Simulations for Open Science Token Communities: Designing the Knowledge Commons

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Abstract

The curation and dissemination of new knowledge between peers is one of the key pillars of science and plays an integral role in maintaining the scientific method. Despite the distributed nature of knowledge, its curation is dominated by a handful of gatekeepers that offer an unequal exchange of intellectual property rights for academic prestige to those using their services. The power imbalance between knowledge producers and curators has led to overall systemic inefficiencies with scientific enterprise, fragmented communities, inequity in knowledge accessibility, underutilized intellectual capital, and suboptimal incentives for the stakeholders within the science ecosystem. This work presents alternative models to bootstrap scientific funding within distributed communities. We use generalized dynamical systems to run simulations of the economic activity in science to identify current inefficiencies and inform the future development of peer-to-peer systems optimized for knowledge creation. Content delivery through autonomous knowledge markets utilizing cryptographic access control protocols and peer-review reward mechanisms is shown to allow for programmable conditional incentives.

1 Introduction

1.1 Token Engineering for Academia

Token engineering is an expanding interdisciplinary field within the Web3 space focusing on the design and verification of tokenized communities, i.e. communities whose incentives are aligned with digital tokens. The tokens can be both fungible or non-fungible and may or may not have monetary value; it is the job of a token engineer to propose the optimal token structure that will incentivize the desirable behaviors of actors within the ecosystem. By relaxing the constraints on this epistemic niché set forth by notions of decentralization, online stigmergy, and transferability of the value represented by tokens, what remains can be described as structure-based economic modeling.

This work aims to elucidate the potential value of the applications of token engineering in the scientific ecosystem from the perspective of generalized dynamical systems theory (11) and behavioral economics (1). By considering the dynamics of different entities within academia, more thoroughly described by the Active Entity Ontology for Decentralized Science (4), we construct agent-based models of different research communities to evaluate their long-term potential in replacing the traditional funding, governance, and incentive structures in academia (10).

1.2 Knowledge Creation as a Generalized Dynamical System

Generalized Dynamical Systems provide the ontology and framework for communicating, designing, and analysing complex cyberphysical systems (11)(12). We use this approach for a rudimentary

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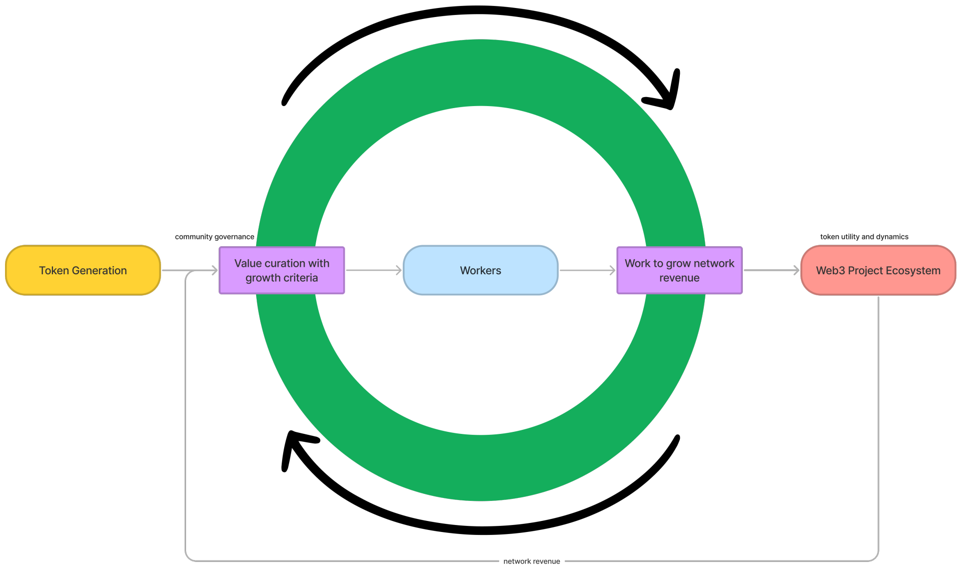

