The Role of Cryptographic Tokens and ICOs in Fostering Platform Adoption

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Abstract

Platform-specific digital tokens are becoming increasingly common with the proliferation of initial coin offerings (ICOs). In addition to a novel financing mechanism, such tokens can help address the coordination problem that is common in network adoption. We develop a model to investigate the use of tradable digital tokens to solve this coordination problem. Our analysis shows that platform-specific tokens, due to their tradability and consequent higher value if the platform succeeds, can provide another tool to overcome the coordination problem in a platform adoption setting and to support equilibria favorable to the platform.

We find that if the platform is not facing capital constraints, the most profitable strategy is the traditional strategy to subsidize adoption. If the platform is capital constrained, however, then token issuance provides an alternative that is increasingly attractive as the platform's cost of capital increases. With tokens, the platform trades off future revenue for present revenue, which helps finance solving the coordination problem. In that sense, even pure utility tokens have certain characteristics of equity: (1) early adopters share the future gains if the platform succeeds, and (2) the tokens provide an alternative when traditional financing is too costly or not available to the platform.

1 Introduction

Initial Coin Offerings (ICOs) have emerged in recent years as a funding mechanism for a variety of platforms. In a typical ICO, a platform issues digital tokens that can be used to access the services it provides, or more commonly will provide once it becomes operational.

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The volume of ICOs has been increasing rapidly; according to a recent report, in the first 5 months of 2018 a total of 537 ICOs with a volume of $13.7 billion have been closed successfully, which is more than all pre-2018 ICOs combined, with the largest ICOs exceeding the $1 billion mark (Diemers *et al*, 2018). In what is probably the largest ICO to date, the total proceeds from the sale of EOS tokens exceeded $4 billion (DeFranco 2018).

While the idea of firm-specific tokens or currencies is not new,[1] the recent developments in blockchain technology, cryptocurrencies and smart contracts have dramatically increased the frontier of capabilities and reduced the cost of token issuance. For instance, such tokens can be issued as a new currency with its own blockchain, or can use the well developed tools provided by blockchains such as Ethereum.[2]

The common perspective on ICOs is that they provide an alternative to more traditional funding sources for project development, such as angel investors, VCs, or crowdfunding venues like Kickstarter. In that capacity, the increasing prominence of ICOs has been attributed to lower friction, better terms, or the ability to sidestep regulations and reach investors that because of regulatory or transactional barriers would not be reachable via more traditional means.

In this paper we analyze a different aspect of tradable digital tokens in the context of platforms: to the extent that such platform-specific tokens can be sold to future platform users, and thus become more valuable if the platform succeeds, they can help address the well known coordination problem in platform adoption by supporting equilibria favorable to the platform. In order to focus on this coordination problem, we take platform development as given and we model how the platform can use a platform-specific token to address the coordination problem in fostering adoption by potential users.

[1]See, for instance, Gans and Halaburda (2015) for a review of local currencies such as BerkShares or Ithaca hours, and private platform currencies such as Facebook credits or Amazon coins. Or the several web currencies started in the late 1990s such as Beenz and Flooz.

[2]Ethereum has been the choice of several large ICOs, including EOS.

We find that if the platform is not facing capital constraints, it is more profitable to address the coordination problem with the traditional strategy of subsidizing adoption. If the platform is capital constrained, however, then token issuance provides an alternative that is increasingly attractive as the platform's cost of capital increases. With tokens, the platform faces a reduced need to subsidize early adopters or may avoid such a subsidy altogether; the sale of tokens provides a mechanism to trade off future revenue for present revenue, which reduces the upfront cost of addressing the coordination problem. In that sense, even pure utility tokens[3] have certain characteristics of equity: early adopters share the future gains if the platform succeeds and the tokens provide an alternative when more traditional financing, such as VCs or the capital markets, would be too costly or not available to the platform.

Our topic is of direct relevance to the Special Issue, as ICOs are becoming a prominent element of the FinTech ecosystem, and token offerings by platforms combine the use of blockchain technology and crypto-currencies to create an alternative financing mechanism. Our analysis and findings are not only illustrative of the application of new financial options enabled by technology, but also apply directly to FinTech markets, as platforms and the associated coordination problems for engaging potential participants are central in these markets.

2 Literature Review

The multiplicity of equilibria and the corresponding coordination problem is a well known issue for markets with network effects, going back to the seminal paper of Katz and Shapiro (1986). In a market with network effects user's utility increases as more other users buy the same good or service. That means that potential users want to join the same network as other users. Multiple outcomes can be an equilibrium, as long as the users coordinate on the same

[3]This term is commonly used for tokens whose only use is to provide access to services of the platform.

one. A potential user may forgo joining an attractive network if he does not believe that other potential users will join as well.

