. This market design can provide an environment for proposers in DAOs to trade on the expected values generated by attention invested in proposals.

A. Harberger Tax

Generally, HT encourages owners to set an adequate price that can balance the tax they pay and the attention duration they keep. The basic rules of HT for pricing DAOs' attention are as follows: 1) The owner announces the self-assessed price of his attention zone publicly and pledges HT accordingly; 2) Ownership of attention can be taken by any other proposer offering the price at any time during the period. Meanwhile, the HT difference between the pledged duration and the actual duration will be returned to the original owner. Then, the new owner sets a new price.

The traditional practice of HT is that only when the new purchasing offer reaches the owner's price, the ownership is immediately transferred to the new owner. However, attention is a perishable resource different from traditional properties. If the ownership transfer conditions of traditional HT are not met, the retained attention will not generate new value for the owner. Because attention invested in proposals instead of proposers can produce values, it is difficult for DAO members to continuously suggest new proposals. Aiming to avoid such invalid waste of attention, it is regulated that nobody can offer prices to obtain attention or pledge HT to retain attention for his proposal with voting duration outside the certain period. Meanwhile, when the voting duration ends, the attention owner will automatically lose ownership. Besides, high HTR is set to encourage the attention trade so as to allow more proposals to get attention in favor of screening out valuable ones from numerous proposals in DAOs.

Aiming to design attention markets of DAOs, attention should be treated as the tradable underlying assets. When quantifying attention as a type of assent within DAOs, the calculation of time invested serves as the most significant and tangible metric. However, it is essential to account for the quality of attention, such as concentration and perceptiveness of proposers. Taking these into consideration, attention is divided into clear trading zones, and each zone is defined by the time dimension and range dimension. From the time dimension, attention in DAOs is divided into J periods equally, each of which is roughly the same as the preset voting duration τ. From the range dimension, we suppose that the size of DAO members stays unchanged and the attention of each one is indiscriminate. By doing so, we can start from the perspective of members and categorize their attentions into different sets from the range dimension. That is, attention within a DAO is divided into K sets, and each set D^k has m DAO members' attention. To ensure that each set can provide enough attention while avoiding the negative impact of excessive attention devoted to some proposals, m is the trade-off between the total number of DAO members and the threshold of attention required by a proposal. The composition of each attention set in the same period does not coincide.

The collection of proposals with voting duration falling into the period j is $Z_j = \{z_{1,j},\ldots,z_{x,j},\ldots\}$. Suppose that each proposer only has one proposal for voting in a specific period, the attention zone owned by the proposal (or proposer) $z_{x,j}$ is denoted by $D_{x,j}$. He can pledge HT $\overline{HT}_{x,j}$ for any desired duration of the attention ownership, but only need to pay $HT_{x,j}$ for the actual duration, that is

$$\overline{HT}_{x,j} = s_{x,j} r_{x,j}$$
$$HT_{x,j} = s_{x,j} r_{x,j} \frac{p_{x,j}}{\tau}. \quad (1)$$

Here, $p_{x,j}$ is the actual attention ownership duration, $s_{x,j}$ is the self-assessed price, and $r_{x,j}$ is the accumulated HTR of the entire period j. Generally, higher $s_{x,j}$ and longer $p_{x,j}$ lead to higher $HT_{x,j}$. Moreover, in an effort to avoid malicious proposals and meaningless proposals taking up attention, the reputation of the proposer is taken into consideration to formulate the individualized HTR $r_{x,j} = \beta_{x,j} r$. Here, r is the base tax rate, $\beta_{x,j}$ is the reputational weight, and higher reputation will lead to lower $\beta_{x,j}$ and lower $r_{x,j}$. It is worth noting that it is possible to have $r_{x,j} \geq 1$. Just like its usage in decentralized applications, the daily rate is adopted while the cumulative tax rate of a certain period can exceed 1. Besides, DAOs' attention markets encourage continuous trading, and a high tax rate is a means to promote it.

B. Attention Trading

In DAOs' attention markets based on HT, blockchain-enabled smart contracts are used to automatically execute trades. These smart contracts are by nature computer protocols that self-verify and automatically enforce the committed rules. Thus, they can ensure that the attention trading can be carried out in a real-time and unmanned fashion, creating an efficient and fair environment for the continuous trading of DAOs' attention. The detailed process of attention trading supported by smart contracts is shown in Fig. 1.

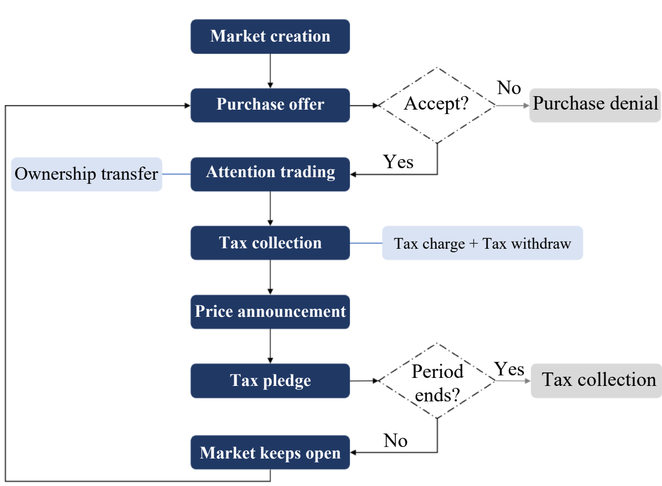

Fig. 1. The trading process of DAOs' attention markets.