Figure 1: **A Tokenomic Regenerative Feedback Loop.** The Web3 Sustainability Loop is a mental model that extends the idea of equity ownership within an enterprise to tokenized representations of value within an organization, community, or market ecosystem. The key distinction between typical equity based corporations, like the Delaware C-Corp, and tokens of ownership in Web3 organizations is that tokens are cryptographic atomic primitives that are programmable, open source, and where all transactions are recorded on a public ledger.

analysis of the funding and overall value flows within science and provide simulations of alternative system designs aiming to solve some of the issues found in the models of traditional scientific funding with Web3 ecosystems in mind. Detailed descriptions of all the available designs, simulations, and guides for development are available at https://opsci.gitbook.io/darc-spice/.

The primary inspiration for the design of alternative models of scientific funding, publishing, and profit sharing is the Web3 Sustainability loop by Trent McConaghy (6). Figure 1 depicts a blueprint for designing token communities based on positive feedback loops, aligning the incentives of individual actors and thus ensuring a stable growth of the ecosystem. The loop starts with the initial token generation which is designed by the community stewards to take place in set time intervals and with fair amounts distributed during each generation cycle. The core of the loop is designed to promote the expansion of the ecosystem by allocating value to the "workers" who transform the economic power of tokens into open-source tools creating more value in the ecosystem. As the ecosystem becomes more useful, it attracts a larger network of users, bringing in revenue and thus increasing the fiscal longevity of the community. In the rest of the paper, we give an example of the Web3 Sustainability loop applied to decentralized science and outline future areas of research.

2 The Hybrid Knowledge Commons

The models are implemented in the TokenSPICE simulator. Originally developed as a verification tool for the Ocean Protocol smart contracts, TokenSPICE offers many degrees of freedom for designing agents, their interactions, and tracking key performance indicators. Furthermore, each simulation outputs a csv file and has built-in functions for plotting relevant data, reducing the friction of post-simulation analysis.

Figure 2 shows a model for an open science ecosystem that aligns the incentives of the DAO towards public research funding and also utilizes the effectiveness of the decentralized knowledge market in unlocking previously hidden value from the private research sector. The loop has similar properties to those depicted in Figure 1, but this time it specifies that funding is exclusively allocated to public research projects. Furthermore, we make the distinction between different types of researchers