Platforms, being strategic players, can use attractive pricing to overcome unfavorable beliefs when enticing users to adopt, or when competing against other platforms (e.g., Caillaud and Jullien, 2001). If the setting is dynamic, a low or negative early price (i.e., a subsidy) is a frequently explored strategy to overcome the coordination problem (e.g., Halaburda, Jullien and Yehezkel, 2017).

There is a nascent literature on cryptographic tokens in platform settings that focuses on discovering demand (Catalini and Gans, 2018) or analyzing the drivers of token prices (Sochiu and Xiong, 2018; Cong, Li, and Wang, 2018). Our work is complementary to the existing literature in the sense that we abstract these issues away to focus on tokens as a tool that a platform can use to resolve the coordination problem in its favor.

Sochiu and Xiong (2018) show that two equilibria exist in a setting with network effects and tokens: one equilibrium with high adoption, and another with low adoption. They focus on deriving the properties of these equilibria in the context of the particular setting. Their setting differs from ours in that users can coordinate on the equilibrium they choose and the platform is not a strategic player. Also, they do not compare equilibrium outcomes in a setting with a token to a similar setting without a token.

Cong, Li, and Wang (2018) do compare equilibrium with a token to an equilibrium without a token. Similarly to our approach, they show that the possibility of resale of the token makes network adoption more appealing. In their setting the platform is not a strategic player, and thus they do not address the question under what circumstances the platform would prefer to overcome the coordination problem by issuing a token rather than by a traditional user subsidy.

Catalini and Gans (2018) focus on the role of the token in demand discovery, but they also discuss using ICOs to address the coordination problem in an environment with network effects. In their model, tokens are auctioned off, as opposed to the platform setting their price. The auction process changes the adoption game from simultaneous to sequential and as a result the ICO process can eliminate the coordination problem. The coordinating role of the token in that environment depends on a large enough stand-alone value of the product or service offered by the platform; and thus the token would not solve the coordination problem for pure network goods, i.e., goods (or services) that have no value if no other user adopts.

Our work extends the existing literature as we derive conditions under which the platform prefers to issue a tradable token to solve the coordination problem in a setting with network effects that also allows for pure network goods. Furthermore, we show that under certain circumstances a traditional user subsidy may be more profitable for the platform than issuing tokens.

3 Model

3.1 Model setup

We model a platform offering a good or service with network effects. We focus on cryptographic tokens as a strategy to address the coordination problem in adoption by potential users, and we compare issuance of cryptographic tokens to traditional price-based strategy options such as subsidizing early adopters.

To focus on the coordination problem, we consider a simple setting with features that result in a meaningful coordination problem among potential users. Specifically, we assume that the network effects are one-sided (i.e., we consider a single type of users, such as the users of a social network), we assume that the platform has already been developed (so we do not need to be concerned about financing development and implementation risk), and we focus on whether the platform will succeed in being adopted (compared to an outside option) by identical potential users that arrive in two periods that we denote with $t = 1, 2$. In each period, n_t identical potential users arrive ($t = 1, 2$); we also refer to period 1 potential users as "early arrivals" and period 2 potential users as "late arrivals."[4]

Potential users that arrive in period 1 choose between joining the platform and some outside option that we normalize at zero utility. Potential users that arrive in period 1 will have to leave the market in period 2 with probability α, i.e., they stay in the market for period 2 with probability $1 - \alpha$. We assume that $n_2 > \alpha n_1$, i.e., there is net growth in the market in period 2.

The utility of potential users from joining the platform exhibits network effects. It is strictly increasing in the number of other users on the platform, i.e., for network sizes ω and ω', if $\omega > \omega'$, then $u(\omega) > u(\omega')$. Furthermore, to make the coordination problem nontrivial, we assume that $u(0) < 0$ and $u(n_1) > 0$; that is, joining an empty platform yields negative utility (e.g., due to adoption cost), and joining a successful platform yields positive utility.

Digital token. Platform access requires possession of a digital token issued by the platform. Tokens provide access for both periods $t = 1, 2$ and are transferable; thus a user that arrives in period 2 and wants to join the platform must acquire a token either directly from the platform or from a user that previously acquired the token (such as a user that leaves the market).

Users that join the platform in period 1 and do not leave the market, can remain on the platform in period 2 unless they sell their token and thus exit voluntarily. Users that arrive in period 2, or arrived in period 1 but did not join the platform then, choose between joining the platform in period 2 and the zero utility outside option.

[4] Although we focus on a single-sided network, our model and results also apply to multi-sided networks if we limit the platform to issuing a single token for all potential participants, irrespective of their side, and all sides can be induced to participate in the platform.

3.2 The coordination problem

Multiple equilibria. Due to the negative utility of joining an unsuccessful platform and the positive utility of joining a successful platform, a potential user wants to join the platform if he beliefs that the other potential users will also join, and does not want to join if he believes that others will not join. This results in multiple equilibria for a broad range of prices set by the platform: since potential users are identical in beliefs and utility, robust equilibria require either all potential users deciding to join (which we term "successful adoption") or deciding not to join (which we term "failed adoption"). We define a corresponding success variable $s_t = \{0, 1\}$ with 0 denoting failed adoption and 1 denoting successful adoption.

