Abstract

The cryptocurrency market is valued in excess of $250 billion. Virtually all these ventures employ cryptocurrencies to incentivize adoption and use of their blockchain-based platforms. For Bitcoin, miners are incentivized to mitigate the double spend problem; for Ethereum, to operate a distributed application development platform. The study of how to set up these incentive mechanisms and to operationalize governance is token economics. Given the size of the crypto market, we believe that there is still great opportunity to research this novel topic. In this paper, we present facets of the token engineering process for a real-life 80-person Swiss blockchain startup, Insolar. We show how Insolar used systems modeling and simulation combined with cryptocurrency expertise to design a mechanism to incentivize enterprises and individual users—and in particular through the use of subsidy pools, application developers—to help adoption of their new MainNet public blockchain network. For example, the study showed that the pool can be too small to properly incentivize developers, but it also can be so large as to signal largesse to greedy developers. For a startup like Insolar, their success will hinge upon how well their model incentivizes various stakeholders to participate on their MainNet network versus that of numerous alternatives.

Keywords: Token economics, token engineering, cryptocurrency, blockchain
1. Introduction

Awareness of blockchain technologies has been driven by the exponential growth in valuations of Bitcoin, Ethereum, and other cryptocurrencies, and frequent announcements of yet another industrial application of blockchain. Yet, the core premise of blockchain is straightforward: rather than relying upon a trusted intermediary to proprietarily maintain one ledger of transactions between members of a network, allow all members to maintain their own copies of the same ledger and ensure that the copies are all synchronized. This would obviate the need for the intermediary, who often exploits its information asymmetry advantage to act in self-interested and extractive, inefficient, or corrupt ways.

One of the key challenges of this decentralized design is incentives. Even when not behaving exploitatively, the intermediary is well-incentivized to provide centralized services in the form of transaction fees (e.g. Visa or Mastercard), fees charged for data resale (e.g. Google), and finder’s fees (e.g. Uber) [1]. When such services are provided in a decentralized way, an alternative scheme for incentives is possible.

For instance, the Bitcoin network design mitigates the “double spend” problem where a sender simultaneously sends money that they cannot fully cover to two different recipients [2]. The network ensures that one recipient is designated to be the rightful recipient and nullifies the money transfer to the other. A third party that is neither the sender nor recipient verifies this designation. That third party must be incentivized to verify accurately and not collude with the sender or the recipient. Roughly every ten minutes, the network selects a “miner” to add the next block to the Bitcoin blockchain, where the block is comprised of all transactions logged since the last block formation and verified by the miner to not be “double spent.” Currently, a miner receives 12.5
bitcoins, or roughly $125,000 each time a new block is added.

We have thus simplistically described Bitcoin’s token (or crypto) economic model. The model lays out the mechanism by which the Bitcoin economy is sustained: Senders and recipients are assured that money cannot be transferred from insufficient funds and third-party miners are incentivized by the promise of receiving (“mining for”) bitcoins to provide this assurance. The Ethereum network, the second most prominent public blockchain network, also has a similar but sufficiently different token economics model. Ethereum is designed as a platform to execute distributed applications or smart contracts. These smart contracts as well as the data they operate upon are stored on the Ethereum blockchain. Like Bitcoin, miners validate new blocks and are rewarded with ethers, the platform’s cryptocurrency. Additionally, though, users must pay ethers to the platform as a transaction fee to execute smart contracts.

Bitcoin and Ethereum are examples where token economics is “in the protocol.” That is, their respective cryptocurrencies—the tokens—are automatically transferred by their programmatic rules, and in so doing properly incentivize their stakeholders to collectively behave to sustain their operations. Contrastingly, platforms such as Hyperledger Fabric and R3’s Corda do not use cryptocurrencies to affect stakeholder behavior. Rather, these platforms are meant for use in private networks and use traditional group policies “outside the protocol.” Private network partners are usually familiar with each other and transact on an ongoing basis; they are inclined to adhere to policies that will sustain their relationships in and outside of the private blockchain.