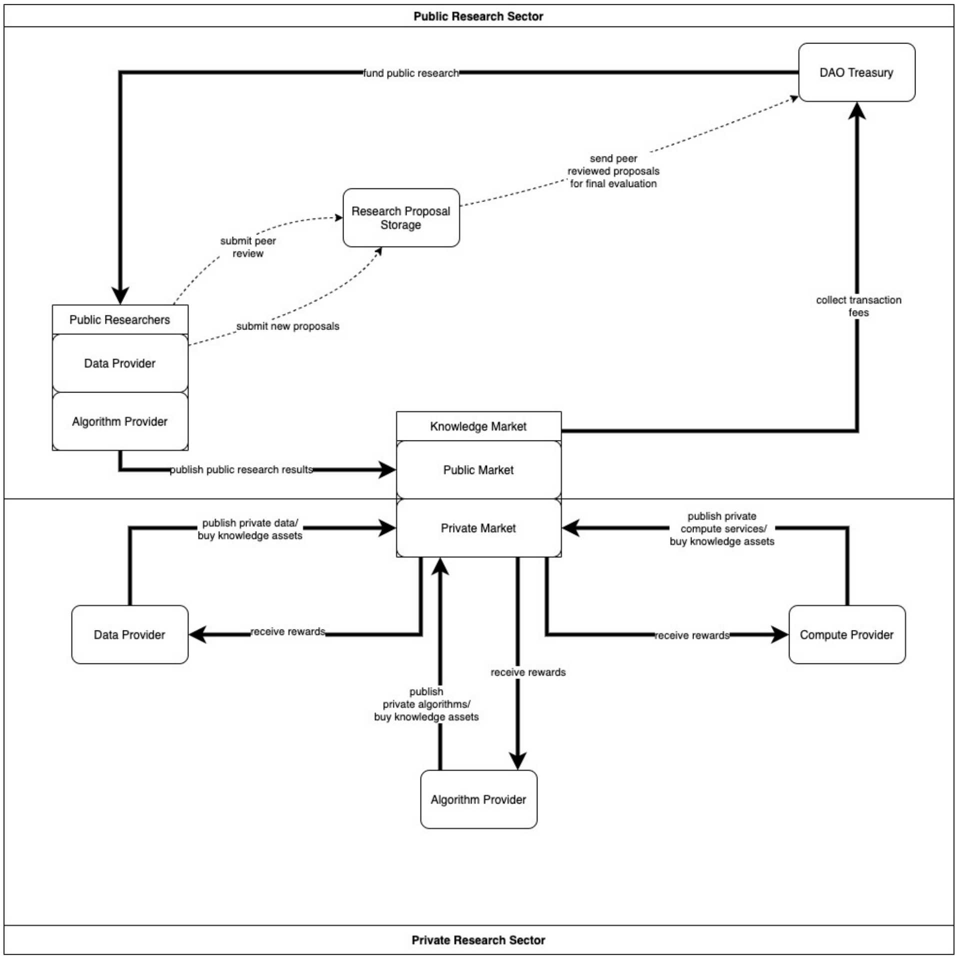

Figure 2: A schema of an alternative model for public and private scientific funding and knowledge dissemination. Public researchers receive funding from a community-curated DAO treasury and publish their research assets to the decentralized knowledge market. Private entities can sell assets on the market and buy access to resources that would be inaccessible in a centralized system.

depending on the knowledge assets they produce. Next, we describe the system's state-space and transition dynamics.

The environment divides agents into three categories depending on the assets and work they provide within the decentralized knowledge market. A data provider is somebody who runs experiments and collects data. An algorithm provider is someone who uses data to create new insights. A compute provider is an entity with significant amounts of data who participates in the market to receive rewards from allowing new algorithms to be trained on that data. Furthermore, this model distinguishes between private and public research sectors, adding additional constraints on the agent's affordances within the system.

The model implemented in TokenSPICE has a number of parameters that may be changed between each simulation, these include:

- price of assets in the knowledge market
- ratio of funds used for publishing/other resources
- transaction fees collected by the knowledge market
- percentage of transaction fees awarded to the staker agent
- number of researchers in the simulation
- number of grants awarded by the treasury at a time

- the funding boundary of the treasury
- initial parameters of the grant proposal submitted by the researchers

The definitions of the agents, their actions, and all other simulation parameters fully describe the state-space dynamics which can be used to study the system in depth. By running multiple simulations, performing parameters sweeps, and introducing stochastic fluctuations to the different parts of the system, we can answer questions such as: "What parameters allow for most public research projects to obtain funding in the longest time period?", "What is the required growth rate of the private research sector to collect enough transaction fees to maintain a stable level of the treasury?" etc.

In addition to studying the value distribution in decentralized scientific ecosystems, the model depicted in Figure 2 specifies the parameters describing the proposed research projects, a first attempt at formalizing the necessary properties of successful proposals and their potential impact on the wider scientific community. This work is closely related to ongoing research in impact certificates (8) and hypercerts (5)(2), establishing both a means of tokenizing the intellectual property associated with research, but also enabling retroactive public research funding (7) in the form of impact measurements. The system proposed here outsources the impact measurement to community stewards in charge of curating the DAO treasury. Despite not implementing a retroactive funding scheme, this system creates the means for continuous economic signals (3) that influence the credibility of the researchers who published an asset to the knowledge marketplace. The simple heuristic considers whether the published research is being used by other agents in the ecosystem and if not, that project implicitly has less impact. We discuss the results of the proposed system in the Appendix.