The multiplicity of equilibria and the associated coordination problem mean that the equilibrium outcome depends on the beliefs of the potential users. This is a common result in platform adoption environments such as format wars: if potential users believe that a particular format will win, this belief will become a self-fulfilling prophecy and the favored format will win as no potential user wants to be stranded with the losing format (e.g., see (McIntyre, 2009) for the BluRay *vs.* HD-DVD format war for high definition optical disks). These beliefs of potential users may be formed based on the history of successes and failures of a platform itself, the reputation of the platform developer, marketing of the platform, expert opinions, or other sources of information.[5]

Focality. The players' beliefs in coordination games frequently result in one equilibrium being more salient than others, a concept known as *focality* (Schelling, 1960). While any of multiple outcomes is an equilibrium if players coordinate on the same one, when one equilibrium is focal, it means that the market coordination is biased towards it. The concept of focality has been used to address coordination among the multiple available equilibria in

[5]It is likely, for instance, that Sony's desire to overcome the history of having lost the Betamax *vs.* VHS format war and to avoid the reputation implications of another loss, contributed to its aggressive adoption strategy for the BluRay format, such as heavily subsidizing the inclusion of a BluRay drive in the PlayStation 3 game console to increase the number of consumer devices capable to play BluRay movies.

the context of platform adoption and platform competition (Fudenberg and Tirole, 2000; Caillaud and Jullien, 2001, 2003). When a platform enters a market with network effects, frequently there are two equilibria for potential users: *adopting* or *not adopting*. Focality can help determine the resulting outcome.

For instance, suppose first that the focal equilibrium is *adopting*. In this case we say that the market coordination bias fully favors the new platform as potential users expect other potential users to adopt; these users themselves will adopt provided the platform sets a price that is acceptable *assuming that the other potential users adopt*. Specifically, if $V(1)$ denotes the benefit of joining the platform when everyone else adopts and $V(0)$ denotes the benefit of joining the platform when nobody else adopts, with $V(0) < V(1)$, then the platform enjoying fully favorable coordination bias can charge a price $p = V(1)$. At this price everyone adopts, and correctly believes that everyone else will adopt.[6]

Now suppose that the focal equilibrium is *not adopting*, i.e., that the market coordination bias is fully against the new platform. This does not mean that the platform will necessarily not be adopted; however, it means that the price needs to be low enough so that a potential adopter would want to adopt *even if nobody else would adopt*, i.e., $p = V(0)$; if $V(0) < 0$, that would mean a negative price, i.e., a subsidy. At this price, the potential user knows that just as he is enticed to join the platform, so will all other potential users, and thus he correctly expects all other potential users to join as well, and to obtain utility $V(1) > p = V(0)$.

If the platform were to charge $p > V(0)$ to capture some of that surplus, however, the potential user would not want to join given the coordination bias against the new platform, as he would correctly expect that others also wouldn't join at $p > V(0)$. Thus, even though all potential users join, the platform can only charge $V(0)$ because of the unfavorable coordination bias of the market.

[6]Note that at $p > V(1)$, a potential user would not want to join the platform even if all other potential users would join. Since he is not adopting, he knows that other potential users will not adopt either, and thus has correct beliefs that nobody will adopt.

Note that the coordination bias may change the adoption outcome. It is possible that the platform will not find it profitable to overcome the coordination problem under unfavorable coordination bias, and thus the platform will not be adopted, while it would have been profitable to do so under a favorable coordination bias, which would have led to platform adoption.

Partial focality. Fully favorable and fully unfavorable coordination bias are the two extreme possibilities in terms of under what conditions users are willing to join; a more realistic scenario is the intermediate case of partial market coordination bias (e.g., see Halaburda and Yehezkel, 2016). If *adopting* is a partially focal equilibrium with coordination bias $\phi \in (0, 1)$, it means that the price needs to be low enough that a potential user is willing to adopt *even if others would join only with probability* ϕ, i.e., $p(\phi) = \phi V(1) + (1-\phi)V(0)$. Fully favorable and fully unfavorable focality for the platform are the special cases for $\phi = 1$ and $\phi = 0$.

At price $p(\phi) = \phi V(1) + (1-\phi)V(0)$, the potential user knows that just as he is enticed to join the platform, so will all other potential users, and he correctly expects all other potential users to join as well. Thus, seeing this price, each potential user expects to enjoy the benefit of everyone joining, or $V(1) > p(\phi)$. Even though everyone joins, the platform cannot set a higher price and extract more surplus. However, the more favorable the market coordination bias the platform enjoys, i.e., the higher the value of ϕ, the higher the price it can charge and still be adopted by the potential users.