Therefore, token economics models mainly apply to public, “permissionless” blockchain platforms that use cryptocurrencies for incentives and utility. Coinmarketcap.com, the de facto authority for
listing cryptocurrencies, lists 1,941 cryptocurrencies with non-zero market capitalization\(^1\). Number 1 is Bitcoin with a market cap of $192 billion; the lowest ranked cryptocurrency valued over $1 million is the WebDollar Token (WEBD) at #748 with a market cap of $1.002 million. At a total market cap in excess of $250 billion, the cryptocurrency ecosystem is quite formidable, and virtually every one of these cryptocurrencies has its own token economics model.

Given its impact, we believe that token economics modeling is an area opportune for further investigation. In this paper, we present a real-life study conducted to develop a token economics model for Insolar, an 80-person blockchain startup with offices in five countries and headquartered in Switzerland. Insolar conducted an Initial Coin Offering (ICO) of their INS coins in December 2017 and raised $42 million [3]. As they recently ramped up their development and marketing efforts, Insolar sought to update their model, and applied systems dynamics modelling and simulation for their update. The simulation study led to insights, which were incorporated into a multi-stakeholder token economics model that complements their updated business model.

We believe that the opportunity to investigate a novel real-world application such as token economics modeling provides rare and contributory visibility to the academic community. To that end, our paper is presented as follows. In the next section, we briefly describe how a token economics model is engineered. Next, we further describe Insolar and detail their specific requirements for token economics modeling. Then, we present a subset of the simulation study and results related to mechanisms for a “subsidy pool,” an incentive program to subsidize third parties who provide applications for user to execute on Insolar’s MainNet public blockchain network. Finally, we provide concluding remarks about how the simulation informed Insolar’s

\(^1\) As of August 20, 2019
implementation of the token economics mechanism and provide general insights about cryptocurrencies and token economics.

2. Token Engineering

The systematic development of token-based economies [4][5], sometimes referred to as token engineering, is an interdisciplinary endeavor incorporating perspectives from Systems Engineering, Complex Adaptive Systems (CAS), Economics & Game Theory, and Data Science. For instance, network dynamics models analytically prove that Bitcoin’s specific token model leads the network to a stable, self-sustaining state [6].

The combination of system complexity and nascence of the field both make it unlikely that an initial attempt will discover an optimal configuration for a token economy model. As a result, the process is naturally iterative with phases of analysis, design, and deployment occurring in repeated cycles [5]. It’s important to distinguish that this is the process for token modeling, not the larger software engineering process that leads to the blockchain system itself. The outputs of the token engineering process are models, results, and documentation that are implemented in the blockchain system.

**Analysis of the Token Model.** At the outset, the system designers must answer which phenomena the blockchain application maximize or minimize. During this phase, it’s key to understand users and stakeholders of the blockchain application, specifically their motivations, behaviors, and inter-relationships.

**Design of the Token Model.** The systems designer must answer how tokens are involved in maintaining the consensus and good governance of the network. In some networks, tokens are used
for voting on consensus or network governance matters [7]. For example, one token may correspond to one vote; or alternatively, one person, one vote [8]. Additionally, means of staking may be specified. Staking entails a participant posting a bond in order to take part in a network activity. The participant may forfeit the bond if they are judged to be a “bad actor” by other participants. Staking ensures that participants have “skin in the game” and are invested in network success [9]. Participant behavior that supports the objective function of the network can be incentivized through token rewards between participants and also through the minting of new tokens. This requires careful design of token emission or minting policies, which represent fiscal policies for the token system and underlying blockchain network. Finally, the application of Game Theory is essential in order to design mechanisms that drive participants toward Nash equilibria, or Schelling point solutions that seem natural or special to participants even without coordination amongst themselves.