Step 1: Market Creation

The attention timeline of a DAO is divided into J periods, and each belongs to one attention trading contract. Before the starting time t_j of period j, the attention trading contract SC_j will be created in advance, but only when the time comes to $\bar{t} = t_j$, it will be opened automatically for proposers to purchase their desired attention sets.

Step 2: Purchase Offer

The contract SC_j is in essence a series of smart contracts corresponding to each attention set, i.e. $SC_j = (SC_j^1,\ldots,SC_j^K)$, which support the ownership exchange between DAO proposers in the jth period. For the trading of an attention zone D_j^k, any price offered by the first owner that is no less than the threshold can be accepted; otherwise, only the price no less than the announced one of the current owner can be accepted. If there are multiple acceptable offers, only the one submitted first will be determined as the new owner.

Step 3: Attention Trading

For the attention zone D_j^k, the payment of its new owner $z_{x,j}$ will be automatically performed by the contract SC_j^k. After that, the ownership will be transferred to the new owner, that is $D_{x,j} = D_j^k$.

Step 4: Tax Collection

Meanwhile, HT will be charged to the previous owner according to the actual ownership duration, and the HT difference due to the actual duration being shorter than the pledged duration will be withdrawn to him.

Step 5: Price Announcement

The new owner $z_{x,j}$ should announce his self-assessed price $s_{x,j}$ of the owned attention zone $D_{x,j}$.

Step 6: Tax Pledge

The new owner $z_{x,j}$ pledges HT for the corresponding attention zone to the tax pool of the DAO.

The attention trading market of period j will remain open until the end time $t_j + \tau$. The state of the specific attention trading contract SC_j depends on the current time $\bar{t}$; if $\bar{t} < t_j$, the contract will be executed automatically when its defined period comes; if $\bar{t} \in [t_j, t_j + \tau)$, the contract is undergoing; while if $\bar{t} \geq t_j + \tau$, the contract has been closed.

Based on the above analysis, taking the attention set D^k as an example, there are two cases of ownership transfer during period j in DAOs' attention markets. *Case 1:* At least one proposer submits the purchasing offer exceeding the price, the ownership of D^k will be transferred in this period (as shown in Fig. 2). *Case 2:* No one proposes the purchase offer with price exceeding that announced by the current owner, so there is no attention trading in this period and the ownership of D^k remains unchanged until the next period $j+1$. Meanwhile, all HT pledged by the owner will be collected by the DAO community (as shown in Fig. 3).

Take the case that the attention ownership is only transferred once in period j as the example to illustrate how DAOs' attention markets work. The owner $z_{1,j}$ obtains the ownership at the very beginning of period j, set the self-assessed price $s_{1,j}$ and also pledges the corresponding HT for the entire period. At time $t_j + t' < t_j + \tau$, the proposer $z_{2,j}$ offering a price $q_{2,j} \geq s_{1,j}$ will take the ownership since then. The actual duration of $z_{1,j}$ is $p_{1,j} = t'$, and he will get paid at the offered price and also be returned the HT difference.

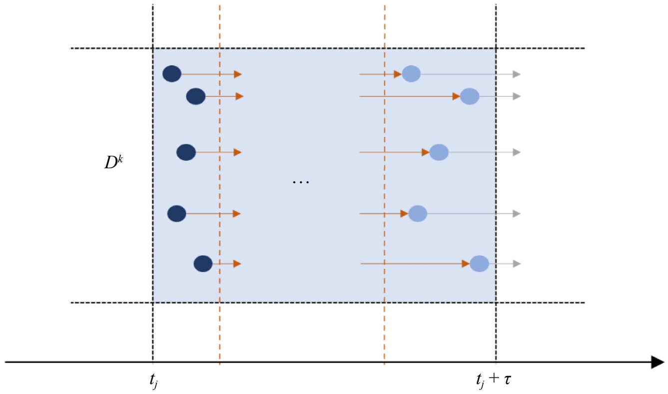

Fig. 2. There is attention trading in period j.

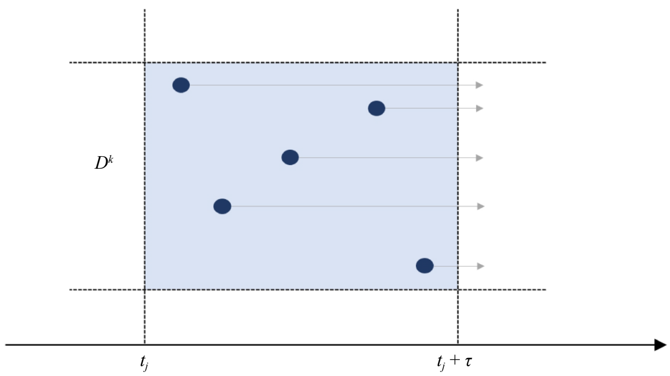

Fig. 3. There is no attention trading in period j.