The coordination bias ϕ can be interpreted as the trust the market places on the platform that the latter will be able to overcome the coordination problem it faces. Given that history may affect this trust, the bias in the second period may be affected by the outcome of the first period. While for simplicity we focus on the case that ϕ_2 does not depend the period 1 outcome, our results remain the same when we allow ϕ_2 to be a function of success at $t = 1$, i.e., $\phi_2 > \phi_1$ if the platform succeeds in period 1 and $\phi_2 < \phi_1$ if the platform fails in period 1.

Also, given that all information is public, everyone shares the same bias ϕ_2 in period 2, whether they arrived in period 1 or 2.

3.3 Timing of the game

Potential users arrive to the market in each period t ($t = 1, 2$); a fraction of the potential users that arrive in period 1 exit the market in period 2. Each period, the platform sells tokens that allow access to its services; potential users can either use tokens they acquire to access the platform, or can sell their token to another potential user. Thus a potential user that wishes to join the platform may acquire a token either directly from the platform, or from another user.

The introduction of platform-specific tradable tokens is a key feature of our model. The tradability of these tokens and consequent higher value if the platform succeeds mean that these tokens can help solve the coordination problem faced by the platform.

The detailed timing of the game is as follows:

Period 1:

- In the beginning of period 1, n_1 potential users arrive to the market.
- The market coordination bias is ϕ_1.
- The platform makes n_1 tokens available for sale in period 1 at price p_1.[7]
- The n_1 potential users either buy a token or not, depending on p_1 and the coordination bias, ϕ_1.
- At the end of period 1, everybody observes whether the n_1 potential users joined the platform, which determines the value of $s_1 \in \{0, 1\}$ with a successful outcome for the

[7] It is easily seen that making fewer than n_1 tokens available is suboptimal, since all potential users are identical.

platform denoted by $s_1 = 1$. Potential users that joined the platform realize period 1 benefit $V_1(s_1)$, which includes their benefit from participating in the period 1 network $u(\omega_1)$, and their expected payoff in period 2.

Period 2:

- In the beginning of period 2, αn_1 potential users that arrived in period 1 leave the market, and n_2 new potential users arrive.
- The market coordination bias is ϕ_2.
- The platform makes additional $n_2 - \alpha n_1$ tokens available for sale in period 2. If there are any unsold tokens from period 1, they are also available for sale by the platform. The platform sets price p_2 for the tokens it sales in period 2.
- Potential users that joined the platform in period 1 and exit the market in period 2 can sell their token to new users; at equilibrium they will sell at price p_2 as they can slightly undercut the price charged by the platform.
- Users that do not have a token at the beginning of period 2, decide whether to buy one or not, depending on p_2 and the coordination bias in period 2, ϕ_2.
- At the end of period 2, everybody realizes their period 2 payoffs.

Depending on the success of the platform in each period, the resulting size of its network is given by

$$\begin{array}{lll} s_1 = 1 \ \& \ s_2 = 1 & \omega_1 = n_1, & \omega_2 = n_1(1-\alpha) + n_2 \\ s_1 = 1 \ \& \ s_2 = 0 & \omega_1 = n_1, & \omega_2 = n_1(1-\alpha) \\ s_1 = 0 \ \& \ s_2 = 1 & \omega_1 = 0, & \omega_2 = n_1(1-\alpha) + n_2 \\ s_1 = 0 \ \& \ s_2 = 0 & \omega_1 = \omega_2 = 0 & \end{array}$$

3.4 Equilibrium with tokens

We solve for the equilibrium in the above game using backward induction:

There are $n_1(1-\alpha)+n_2$ potential users in period 2. Some of them, specifically $(1-\alpha)\,\omega_1(s_1)$, already own a token from period 1, and the rest can acquire a token at price p_2.

If a user purchases a token but no other user joins the platform, his utility in period 2 is $u\big((1-\alpha)\,\omega_1(s_1)\big)$.[8] If all potential users in period 2 join the platform, each realizes utility $u\big((1-\alpha)n_1+n_2\big)$. A user that does not purchase a token in either period receives payoff of 0 in period 2.

Since $(1-\alpha)\,\omega_1(s_1)<(1-\alpha)n_1+n_2$, then $u\big((1-\alpha)\,\omega_1(s_1)\big)<u\big((1-\alpha)n_1+n_2\big)$. Thus there is a range for p_2 such that

$$u\big((1-\alpha)\,\omega_1(s_1)\big)<p_2<u\big((1-\alpha)n_1+n_2\big)$$

where a potential user in period 2 without a token will want to join only if he believes that the other potential users will join as well. This leads to two possible Nash equilibria in the period 2 subgame.

Given the coordination bias ϕ_2 in period 2, a potential user without a token will purchase a token and join the platform in period 2 if the platform sets a period 2 price for its token

$$p_2\leq\bar{p}_2(\phi_2,s_1)=\phi_2\,u\big((1-\alpha)n_1+n_2\big)+(1-\phi_2)\,u\big((1-\alpha)\,\omega_1(s_1)\big)$$

based on the expectation that everybody will join at this price (which indeed happens). Similarly, if the platform sets $p_2>\bar{p}_2(\phi_2,s_1)$ no new potential users will join based on the expectation that other potential users will not be enticed to join at this price either.