Deployment of the Token Model. Techniques such as Agent-Based Modelling and simulation are used to bridge the micro characteristics (individual behaviour and transactions on the blockchain), to the emergent macro behaviour of the network as a whole (e.g. markets and coalitions). Ahead of putting an open test network into production with real valued tokens at stake, the simulation approach can often mitigate risk and save resources. In this context, an agent-based simulation model can be used to test the limits of the system by incentivizing simulated agents to break or otherwise take advantage of other participants in the network. Furthermore, an evolutionary or metaheuristic approach can be used to explore the space of agent behavior [10]. This can lead to a better understanding of how tokens are likely to move based on economic incentives, the so-called “token gravity” of the network [5].
3. Analysis and Design of the Insolar Token Economics Model

Analysis. Insolar ranks #310 with a market capitalization of over $7.1 million, and its daily volume of trades also ranks around there. Notably, Gartner recognizes it as one of a minority of the crypto-startups to work on enterprise use cases; that is, of the thousands of ICO’s and lots of ventures driven by companies like IBM, SAP, and Oracle, only these handful are deemed worthy for inclusion into Gartner’s global blockchain platform landscape [11].

Insolar’s stated mission is to “transform the way the world does business by building the best open-source blockchain platform, applications and tools” [12]. Similar to the Ethereum model, individuals and small enterprises can use the Insolar MainNet as a public, permissionless blockchain for a per transaction fee. In this paper, we will discuss MainNet’s token economics model. Insolar also has a complementary model that does not involve tokens: For a fee in fiat currency, Insolar designs and operates a private blockchain for enterprises in a business network. This version of Insolar’s platform is used, for example, to operate a neighborhood micro-grid in Toronto Canada. Insolar is involved in other projects in renewable energy, supply chain management, and mining and natural resources.

A key precept in designing MainNet’s token model is that consistent to the rationale for blockchain use the MainNet must not be centralized: Insolar is a critical stakeholder but there must be other stakeholders in the governance and operations of the blockchain. Here are those stakeholders.

- Individual and enterprise users, who will use and pay for applications (smart contracts) that are deployed on the MainNet.

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2 As of August 20, 2019, according to coinmarketcap.com
- Application Service Providers (ASP’s), who develop and deploy applications (smart contracts) and receive fees for their usage.

- Infrastructure Service Providers (ISP’s), who provide hardware capacities for running applications and receive fees for this provision. Whereas Bitcoin and Ethereum are peer-to-peer networks that do not pay those that provide CPU cycles, bandwidth, or databases, Insolar’s MainNet will pay such ISP’s.

The other key MainNet precept is that there must be a transition path from the INS coins that were raised in Insolar’s ICO in late 2017. Prior to the MainNet, INS coins served solely as instruments to be traded like stocks. Once MainNet is operational, INS coins, or a coin monetarily related to it, can be used as tokens of utility to incentivize the operations of the MainNet. Insolar Management have decided that once MainNet is operational original INS coins that are currently tokens on the Ethereum network will be converted 1:1 as tokens they deemed “XNS coins” to be used on the MainNet.

*Design.* Moreover, these XNS coin holders stake their XNS’s to maintain consensus in the network via staking. Whereas in Bitcoin and Ethereum networks, miners receive tokens to maintain consensus throughout the blockchain (Proof-of-Work), coin holders that have “skin in the game” vote to ensure consensus (Proof-of-Stake). By ensuring that there is a trustworthy consensus mechanism, coin holders/stakers provide confidence to individual users, enterprises, ASP’s, and ISP’s to use the MainNet, in turn ensuring stability for their coin investments. The coins that are staked serve as a source of insurance for the MainNet: If users, ASP’s, or ISP’s violate Service

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3 Miners do expend exorbitant amount of resources but that constitutes more of an indirect provision, where contribution is not necessarily proportional to the reward. It’s really more like winning the lottery than getting paid for service.
Level Agreements (SLA’s) with each other, coins from the pool of staked funds can be used to pay the rightfully aggrieved party. Stakers in turn are rewarded a staking fee— an investment income, akin to interest, earned from leaving their staked funds unwithdrawn.

Recall the precept for decentralization. Not only should the operation of the MainNet be decentralized, so should its governance. A MainNet governed exclusively and in perpetuity by Insolar is not desirable. Instead, a governance foundation, similar to those that underlie the Bitcoin and Ethereum networks, is needed.