$$G_{1,j}=q_{2,j}+s_{1,j}r_{1,j}\frac{\tau-t'}{\tau}. \tag{2}$$

Then, the new owner $z_{2,j}$ sets the price $s_{2,j}$, and pledges $\overline{HT}_{2,j}$ for the duration $p_{2,j}=\tau-t'$,

$$\overline{HT}_{2,j}=s_{2,j}r_{2,j}\frac{\tau-t'}{\tau}. \tag{3}$$

C. Proposers' Revenues

The revenue $R_{x,j}$ of the owner $z_{x,j}$ is composed of four parts: 1) the value $V_{x,j}$ generated by attention invested to his proposal that makes it be noticed or passed, 2) the payment from transferring the ownership $G_{x,j}$, 3) the price charged to obtain attention ownership $q_{x,j}$, 4) the paid HT $HT_{x,j}$.

$$R_{x,j}=V_{x,j}+G_{x,j}-q_{x,j}-HT_{x,j}. \tag{4}$$

Among them, $V_{x,j}$ is calculated by the following function:

$$V_{x,j}=A_{x,j}p_{x,j}v_{x,j}. \tag{5}$$

Here, the product of attention intensity $A_{x,j}$ and ownership duration is used to express the invested attention, and $v_{x,j}$ represents the value of unit attention to the owner. With the attention ownership transfer, the attention of a DAO member can be paid to multiple proposals in the same period. However, people's attention is limited and will be rapidly consumed with the increase of information obtained. Therefore, we consider that the attention intensity decreases with the sequence of obtaining attention, that is

$$A_{x,j}>A_{x+1,j}, \forall z_{x,j}\in Z_j. \tag{6}$$

Here, $z_{x,j}$ denotes the xth proposal with attention paid by a DAO member in the period j, and $A_{x,j}$ is its attention intensity. The attention intensity is modeled as the following exponential attenuation function:

$$A_{x,j}=\alpha^{x-1}m \tag{7}$$

where $0<\alpha<1$ is the attenuation coefficient. If $x=1$, there is $A_{1,j}=m$, which means the first owner of the attention set wins the complete attention; otherwise, $0<A_{x,j}<m$, which means the other owners win the incomplete attention.

Accordingly, we have

$$R_{x,j}=\alpha^{x-1}mp_{x,j}v_{x,j}+q_{x+1,j}-q_{x,j}-s_{x,j}r_{x,j}\frac{p_{x,j}}{\tau}. \tag{8}$$

III. The Stackelberg Game Model of DAOs' Attention Markets

The price of attention zone is the result of the game played by the owner and other proposers in DAOs' attention markets. The owner's self-assessed strategy is affected by the coming purchasing offers; meanwhile, other proposers' purchasing strategies are the response to it. However, the owner's self-assessed strategy will neither influence that of the next owner nor be influenced by that of the previous owner. In view that both self-assessed prices and purchasing offers are public information in the blockchain-based DAOs, we consider the trading game in attention markets to be a sequential dynamic game with complete information that can be regarded as a Stackelberg game [59], [60]. In such a game, the owner $z_{x,j}$ is the leader who sets the price $s_{x,j}$, and another proposer $z_{x+1,j}$ is the follower who submits the purchasing offer $q_{x+1,j}$.

For any proposer $z_{x+1,j}$ who wants to purchase the attention set, given $s_{x,j}$, there are only two strategies for him to choose: either $q_{x+1,j}=0$ or $q_{x+1,j}=s_{x,j}$, which depends on the revenues generated by the optimal price $s^*_{x+1,j}$. Consequently, there is

$$q^*_{x+1,j}=\begin{cases} s_{x,j}, & R_{x+1,j}(s_{x,j},s^*_{x+1,j})>0\\ 0, & R_{x+1,j}(s_{x,j},s^*_{x+1,j})\le 0. \end{cases} \tag{9}$$

Especially, when $x=1$, the offered price $q_{1,j}$ equals the predetermined fixed threshold $s_{0,j}$.

The leader $z_{x,j}$ must have paid at the price $q^*_{x,j}=s_{x-1,j}$ to take the attention, and currently should determine the optimal self-assessment $s^*_{x,j}$, which is subject to the follower's purchasing offer $q^*_{x+1,j}$. The follower $z_{x+1,j}$ cannot determine the optimal offer $q^*_{x+1,j}$ separately, but needs to optimize jointly with his self-assessment $s^*_{x+1,j}$, considering that $q^*_{x+1,j}$ only resolves the transfer of attention ownership while the ownership duration depends on $s^*_{x+1,j}$.

The Stackelberg game in DAOs' attention markets continues for multiple rounds as shown in Fig. 4, where $q^*_{x+1,j}$ is influenced by $s^*_{x+1,j}$, while $s^*_{x+1,j}$ is coupled with $q^*_{x+2,j}$, so that the proposer $z_{x+1,j}$ and $z_{x+2,j}$ will form the new leader-follower game relationship. This game continues until the end

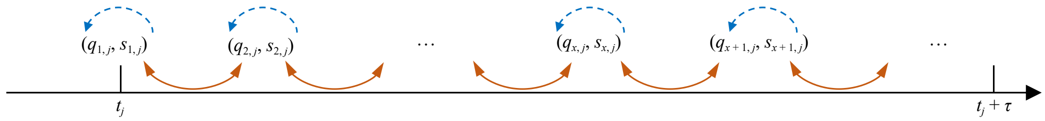

Fig. 4. The strategic response in the multi-round Stackelberg game.

of period j or there is no demand for attention trades. This indicates that only considering $z_{x,j}$ and the closely followed $z_{x+1,j}$ cannot figure out the equilibrium strategy $(s^*_{x,j}, q^*_{x+1,j})$ of the Stackelberg game.