Since $t=2$ is the last period, if $\bar{p}_2(\phi_2,s_1)<0$, the platform will not want to subsidize

[8] Users that acquire a token in period 1 and do not exit the market in period 2 will stay on the platform in period 2 and thus will keep using their token.

the users to join. It will set $p_2 = 0$ and no new potential users will join. But if $\bar{p}_2(\phi_2, s_1) \geq 0$, the platform will set $p_2 = \bar{p}_2(\phi_2, s_1)$, and all potential users will join. Thus $p_2(s_1) = \max\{0, \bar{p}_2(\phi_2, s_1)\}$.

Lemma 1. If $\phi_2 < 1$, then $p_2(1) > p_2(0)$, i.e., success in period 1 allows the platform to charge a higher price for its token in period 2.

Proof Since $\omega_1(0) = 0$ and $\omega_1(1) = n_1 > 0$, $\bar{p}_2(\phi_2, 1) > \bar{p}_2(\phi_2, 0)$. Also $u(n_1) > 0$ and the network expands in period 2, thus $\bar{p}_2(\phi_2, 1) > 0$; however we allow $\bar{p}_2(\phi_2, 0) < 0$, because $u(0) < 0$. Thus, $p_2(1) > p_2(0)$.

Lemma 1 means that the platform can charge a higher price in period 2 if it was successful in period 1, because the period 1 users that do not exit in period 2 are already on the network, and stay there whether the platform succeeds in attracting more users in period 2.[9]

Users who arrived in period 1 and purchased a token will either have to leave the market in period 2 and then they will sell their token at price p_2, which will be their period 2 payoff, or will stay in the market for period 2 and obtain an expected payoff $EU_2^{stay}(s_1)$.[10]

We now solve for period 1 equilibria. A potential user that arrives in period 1 can purchase a token at price p_1. If the platform fails, i.e., no other user joins the platform, his individual benefit is

$$V_1(0) = u(0) + \alpha p_2(0) + (1 - \alpha) EU_2^{stay}(0)$$

while if the platform succeeds, i.e., all n_1 potential users arriving in period 1 purchase a

[9] If we allow $\phi_2(s_1)$ to depend on the equilibrium played in the first period, such that $\phi_2(0) < \phi_2(1) < 1$, then it would be another factor reinforcing $\bar{p}_2(\phi_2, 1) > \bar{p}_2(\phi_2, 0)$, because $u(n_1(1-\alpha)+n_2) > u(n_1(1-\alpha)) > u(0)$.

[10] Note that as long as $EU_2^{stay}(s_1) \geq \bar{p}_2$, then the assumptions about how $EU_2^{stay}(s_1)$ is calculated (e.g., is the adoption cost realized in each period, or can users voluntarily exit the platform in period 2 if it is not successful) will apply to both settings with and without tokens and thus will not affect the comparison of these settings.

token, the individual benefit realized by each user is

$$V_1(1) = u(n_1) + \alpha p_2(1) + (1-\alpha) EU_2^{stay}(1)$$

and the total payoff for a potential user from buying the token in period 1 is $V_1(s_1) - p_1$. If the platform sets p_1 between $V_1(0)$ and $V_1(1)$ then we have a coordination problem: potential users arriving in period 1 want to join only if the other period 1 potential users will be joining. If the period 1 coordination bias for the platform is ϕ_1, period 1 potential users will join if $p_1 \leq \bar{p}_1(\phi_1)$ where

$$\bar{p}_1(\phi_1) = \phi_1 V_1(1) + (1-\phi_1) V_1(0)\,,$$

as they know that at this price all other users will join as well; and they will not join if $p_1 > \bar{p}_1(\phi_1)$, as they correctly believe that in that case others will not join as well.

For the platform to solve the coordination problem, it must set $p_1 = \bar{p}_1(\phi_1)$ so that all users join. Note that if $u(0) < 0$, then $\bar{p}_1(\phi_1)$ may be negative, i.e., the platform may need to subsidize potential users to induce them to join in period 1. This can be optimal for the platform as the subsidy will be recovered in period 2 if $\bar{p}_1(\phi_1) n_1 + p_2(n_2 - \alpha\, n_1) > 0$ and can lead to higher total profits.

By solving the coordination problem the platform realizes total profit

$$\Pi^T = \bar{p}_1(\phi_1) n_1 + p_2(n_2 - \alpha\, n_1).$$

We focus our discussion on the case where $\Pi^T > 0$, i.e., it is profitable for the platform to issue tradable tokens, as otherwise tokens do not provide a viable alternative to a subsidy in period 1.