3 Conclusion and Future Work

We outlined existing approaches in token engineering and discussed their applications in decentralized science for the creation of incentive-aligned, open scientific communities. We also discussed one of the models of decentralized scientific collaboration, leveraging the affordances of non-custodial data marketplaces and transparent participation. One approach to foster a truly decentralized scientific community is through a knowledge market that allows researchers to publish datasets, algorithms, preprints, papers, or any other knowledge asset while retaining full ownership of it. This would allow researchers to gain rewards over time depending on the value their research provides to the community. However, a key problem for any decentralized knowledge community is ensuring that knowledge contributions are subject to rigorous peer review.

While token engineering in the context of systems design for science is still in its infancy, we hope this initial contribution can lead to meaningful conversations and future participation in the design of the knowledge commons. Future work will focus on integrating different modeling frameworks such as cadCAD (9) which are more closely connected to the theory of generalized dynamical systems. More information about existing simulations and how to get involved is available at https://opsci.gitbook.io/darc-spice/.

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A Appendix

We give a brief overview of the results obtained from the model described in Figure 2. For more detailed discussions of all the decentralized science systems designs, visit https://opsci.gitbook.io/darc-spice/. The figures below show the evolution of the value distribution across different entity types within the public funding model. Overall, the results suggest this model makes public research economically viable for the researchers who, provided they can produce high-quality research proposals and subsequent research outputs, gain continuous contributions to support their work. Furthermore, while the DAO treasury gets depleted on aggregate, the transaction fees collected from the activity in the decentralized knowledge market is able to extend its longevity compared to the baseline model depicted in Figures 6 and 7, requiring less external injections to the system. Lastly, as shown in Figure 5, the benefits of privacy-preserving data sharing allow private actors to take full advantage of the knowledge market, increasing traffic and overall growth of the system.

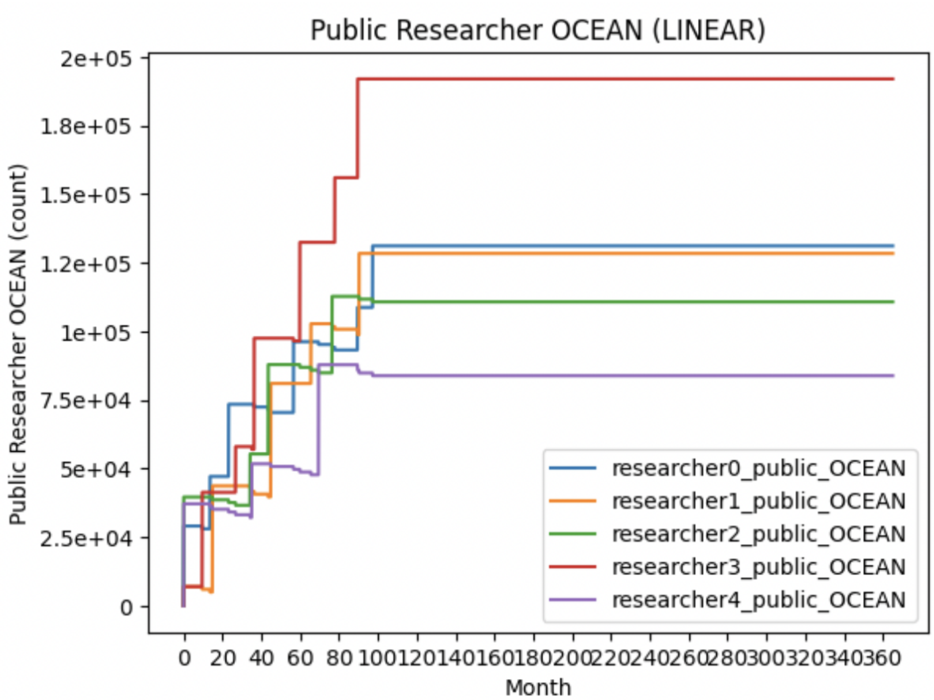

Figure 3: The monetary value of public researchers in the model described in Figure 2, measured in Ocean Protocol's OCEAN tokens over time.