First, we discuss the equilibrium strategy for any pair of leader-follower in the multi-round Stackelberg game.

If $q^*_{x+1,j} = s_{x,j}$, the leader's revenue is

$$R_{x,j}(1) = \alpha^{x-1} m p_{x,j} v_{x,j} + s_{x,j} - s_{x-1,j} - s_{x,j} r_{x,j} \frac{p_{x,j}}{\tau}. \quad (10)$$

Taking the partial of $R_{x,j}(1)$ with respect to $s_{x,j}$, we get

$$\frac{\partial R_{x,j}(1)}{\partial s_{x,j}} = (\alpha^{x-1} m v_{x,j} - \frac{s_{x,j} r_{x,j}}{\tau}) \frac{\partial p_{x,j}}{\partial s_{x,j}} + 1 - \frac{r_{x,j} p_{x,j}}{\tau}. \quad (11)$$

Let $\frac{\partial R_{x,j}(1)}{\partial s_{x,j}} = 0$, the optimal self-assessment $s^*_{x,j}(1)$ under this case can be got.

If $q^*_{x+1,j} = 0$, the leader's revenue is

$$R_{x,j}(2) = (\alpha^{x-1} m v_{x,j} - \frac{s_{x,j} r_{x,j}}{\tau})(\tau - \sum_{d=1}^{x-1} p_{d,j}) - s_{x-1,j}. \quad (12)$$

The self-assessment in this case must be high enough to exclude any potential purchasing offer. Meanwhile, the leader wants to pay HT as little as possible. As such, the optimal price will be set as

$$s^*_{x,j}(2) = \min\{s_{x,j} | R_{x+1,j}(s_{x,j}, s^*_{x+1,j}) \leq 0\}. \quad (13)$$

The leader's optimal self-assessed price $s^*_{x,j}$ can be got by comparing $R^*_{x,j}(1)$ and $R^*_{x,j}(2)$.

$$s^*_{x,j} = \begin{cases} s^*_{x,j}(1), & R^*_{x,j}(1) > R^*_{x,j}(2) \\ s^*_{x,j}(2), & R^*_{x,j}(1) < R^*_{x,j}(2) \\ s^*_{x,j}(1) \quad or \quad s^*_{x,j}(2), & R^*_{x,j}(1) = R^*_{x,j}(2). \end{cases} \quad (14)$$

Then, the backward iteration is conducted to finally get the equilibrium strategy $(s^*_{x,j}, q^*_{x+1,j})$ of the Stackelberg game in DAOs' attention markets. It starts from analyzing the game of the last pair of leader-follower and obtaining their equilibrium strategies, which will be iterated to the revenue functions of the previous pair to obtain their equilibrium strategies, and so on until the first pair of leader-follower in period j.

IV. Trading Strategies in the Stackelberg Game

Although the multi-round Stackelberg games discussed above are more accordant with DAOs' practices, proposers are inclined to assume that they can keep the attention ownership for the rest of the period when pledging HT and estimating returns, because it is very difficult for proposers to precisely predict the purchasing offers in the future rounds. This will lead them to optimize their strategies with the thinking of the single-round games. Besides, we try to discuss the game equilibrium in a more detailed way as well as analyze the impact of HT on it. In view of these, this section studies the special case of the proposed Stackelberg game, namely the single-round Stackelberg game in DAOs' attention markets, where the leader is $z_{1,j}$ and the follower is $z_{2,j}$.

A. Equilibrium Analysis

As follows, we first investigate the proposers' equilibrium pricing decisions in the single-round Stackelberg Game of DAOs' attention markets. To facilitate the following analysis, the example function is formulated to calculate $p_{x,j}$, considering that $p_{x,j}$ grows longer with the increase of $s_{x,j}$ when $s_{x,j} > 0$, but the growth rate will gradually decrease.

$$p_{x,j} = \tau - \frac{c}{s_{x,j}}. \quad (15)$$

Here, we have $p_{x,j} \geq 0$.

Lemma 1: In the single-round Stackelberg game of DAOs' attention markets, when $r_{1,j} > 1 + \frac{v_{1,j}}{\alpha v_{2,j}}$, the strategy profile $(s^*_{1,j} = \sqrt{\frac{c v_{1,j}}{r_{1,j}-1}}, q^*_{2,j} = s^*_{1,j})$ qualifies as its possible equilibrium.