4 Benefits of Tradable Tokens in Solving the Coordination Problem

To derive the potential benefit from tradable tokens, we next consider the platform's optimal pricing strategy without them.

4.1 Coordination without tokens

The timing of the game is similar in the setting without tokens:

Period 1:

- In the beginning of period 1, n_1 potential users arrive to the market.
- The market coordination bias is ϕ_1.
- The platform sets a price for access to the network, p_1^{NT}
- The n_1 potential users decide whether to join the platform, depending on the price, p_1^{NT}, and the coordination bias, ϕ_1.
- At the end of period 1, everybody observes whether the n_1 potential users joined the platform, which determines the value of $s_1 \in \{0, 1\}$ as in the case with tokens. Potential users that join the platform realize period 1 benefit $V_1^{NT}(s_1)$, which includes their utility from participating in the period 1 network, $u(\omega_1) - p_1$, and their expected payoff in period 2.

Period 2:

- In the beginning of period 2, αn_1 potential users that arrived in period 1 leave the market, and n_2 new potential users arrive.

- Users that leave the market receive continuation payoff 0.[11]
- The market coordination bias is ϕ_2.
- The platform sets a price for access to the network, p_2^{NT}
- Users who are not participating in the network at the beginning of period 2, decide whether to join or not, depending on p_2^{NT} and ϕ_2.
- At the end of period 2, everybody realizes their period 2 payoffs.

We solve for the equilibrium in the game without tokens using backward induction.

Period 2 analysis is the same as in the case with tokens, and platform sets the same price, i.e., $p_2^{NT} = p_2$, and Lemma 1 still holds. Without the tokens, however, the platform sells access to all n_2 new potential users in period 2, rather than $n_2 - \alpha n_1$, as period 1 users that leave the platform in period 2 cannot sell their participation rights.

Potential users that arrive in period 1 can join the network at price p_1^{NT}. The benefit of joining is

$$V_1^{NT}(1) = u(n_1) + (1-\alpha)EU_2^{stay}(1)$$

if other potential users join and the platform is successful in period 1, or it is

$$V_1^{NT}(0) = u(0) + (1-\alpha)EU_2^{stay}(0)$$

if other potential users do not join and the platform fails in period 1. Since period 1 arrivals will leave in period 2 with probability α, $V_1^{NT}(s_1) = V_1(s_1) - \alpha p_2(s_1)$ as these users will not be able to resell their platform access.

[11]This is a key difference from the setting with tokens, where departing users can sell their token to potential users that arrive in period 2.

For p_1^{NT} such that

$$u(0) + (1-\alpha)EU_2^{stay}(0) < p_1^{NT} < u(n_1) + (1-\alpha)EU_2^{stay}(1)$$

there are two possible Nash equilibria. Given the coordination bias ϕ_1, potential users will join the platform if $p_1^{NT} \leq \bar{p}_1^{NT}(\phi_1)$ where

$$\bar{p}_1^{NT}(\phi_1) = \phi_1 V_1^{NT}(1) + (1-\phi_1)V_1^{NT}(0)\,.$$

Notice that $\bar{p}_1^{NT}(\phi_1) < \bar{p}_1(\phi_1)$, since

$$\bar{p}_1(\phi_1) = \bar{p}_1^{NT}(\phi_1) + \alpha\big(\phi_1\, p_2(1) + (1-\phi_1)\, p_2(0)\big).$$

This result leads to the following lemma:

Lemma 2. For $\alpha > 0$, $\bar{p}_1 > \bar{p}_1^{NT}$, i.e., the platform can charge a higher period 1 price in the setting with tokens, unless both $\phi_1 = 0$ and $p_2(0) = 0$.

The platform can charge a higher price in the first period when it issues tradable tokens because potential users can resell the token in case they have to leave the market in the second period. Without tradable tokens, potential users are willing to pay a lower price to join the platform in the first period.

If the platform sets $p_1^{NT} = \bar{p}_1^{NT}(\phi_1)$ all users join in the first period.[12] The platform solves then the coordination problem and earns

$$\Pi^{NT} = \bar{p}_1^{NT}(\phi_1)\, n_1 + p_2\, n_2.$$

[12]As before, the period 1 price can be negative, i.e., a subsidy may be required to induce period 1 potential users to join.

We focus on the case where $\Pi^{NT} > 0$ so that it is profitable for the platform to overcome the coordination problem.

4.2 Tokens *vs.* no tokens

Issuance of a tradable token allows the platform to increase its revenues in period 1, per Lemma 2. However, revenues are lower in period 2, because the platform loses αn_1 sales from departing users.

Specifically, by issuing tokens, the platform gains revenue

$$n_1\alpha(\phi_1 p_2(1) + (1-\phi_1)p_2(0))$$

in period 1, and loses revenue

$$n_1\alpha p_2(1).$$

in period 2. By Lemma 1 the latter is larger than the former, leading to the following Proposition:

Proposition 1. For any $\alpha > 0$ and $\phi_1, \phi_2 < 1$, $\Pi^T < \Pi^{NT}$, i.e., total platform profits are higher without tokens.