In the following table, we summarize the stakeholders and their roles in the MainNet, and describe what characteristics the right token economics model would achieve for these roles [13].

| Stakeholder                               | Role in Insolar MainNet                                                                 | The token economics model should:                                                                 |
|-------------------------------------------|----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| Individual and enterprise users           | Use applications deployed on Insolar MainNet                                          | • Provide predictable fee structure<br>• Assure predictable quality of application performance       |
| Application Service Providers (ASP’s)     | Develop and deploy applications (smart contracts) and receive fees for their usage      | • Provide sufficient consumer base and resource capacities<br>• assure performance of infrastructure service providers within given SLA |
| Infrastructure service providers (ISP’s)  | Provide hardware capacities for running applications and receive fees for this provision | • Provide stable and predictable income for hardware providers                                      |
| Coin holders                              | Provide coins for staking as collateral behind the SLA’s and receive staking fees. These stakes effectively provide insurance to ASP and ISP customers, and the premiums coin holders collect from ASP’s and ISP’s to provide this service constitutes the staking fee they collect. | • Provide sufficient staking demand from hardware capacity providers                             |
Table 1: MainNet Stakeholder Roles and Requirements

Although Insolar conducted an extensive study addressing all stakeholders, we highlight one facet to bound the scope of this paper: how to incentivize pioneering ASP’s to contribute applications when the MainNet is nascent and network effect has not been achieved yet.

The diagram below shows the costs incurred by an application developer (ASP). They have to pay fees to resource providers (ISP’s) for CPU cycles, bandwidth, and database provisions required to run their applications. They also pay the Insolar Foundation resource platform fees to use the MainNet. Whereas these fees are paid for by an application provider grossly, there are application...
platform fees charged on a metered basis per deployed application; the more a particular application is executed, the more fees have to be paid to the MainNet.

Though not shown on the figure, there may also be pre-deployment fees like an entrance or initiation fee as well as prepaid deposits if the Insolar Foundation has to commit or source resources to serve the application developer. Given all these fees, the developer must have confidence that they will be able to collect enough revenue from users to be viable. It may not be easy to instill that confidence shortly after MainNet launch and before any network effect is achieved. To entice application development on the MainNet during this critical stage then, Insolar would provide subsidies to the pioneering application developers.

Figure 1: Fees and Subsidies for application developers (ASP’s)
In the next section, we showcase the next phase, deployment of the token model, by presenting how the specific policies around application developer subsidies are developed using agent-based modeling and simulation. That is, specifics of policy like how much should be set aside for a subsidy pool, how much subsidy should a developer receive, when should subsidization expire, and many others are determined in this phase.

4. Deployment of Insolar Token Model: Application Developer Subsidy Simulations

In order to help foster the organic growth of the Insolar network ecosystem, the Insolar foundation will offer an application developer subsidy paid in XNS token incentives to build and deploy applications on the Insolar platform. The application developer subsidy is initially funded with a seed amount of XNS tokens which are released from a treasury at an exponential decay rate. However, this subsidy pool is replenished with the application platform fees that are collected.

A key piece of information needed is the amount of tokens with which to initially seed the pool. We perform simulation experiments using the open source cadCAD [14] to better understand the effects of varying the initial amount tokens devoted to the developer subsidy. The initial number will consequently affect the absolute rate of XNS token dispersal. The desired effect of this subsidy may include: 1) Increased number of applications deployed; 2) Increased resources used; 3) Increased users; 4) Increased platform fees; 5) Increased demand for XNS; and 6) Increased price of XNS. The increased price of XNS is reflective of the market demand for a fixed supply of tokens available within the economy.
The number of tokens distributed to developers at a particular time, $A(t)$, through the Application Developer Subsidy is governed by the initial reward pool size $A(0)$, and the exponential decay rate, $\lambda$. The differential equation governing the change in subsidy over time is therefore:

$$\frac{dA}{dt} = -\lambda \cdot A$$

Through integration this results in.

$$A(t) = A_0 \cdot e^{-\lambda t}$$

The output state variables in the model include subsidies paid to application developers as well as the amount of value remaining in the Foundation’s treasury.