Proof: If $q_{2,j} = s_{1,j}$, the leader's attention ownership duration will be shorter than τ. For the simplicity of calculation, we also suppose $m = 1$. Therefore, the leader's revenue is

$$R_{1,j}(1) = (\tau - \frac{c}{s_{1,j}}) v_{1,j} + s_{1,j} - s_{0,j} - s_{1,j} r_{1,j} (1 - \frac{c}{\tau s_{1,j}}). \quad (16)$$

Accordingly, there is

$$\frac{\partial R_{1,j}(1)}{\partial s_{1,j}} = \frac{(\tau v_{1,j} - s_{1,j} r_{1,j}) c}{\tau {s_{1,j}}^2} + 1 - r_{1,j} (1 - \frac{c}{\tau s_{1,j}}). \quad (17)$$

Then, we figure out the leader's optimal self-assessed price $s^*_{1,j}(1)$ that makes $\frac{\partial R_{1,j}(1)}{\partial s_{1,j}} = 0$. So, we have

$$\frac{c v_{1,j}}{{s_{1,j}}^2} = r_{1,j} - 1. \quad (18)$$

When $0 < r_{1,j} \leq 1$, there is no optimal self-assessed price, because the leader is motivated to raise the price to fight for the duration infinitely approximate to the entire period j. When $r_{1,j} > 1$, the leader's optimal self-assessed price under the case $q_{2,j} = s_{1,j}$ is

$$s^*_{1,j}(1) = \sqrt{\frac{c v_{1,j}}{r_{1,j} - 1}}, \quad (19)$$

which leads his maximal revenue to be equal to

$$R^*_{1,j}(1) = \tau v_{1,j} + \frac{c r_{1,j}}{\tau} - s_{0,j} - 2\sqrt{c v_{1,j} (r_{1,j} - 1)}. \quad (20)$$

Meanwhile, the follower's revenue is defined by

$$R_{2,j}(1) = (\alpha v_{2,j} - \frac{v_{1,j}}{r_{1,j} - 1} - \frac{s_{2,j} r_{2,j}}{\tau}) \sqrt{\frac{c(r_{1,j} - 1)}{v_{1,j}}}. \quad (21)$$

Since there is no minimum limit for proposers to set the self-assessment, the follower's optimal price is $s^*_{2,j}=0$. As a result, his maximal revenue is

$$R^*_{2,j}(1)=(\alpha v_{2,j}-\frac{v_{1,j}}{r_{1,j}-1})\sqrt{\frac{c(r_{1,j}-1)}{v_{1,j}}} \tag{22}$$

which should meet the condition described by (9). That is,

$$\alpha v_{2,j}-\frac{v_{1,j}}{r_{1,j}-1}>0. \tag{23}$$

This implies that the strategy profile ($s^*_{1,j}=\sqrt{\frac{cv_{1,j}}{r_{1,j}-1}}$, $q^*_{2,j}=s^*_{1,j}$) is a potential equilibrium when $r_{1,j}>1+\frac{v_{1,j}}{\alpha v_{2,j}}$. ■

Lemma 2: In the single-round Stackelberg game of DAOs' attention markets, the strategy profile ($s^*_{1,j}=\sqrt{\alpha c v_{2,j}}, q^*_{2,j}=0$) qualifies as its possible equilibrium.

Proof: If $q_{2,j}=0$, the leader's attention ownership duration is $p_{1,j}=\tau$ and his revenue is

$$R_{1,j}(2)=\tau v_{1,j}-s_{0,j}-s_{1,j}r_{1,j}. \tag{24}$$

Here, $s^*_{1,j}(2)$ must be high enough to force the follower to take the response strategy of giving up the purchasing offer. As such, the following conditions should hold:

$$R_{2,j}(2)=\alpha p_{2,j}v_{2,j}-s_{1,j}\le 0, \forall p_{2,j}>0. \tag{25}$$

That is,

$$\alpha v_{2,j}(\tau-(\tau-\frac{c}{s_{1,j}}))-s_{1,j}\le 0, \forall p_{2,j}>0. \tag{26}$$

Then, the leader's optimal price and the maximal revenue under this case can be got as

$$s^*_{1,j}(2)=\sqrt{\alpha c v_{2,j}} \tag{27}$$

$$R^*_{1,j}(2)=\tau v_{1,j}-s_{0,j}-r_{1,j}\sqrt{\alpha c v_{2,j}}. \tag{28}$$

Here, we obtain that the strategy profile ($s^*_{1,j}=\sqrt{\alpha c v_{2,j}}$, $q^*_{2,j}=0$) can be a possible equilibrium. ■

Theorem 1: In the single-round Stackelberg game of DAOs' attention markets, if $r_{1,j}>1+\frac{v_{1,j}}{\alpha v_{2,j}}$, the equilibrium ($s^*_{1,j}=\sqrt{\frac{cv_{1,j}}{r_{1,j}-1}}$, $q^*_{2,j}=s^*_{1,j}$) will be achieved when either $0<v_{1,j}\le(\frac{\sqrt{c}}{\tau}+\sqrt{\alpha v_{2,j}})^2$ or $v_{1,j}>(\frac{\sqrt{c}}{\tau}+\sqrt{\alpha v_{2,j}})^2$ with $r_{1,j}$ satisfying one of the following conditions:

1) $r_{1,j}>\frac{2\tau^2 v_{1,j}}{(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2}+\Lambda$ or $1+\frac{v_{1,j}}{\alpha v_{2,j}}<r_{1,j}<\frac{2\tau^2 v_{1,j}}{(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2}-\Lambda$, when $1+\frac{v_{1,j}}{\alpha v_{2,j}}<\frac{2\tau^2 v_{1,j}}{(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2}-\Lambda$;

2) $r_{1,j}>\frac{2\tau^2 v_{1,j}}{(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2}+\Lambda$, when $\frac{2\tau^2 v_{1,j}}{(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2}-\Lambda\le 1+\frac{v_{1,j}}{\alpha v_{2,j}}\le\frac{2\tau^2 v_{1,j}}{(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2}+\Lambda$;

3) $r_{1,j}>1+\frac{v_{1,j}}{\alpha v_{2,j}}$, when $1+\frac{v_{1,j}}{\alpha v_{2,j}}>\frac{2\tau^2 v_{1,j}}{(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2}+\Lambda$.