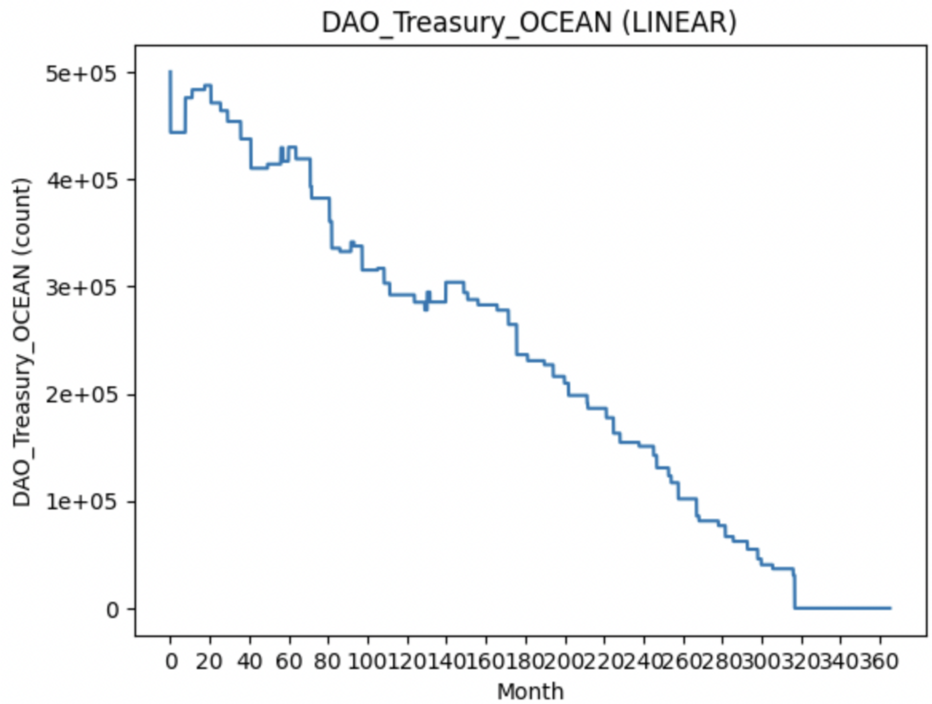

Figure 4: The monetary value of the community-curated DAO treasury in the model described in Figure 2, measured in Ocean Protocol's OCEAN tokens over time.

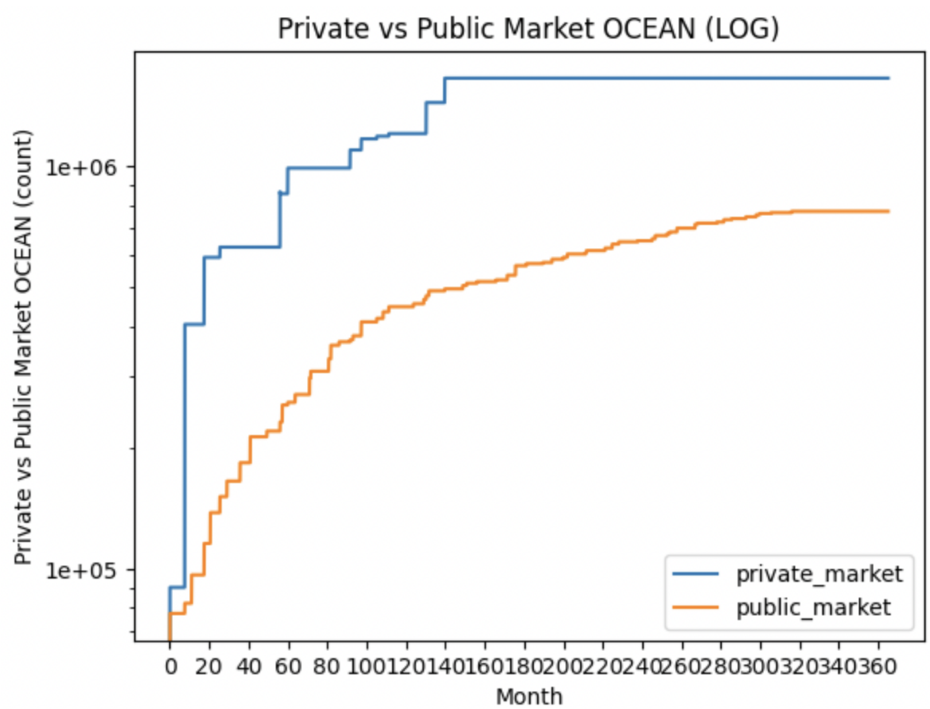

Figure 5: The monetary value of the public and private markets in the model described in Figure 2, measured in Ocean Protocol's OCEAN tokens over time.