This is because when the platform sets the period 2 prices, it chooses a price that will overcome the coordination problem. But some of the period 2 access is indirectly sold to the users in period 1, by allowing the period 1 users that exit the market to resell to period 2 users, the platform needs to compensate period 1 potential users for partial coordination bias in period 1, i.e., for joining the platform despite some lack of trust that the platform will overcome the coordination problem. Essentially, the platform gives the period 1 potential users an equity stake in the success of the platform in period 2, and thus it must share part of the period 2 profits with them. As shown in the Appendix, the result in Proposition 1 holds also if both the platform and the period 1 potential users discount the future at the same rate.

While Proposition 1 means that total profits may be lower in the setting with tokens, the platform might still find it optimal to issue a tradable token to overcome the coordination problem because of the ability to move revenue from period 2 to period 1. For instance, if $p_1^{NT} < 0 < p_1$, then solving the coordination problem without a token requires a negative price (i.e., a subsidy) in period 1, but with a token the subsidy can be avoided. If the platform faces capital constraints, or a negative price is otherwise not feasible,[13] token issuance may be the preferred strategy. Proposition 2 derives conditions under which this is true because financing is costly.

In summary, a tradable token provides a new tool for solving the coordination problem for a platform in an environment with network effects.

Costly financing. Let $\bar{p}_1^{NT} < 0 < \bar{p}_1$, i.e., a subsidy is needed in period 1, and the platform can borrow the capital needed for period 1 subsidy, $n_1\bar{p}_1^{NT}$, at the rate $r > 0$. The cost of capital affects platform profits if it needs to offer a subsidy to overcome the coordination problem:

$$\Pi^{NT}(r) = \bar{p}_1^{NT} n_1 + p_2\, n_2 + r\, \bar{p}_1^{NT} n_1 < \Pi^{NT}$$

If the platform overcomes the coordination problem by issuing a tradable token, then there is no subsidy needed in period 1 and its profits are not affected by r:

$$\Pi^T = \bar{p}_1 n_1 + p_2\,(n_2 - \alpha n_1)\,.$$

The following Proposition directly follows from the above derivations for Π^{NT} and Π^T:

[13] Subsidies are often difficult to execute, for instance because of costly administration or the need to limit abuse by potential users.

Proposition 2. Suppose $\bar{p}_1^{NT} < 0 < \bar{p}_1$. Then $\Pi^T > \Pi^{NT}(r)$ for $r > \bar{r}$, where

$$\bar{r} \;=\; \frac{\alpha(1-\phi_1)\big(p_2(1)-p_2(0)\big)}{-\bar{p}_1^{NT}}$$

Proposition 2 shows that the platform prefers to use tokens rather than a subsidy to solve the coordination problem if it faces a high enough cost of capital.

Lemma 3. The threshold $\bar{r}$ is increasing with ϕ_1.

Proof

$$\bar{p}_1^{NT} = \phi_1 V_1^{NT}(1) + (1-\phi_1)V_1^{NT}(0)$$

$$\begin{aligned}
\frac{\partial \bar{r}}{\partial \phi_1} &= \frac{-\alpha(p_2(1)-p_2(0))(-\bar{p}_1^{NT}) - \alpha(1-\phi_1)(p_2(1)-p_2(0))(V_1^{NT}(0)-V_1^{NT}(1))}{[\bar{p}_1^{NT}]^2} \\
&= \frac{\alpha\,(p_2(1)-p_2(0))}{[\bar{p}_1^{NT}]^2}\left[\bar{p}_1^{NT} - (1-\phi_1)(V_1^{NT}(0)-V_1^{NT}(1))\right] \\
&= \frac{\alpha\,(p_2(1)-p_2(0))}{[\bar{p}_1^{NT}]^2} V_1^{NT}(1) \;>0\,.
\end{aligned}$$

As shown in Proposition 2, the platform prefers to use tokens rather than a subsidy to solve the coordination problem if its cost of capital is above a certain threshold. Lemma 3 shows that the lower ϕ_1, the lower this threshold. For high ϕ_1, when the platform enjoys high coordination bias in its favor and the coordination problem is easier to overcome, capital must be more expensive to make tokens the preferred solution. But as ϕ_1 gets lower, i.e., coordination bias is increasingly against the platform and it faces a coordination problem that is increasingly more costly to solve, financing the subsidies needed to launch the platform becomes more expensive and issuing tradable tokens may be a better option than borrowing to finance a subsidy, even for a relatively low cost of capital.