Proof: To make the potential equilibrium strategy ($s^*_{1,j}=\sqrt{\frac{cv_{1,j}}{r_{1,j}-1}}$, $q^*_{2,j}=s^*_{1,j}$) described in Lemma 1 be the final equilibrium strategy, it must have $R^*_{1,j}(1)\ge R^*_{1,j}(2)$, namely

$$\frac{cr_{1,j}}{\tau}-2\sqrt{cv_{1,j}(r_{1,j}-1)}+r_{1,j}\sqrt{\alpha c v_{2,j}}\ge 0. \tag{29}$$

Further calculation yields

$$(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2 {r_{1,j}}^2-4\tau^2 v_{1,j}r_{1,j}+4\tau^2 v_{1,j}\ge 0. \tag{30}$$

Here, we have $\Delta=16\tau^2 v_{1,j}(\tau^2 v_{1,j}-(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2)$.

If $\tau^2 v_{1,j}-(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2<0$, (29) is always established, and ($s^*_{1,j}=\sqrt{\frac{cv_{1,j}}{r_{1,j}-1}}, q^*_{2,j}=s^*_{1,j}$) is the final equilibrium.

If $\tau^2 v_{1,j}-(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2=0$, when $r_{1,j}=\frac{2\tau^2 v_{1,j}}{(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2}=2$, we have $R^*_{1,j}(1)=R^*_{1,j}(2)$. However, since $r_{1,j}>1+\frac{v_{1,j}}{\alpha v_{2,j}}$, there is

$$r_{1,j}>1+\frac{(\frac{\sqrt{c}}{\tau}+\sqrt{\alpha v_{2,j}})^2}{\alpha v_{2,j}}>2. \tag{31}$$

This means we can only get $R^*_{1,j}(1)>R^*_{1,j}(2)$ if $v_{1,j}=(\frac{\sqrt{c}}{\tau}+\sqrt{\alpha v_{2,j}})^2$.

The above analysis signifies that if $0<v_{1,j}\le(\frac{\sqrt{c}}{\tau}+\sqrt{\alpha v_{2,j}})^2$, it will always be $R^*_{1,j}(1)>R^*_{1,j}(2)$.

If $\tau^2 v_{1,j}-(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2>0$, i.e., $v_{1,j}>(\frac{\sqrt{c}}{\tau}+\sqrt{\alpha v_{2,j}})^2$, one of the following conditions should be satisfied for (29). That is, either

$$r_{1,j}>\frac{2\tau^2 v_{1,j}+2\tau\sqrt{v_{1,j}(\tau^2 v_{1,j}-(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2)}}{(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2} \tag{32}$$

or

$$r_{1,j}<\frac{2\tau^2 v_{1,j}-2\tau\sqrt{v_{1,j}(\tau^2 v_{1,j}-(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2)}}{(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2}. \tag{33}$$

To facilitate the following analysis, let:

$$\Lambda=\frac{2\tau\sqrt{v_{1,j}(\tau^2 v_{1,j}-(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2)}}{(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2}. \tag{34}$$

When $1+\frac{v_{1,j}}{\alpha v_{2,j}}<\frac{2\tau^2 v_{1,j}}{(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2}-\Lambda$, to make (29) established, there should be either

$$r_{1,j}>\frac{2\tau^2 v_{1,j}}{(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2}+\Lambda \tag{35}$$

or

$$1+\frac{v_{1,j}}{\alpha v_{2,j}}<r_{1,j}<\frac{2\tau^2 v_{1,j}}{(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2}-\Lambda. \tag{36}$$

When $\frac{2\tau^2 v_{1,j}}{(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2}-\Lambda\le 1+\frac{v_{1,j}}{\alpha v_{2,j}}\le\frac{2\tau^2 v_{1,j}}{(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2}+\Lambda$, (29) holds only when

$$r_{1,j}>\frac{2\tau^2 v_{1,j}}{(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2}+\Lambda. \tag{37}$$

When $1+\frac{v_{1,j}}{\alpha v_{2,j}}>\frac{2\tau^2 v_{1,j}}{(\sqrt{c}+\tau\sqrt{\alpha v_{2,j}})^2}+\Lambda$, (29) holds only when

$$r_{1,j} > 1 + \frac{v_{1,j}}{\alpha v_{2,j}}. \tag{38}$$

■

Theorem 2: In the single-round Stackelberg game of DAOs' attention markets, the equilibrium $(s^*_{1,j} = \sqrt{\alpha c v_{2,j}}, q^*_{2,j} = 0)$ will be achieved if $0 < r_{1,j} \le 1 + \frac{v_{1,j}}{\alpha v_{2,j}}$, or $r_{1,j} > 1 + \frac{v_{1,j}}{\alpha v_{2,j}}$, $v_{1,j} > (\frac{\sqrt{c}}{\tau} + \sqrt{\alpha v_{2,j}})^2$ and none of conditions illustrated in Theorem 1 is met.