The specific features of the developer subsidies and associated pools can be described functionally as follows:

Subsidies to Application Developers are paid in the form of existing XNS tokens held by the Insolar Foundation. Once received by the Application Developer, subsidies can be spent however the Application Developer sees fit, for example to pay Resource Fees to Resource Providers. There are four main ways for Application Developers to earn Subsidies that are explained below: App Seeding, New Application Subsidy, Volume Resource Subsidy, and Success Reward.

**App Seeding**

In the *App Seeding* context, a subsidy is paid to Application Developers to incentivize application creation such as in the cases of competitions such as “code jams” or “hackathons” based on Insolar Foundation judgement of which Application Developers and applications are most promising. This may be seen as a grant for which the Application Developers have to apply. An assumed adoption
model governs the number of Application Developers at a particular time. Therefore, given a tuning parameter of the total amount of tokens to be distributed through *App Seeding*, the number of tokens available for an individual Application Developer will be a function of the total amount of tokens available and the number of Application Developers.

**New Application Subsidy**

The *New Application Subsidy* is made available much in the same spirit as introductory offers to new, small business customers, for example 50% off fees for a limited time. Therefore this subsidy is offered for newly deployed applications, with the subsidy decreasing to 0 over time. As with the *App Seeding* subsidy, the New Application Subsidy must be explicitly applied for by the Application Developer. A tuning parameter for this subsidy is the total amount of tokens to be distributed, and the subsidy to an individual application is also a function of the number of subsidized applications, subject to a time-decay model.

**Volume Resource Subsidy**

The *Volume Resource Subsidy* is designed to ease the costs of more popular applications, therefore the subsidy should correlated with the popularity of a particular application. As with the other subsidies, Application Developers apply for this subsidy as a grant from the Insolar Foundation. This subsidy is a function of the expected resource fees incurred by the application, the actual invoiced resource fees, and a minimum threshold in order for the application to be eligible for this subsidy. Key tuning parameters are the total amount of tokens to be distributed for resource discounts, and the threshold representing minimum required capacity.
Success Reward

Finally, there exists a *Success Reward* which is awarded to Application Developers for meeting certain Key Performance Indicators (KPIs) as determined by the Insolar Foundation. As with the other subsidies offered, Application Developers apply for this subsidy in a similar fashion to a grant. The amount awarded to an Application Developer is a function of the number of applications, and KPIs achieved. Unlike the other subsidies, it is not time based, rather it’s awarded discretely in the event of an application achieving the aforementioned KPI metrics. The main tuning parameter is the total amount of tokens to be distributed for *Success Rewards*.

Key Question

When designing the system this is a key question: What is the upper limit of tokens Insolar is willing to commit in total to subsidizing the success of application development and their use on the platform?

| Initial Reward Pool Size (XNS) | Decay Rate\(^4\) | Time Steps | Monte Carlo Runs |
|--------------------------------|------------------|------------|------------------|
| 250 x 10\(^e\)6               | 0.0005           | 3652       | 100              |
| 500 x 10\(^e\)6               | 0.0005           | 3652       | 100              |
| 750 x 10\(^e\)6               | 0.0005           | 3652       | 100              |
| 1000 x 10\(^e\)6              | 0.0005           | 3652       | 100              |

Table 2: Simulation Scenario Parameters

\(^4\) Additional experiments were run during the Insolar economic parameter design and validation research, including but not limited to exploring the effects of varying the decay rate.
As per Table 2, the simulations were carried out in a Monte Carlo fashion using four possible scenarios for the starting reward pool size, and the mean of the resulting observed variables were computed. Although explored elsewhere, the Decay Rate remains constant throughout these experiments, as do the number of simulated time steps, and Monte Carlo runs.

The variables that were observed to address the key question include:

1. The pool of XNS tokens at any given time
2. The accumulated XNS tokens flowing to application developers
3. The converted (dollars) income of XNS tokens to application developers
4. The predicted XNS price in dollars
5. The number of XNS tokens held by the foundation treasury.
6. The value of XNS tokens held by the foundation treasury.