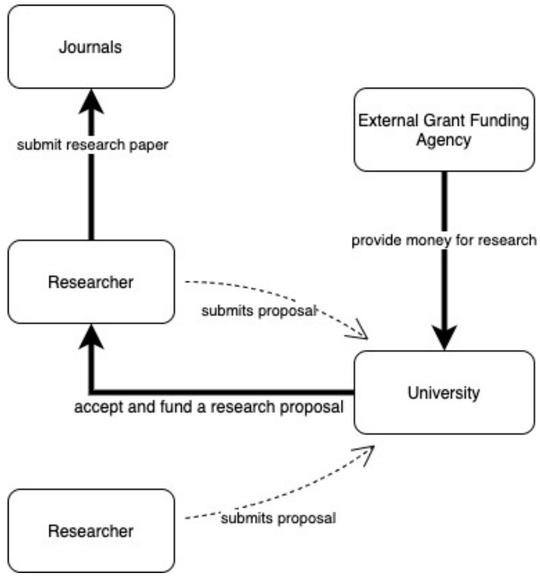

Figure 6: Schema of the baseline model for scientific funding.

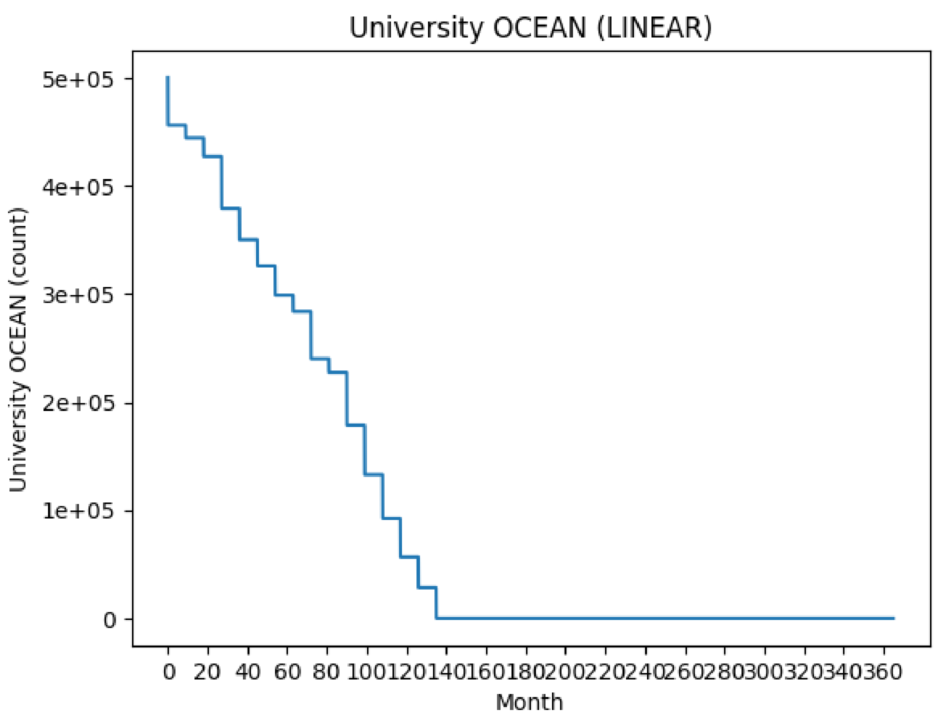

Figure 7: The monetary value of a university's treasury in the model described in Figure 6, measured in Ocean Protocol's OCEAN tokens over time.