Proof: If $0 < r_{1,j} \le 1 + \frac{v_{1,j}}{\alpha v_{2,j}}$, only strategy profile $(s^*_{1,j} = \sqrt{\alpha c v_{2,j}}, q^*_{2,j} = 0)$ can be the equilibrium. Then, it can be easily proved that $\forall s_{1,j}$, $R_{1,j}(\sqrt{\alpha c v_{2,j}}, 0) \ge R_{1,j}(s_{1,j}, 0)$, and $\forall q_{2,j}$, $R_{2,j}(\sqrt{\alpha c v_{2,j}}, 0) \ge R_{2,j}(\sqrt{\alpha c v_{2,j}}, q_{2,j})$. This means neither the leader nor followers can improve their revenues by unilateral strategies that deviate from this strategy profile.

If $r_{1,j} > 1 + \frac{v_{1,j}}{\alpha v_{2,j}}$ and $v_{1,j} > (\frac{\sqrt{c}}{\tau} + \sqrt{\alpha v_{2,j}})^2$, when none of conditions illustrated in Theorem 1 is satisfied, we can only have $R^*_{1,j}(1) < R^*_{1,j}(2)$. Accordingly, the equilibrium $(s^*_{1,j} = \sqrt{\alpha c v_{2,j}}, q^*_{2,j} = 0)$ will be achieved. ■

B. The Impact of Individualized HTR

Building upon the equilibrium analysis above, we will further examine the impact of the reputation-based individualized HTR on proposers' pricing strategies as well as the resulting revenues in attention trading.

It can be found that the leader's HTR creates impacts on the equilibrium strategy, but the follower's HTR does not. In view of this, we focus on analyzing how the leader's HTR affects their pricing and purchasing strategies, especially the individualized HTR defined by the reputational weight.

Theorem 3: While the impact of the individualized HTR on the leader's equilibrium self-assessed price and ownership duration shows a negative correlation, its effect on his equilibrium revenues varies depending on the specific conditions.

Proof: First, we consider that a lower HTR $r_{1,j}$ either results from a better reputation (i.e., a lower reputational weight $\beta_{1,j}$) or a lower base tax rate r. According to Theorem 1 and 2, we discuss the following two equilibrium scenarios.

1) $0 < v_{1,j} \le (\frac{\sqrt{c}}{\tau} + \sqrt{\alpha v_{2,j}})^2$

If a lower $r_{1,j}$ does not change the condition $r_{1,j} > 1 + \frac{v_{1,j}}{\alpha v_{2,j}}$, the equilibrium will remain as a state of attention ownership transfer. Here, a lower $r_{1,j}$ will raise the price $s^*_{1,j}$ set by the leader and prolongs his ownership duration $p^*_{1,j}$. However, its impact on the leader's equilibrium revenue depends on their correlation, which is analyzed by

$$\frac{\partial R^*_{1,j}(1)}{\partial r_{1,j}} = \frac{c}{\tau} - \sqrt{\frac{c v_{1,j}}{r_{1,j} - 1}}. \tag{39}$$

Let $\frac{\partial R^*_{1,j}(1)}{\partial r_{1,j}} = 0$, we obtain $\hat{r}_{1,j} = \frac{\tau^2 v_{1,j}}{c} + 1$. When $1 + \frac{v_{1,j}}{\alpha v_{2,j}} < r_{1,j} \le \hat{r}_{1,j}$, a lower $r_{1,j}$ will make the leader's revenue decreased; and when $r_{1,j} > \hat{r}_{1,j}$, a lower $r_{1,j}$ will make the leader's revenue increased.

If a lower $r_{1,j}$ makes the condition $r_{1,j} > 1 + \frac{v_{1,j}}{\alpha v_{2,j}}$ no longer hold, the equilibrium will change from the state of attention ownership transfer to no attention ownership transfer as discussed in Theorem 2. Consequently, the equilibrium self-assessed price $s^*_{1,j}$ will be elevated, resulting in a longer ownership duration and an increase in his revenue.

2) $v_{1,j} > (\frac{\sqrt{c}}{\tau} + \sqrt{\alpha v_{2,j}})^2$

If a lower $r_{1,j}$ makes at least one of the conditions discussed in Theorem 1 still holds, the equilibrium state of the game will not change (i.e., remain as if the attention ownership transfer occurs), but the equilibrium self-assessed price will increase, leading to a longer ownership duration.

Meanwhile, there are multiple possibilities for changes that the individualized HTR brings to his revenue. If $\hat{r}_{1,j}$ falls into the range specified by any equilibrium condition of Theorem 1, a lower $r_{1,j}$ can cause the leader's revenue to stay unchanged, increase or decrease. If $\hat{r}_{1,j}$ goes out of the range specified by each equilibrium condition of Theorem 1, there only exists $r_{1,j} > \hat{r}_{1,j}$ such that $\frac{\partial R^*_{1,j}(1)}{\partial r_{1,j}} < 0$, which means a lower $r_{1,j}$ will make the leader's revenue increase.

If a lower $r_{1,j}$ makes the equilibrium conditions of Theorem 1 do not hold anymore, the equilibrium state of the game will change from the occurrence of attention ownership transfer to the non-occurrence of attention ownership transfer as discussed in Theorem 2. Under this situation, the optimal self-assessed price $s^*_{1,j}$ will increase, resulting in a longer ownership duration and an increase in his revenue.