Our initial experiment was to provide some evidence that the model is functioning correctly.

**Figures 1 a and b: Comparison of Subsidy values I**

Depletion of the application developer subsidy over time is shown in Figure 1a, confirming the expected exponential decay in token distribution, as well as the pattern resulting from the change in initial starting reward pool size.
The resulting XNS token distribution to the application developers can be seen in Figure 1b, which is again intuitively reasonable given the described model and varying initial reward pool size.

Interestingly, the net effect on the cumulative income to application developers converted to dollars shown in Figure 2a is less intuitive. Although, the greatest subsidy does yield the most benefit to application developers, converse is not necessarily true. Clearly, there exists a complex and non-linear relationship between the initial subsidy pool size and reward value delivered to application developers.

To gain some further insight into why this relationship exists, we can look at projected XNS token price for each initial reward pool size scenario. As shown in Figure 2b, the larger the initial reward pool size, the higher the resulting token price (generally).

**Figures 2 a and b: Comparison of Subsidy values II**

Also the the initial reward pool size has an interesting effect on the value of the tokens held by the foundation. Predictably, the foundation’s holdings of XNS tokens vary inversely with initial application subsidy pool size as shown in Figure 3a. However, due to the XNS price action demonstrated earlier, the value of tokens held by the foundation does increase as initial subsidy pool size is increased as evidenced by Figure 3b.
5. Simulation Insights

Based on these findings, if the team feels that rewarding the application developers to an optimal degree from the initial reward pool would elicit a potentially negative community outcomes due to perceived largesse, then the smallest pool size appears to be the optimal choice since Application Developers will accrue nearly the same value. However, taking the XNS token price into consideration, much like shareholders in a corporation wish to maximize share price, the token holders would be pleased by an increase in XNS token price. Taking this view into consideration, the largest initial reward pool size appears to be the best choice, here. Since the value of tokens held by the foundation increases with the tokens given away, this also augurs well for the largest initial reward pool size of the four scenarios considered.

The inclusion of an application development subsidy does improve the overall economy of the system, in terms of predicted token performance. The direct overall benefit to application developers is less clear. While more XNS tokens are granted to application developers through the subsidy, the net effect on application developers is not guaranteed at every point in time.
Application developers pay application platform and resource platform fees in XNS tokens. The application platform fees collected by the foundation are put back into the application subsidy pool, but are still distributed through to the application developer at a decaying rate. On the other hand, the foundation value (XNS token holding multiplied by predicted price) does enjoy the overall benefit that application developer subsidies provide.

**Recommended Action.** The application subsidy mechanism does not guarantee an income, unlike the resource provider subsidy. Therefore, it is decoupled from being dependent on the XNS token price. While this provides insulation from a negative feedback loop when XNS price decreases, it occurs with a loss of guarantee to the application developers. It is recommended that decision logic centered around financial returns for application developers be applied. Application developers would apply analysis of performance of the economy to determine whether to deploy and continue to deploy on the system.

### 6. Concluding Remarks

To summarize, given the increasing role of cryptocurrencies—especially in light of recent announcements of corporate cryptocurrencies from Facebook, JP Morgan, and Walmart—we believe that token economics is under-researched. This paper presents various steps in the token engineering process to demonstrate how token economics simulation modelling informed policy design for Insolar’s subsidy pool—their mechanism to incentivize application providers to develop more applications onto the public MainNet. The modeling will be important as Insolar tries to foster a vibrant ecosystem of application developers and infrastructure providers that will entice individual and enterprise users to join the MainNet after launch.
We did not fully explore theoretical issues. We did not delve much into the formal control theory underlying these simulation models, nor did we relate much to traditional literature on market design from Economics and Operations Research. We will tackle these issues in future work. Nevertheless, for a fledgling startup like Insolar, their future success will in no small part hinge upon how well their model incentivizes various stakeholders to participate on their MainNet network versus that of numerous alternatives. We believe that providing visibility to such a strategic and academically novel exercise serves a contribution to the research community.

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