From the above analysis, we can conclude that a lower HTR of the leader promotes the increase in his equilibrium price as well as ownership duration but does not necessarily elevate his equilibrium revenue in the single-round Stackelberg game of DAOs' attention markets.

Then, following a similar proof process, we can also get that a higher HTR of the leader induces a decrease in his equilibrium price as well as ownership duration but does not necessarily reduce his equilibrium revenue.

By applying the above analysis, the conclusion of Theorem 3 can be obtained. ■

V. Discussion

Attention is an important resource for blockchain-based DAOs to realize self-governance, as they rely on the collective attention of their members to make decisions in the mode of proposal and voting. Aiming at voting the truly valuable proposals that are in favor of the development of DAOs, attention markets are established to create continuous trading to allow the attention allocation to reach a wide range and achieve high efficiency via the HT-based pricing mechanism.

In these attention markets, no one can independently determine his trading strategy. Instead, the owner's pricing strategy is affected by the coming purchasing offers; and in turn, the purchasing offers are the competitive proposers' response strategies to it. The owner sets the price first and then others submit offers accordingly, forming a leader-follower game relationship. This inspires us to use the Stackelberg game model to study the trading and pricing strategies of DAOs' attention markets. Our study shows that there is equilibrium in the attention trading game, which is instrumental in establishing stable attention markets for DAOs and making the trading process standardized and automated by smart contracts.

Moreover, the tax rate plays a crucial role in these markets.

If HTR is kept very low owners' prices can be declared high to prevent ownership change; while if HTR is set high so that owners' willingness to submit high prices will be weakened to promote ownership transfer. Besides, even though the impact of HTR on owners' revenues is inconsistent under different conditions, the lower HTR resulting from the better reputation or the lower base tax rate still encourages them to announce a high price to retain ownership of attention for longer. By understanding the impact of individualized HTR on attention's trading prices and its ownership transfer, not only DAO members can make informed decisions on trading strategies but also the DAO community can set proper base rates and reputational weight in attention markets.

This study provides a preliminary solution with HT-based attention markets as the core to deal with the tragedy of commons concerning attention in DAOs. However, there are also more complexities raised with the proposed attention market to be resolved. First, the attention difference among DAO members is ignored in the current analysis. Actually, because DAO members' governance power is unequal, their attention engagement will result in different effects on the promotion and implementation of proposals, thus creating varying values for proposers and also the whole DAO community. Second, we do not consider the relevance of attention price with its ownership duration. However, there exists the strong correlation between the attention's value and the duration of its retention time. Only when the duration is appropriately long, can the invested attention produce better returns to owners, because too short a duration may not make the proposal accumulate enough votes, while too long a duration may make owners pay unnecessary fees for the invalid duration. Third, despite that the formulated attention markets support dynamic HTR, we have not considered it in-depth in this paper. On the one hand, from the perspective of the DAO community, the base tax rate can be dynamically adjusted according to the attention supply and demand. On the other hand, from the perspective of proposers, their reputation is dynamic. Both of these dynamics can be used to design dynamic and adaptive attention markets. Therefore, DAOs' attention markets are still a developing topic that deserves further exploration and innovation.

VI. Conclusions and Future Work

This paper seeks to address the challenge of allocating limited attention resources in DAOs by designing HT-based attention markets. On one hand, the unique trading rules of HT offer a novel approach to pricing attention within DAOs and establishing corresponding property rights; on the other hand, the integration of blockchain and smart contract technologies in DAOs facilitates the implementation of HT. First, DAOs' attention markets based on individualized HT are designed, involving a detailed discussion of the trading process and the formulation of proposers' revenue function. Within this framework, attention trading unfolds through six distinct steps, encompassing market creation, purchase offers, attention trading, tax collection, price announcement, and tax pledges. Then, The Stackelberg game model is formulated within these markets, with attention owners assuming the role of leaders, while other competitive proposers act as followers. The examination of attention pricing is conducted through an exploration of the equilibrium trading strategies employed by proposers within the Stackelberg game. Especially, in the single-round game, the equilibrium strategies under different conditions are discussed. Furthermore, the analysis is conducted on the impact of individualized HTR on equilibrium trading strategies, revealing a distinct negative correlation with leaders' announced prices and ownership duration. However, the impact on their revenues is found to be mixed.

This study supports the designs of market trading methods and allocation mechanisms for managing attention in DAOs. Additionally, it enhances our comprehension of proposers' strategies in garnering attention for their proposals during the decision-making process within DAOs. Furthermore, this study provides a potential approach for managing other intangible and perishable resources similar to attention within DAOs. Such insights contribute to the evolution of improved governance models and decentralized decision-making processes, fostering more equitable and sustainable resource management within DAOs and the burgeoning Web 3.0 landscape.

In the future, we will explore the dynamics and complex inter-dependencies of attention markets within DAOs, especially the potential differences in proposers' attention, the long-term dynamics and evolving strategies of the proposed game, and the measurement of the reputation and its influence on tax rate. Besides, the advanced AI models like ChatGPT and Sora will be integrated to optimize the attention pricing strategies, due to their capability of comprehend and predict the market information [61]–[64]. Moreover, more sophisticated and innovative models for artificial societies will be established [65]–[67], to advance the experimentation and evaluation of DAOs' attention markets [68], [69].

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