Figure **??** shows the comparative statics for the period 1 coordination bias ϕ_1. Proposi-

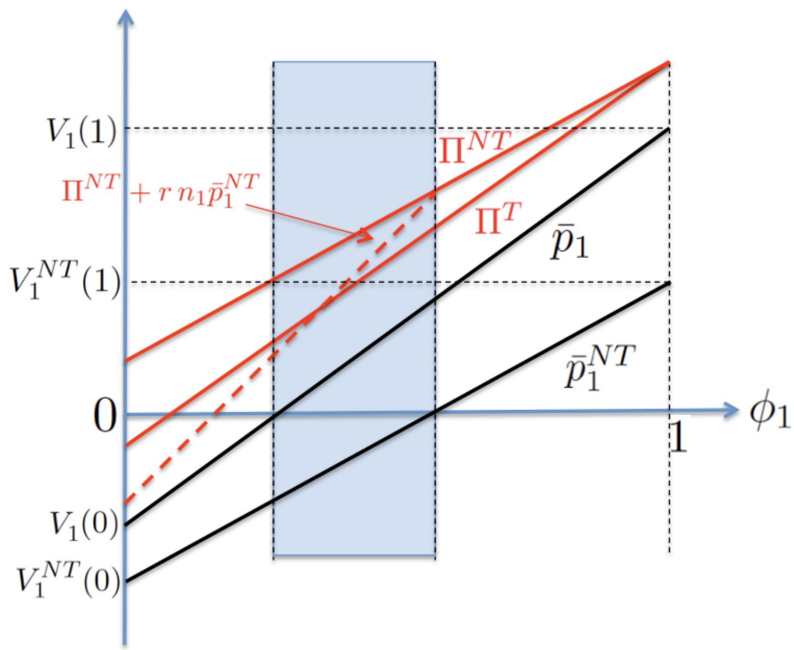

Figure 1: Coordination bias, first period price and total platform profit

tion 1 implies that platform profit without tokens, the solid red Π^{NT} line, is above Π^T for $\phi_1 < 1$. The two meet for $\phi_1 = 1$. Both Π^T and Π^{NT} are increasing with ϕ_1 but Π^T increases faster and catches up with Π^{NT} for $\phi_1 = 1$.

From Lemma 2 we know that $\bar{p}_1$ is above $\bar{p}_1^{NT}$ for all ϕ_1. The shaded region represents the particularly interesting area where $\bar{p}_1^{NT} < 0 < \bar{p}_1$; that is, without tokens a subsidy is required in period 1, but with tokens the coordination problem is solved in the platform's favor even though the price for tokens is positive.

Both $\bar{p}_1$ and $\bar{p}_1^{NT}$ are increasing in ϕ_1 as well, with $\bar{p}_1$ increasing faster. That means that for lower ϕ_1 a larger subsidy is required in period 1 to overcome the coordination problem.

As ϕ_1 decreases, the cost of financing the increasing subsidy in the absence of tokens, outweighs the loss of total revenue resulting from issuing tokens; this corresponds to the dashed red line that shows the total platform profits adjusted for the cost of financing the subsidy crossing below Π^T. By Proposition 2, the two lines meet for such value of ϕ_1 that

$\bar{r} = r$. As the cost of capital r increases, the slope of the dashed red line increases, and it crosses the Π^T line at higher ϕ_1 values, which is captured by Lemma 3.

5 Discussion

The explosive growth of ICOs has fueled a lot of recent debate about their nature, role and value. For instance, do the tokens created in ICOs fill a niche not covered by other types of financing? Are they an attractive option for entrepreneurs aspiring to develop a digital platform? Potential platform users? Hopeful investors? Are the tokens created in ICOs a form of equity? A commodity? Advance sales?

Much of the focus on ICOs has been in the context of using their proceeds as a primary or secondary source of funds for the development of a digital platform. Several potential sources of value can be identified in this context, including allowing entrepreneurs to tap a source of financing outside the traditional equity or debt channels, and the potential of a prospective platform to gauge demand for its services based on the demand for the digital tokens it issues.

Our paper contributes to this discussion by addressing an aspect frequently overlooked: the ability to issue tradable digital tokens required to access platform services offers platforms a way to address the coordination problem in fostering adoption by potential users. It is certainly true that transferable participation rights could be issued and traded without blockchain and crypto-token technology;[14] however the extraordinary reduction in the associated transaction costs and the increase in functionality, awareness, popularity and acceptance of these mechanisms, has resulted in a qualitative change that makes such mechanisms practical, and, in fact, enjoying rapid growth.

We employ a model that focuses on the coordination aspect of digital tokens. To simplify

[14] And this also applies to the ability of ICOs to emulate aspects of equity, debt or pre-sales, as non-blockchain and even non-digital versions exist for all of the above.

the model we assume:

(1) The platform is already developed thus there is no uncertainty about its financing or technological risk.

(2) There are two periods (early and late arrival of potential users), which allows us to capture the dynamic nature of platform adoption, as platforms may need to subsidize early users, but, if successful, are able to enjoy economic value in later periods.

(3) All potential users are identical in terms of willingness to pay (as a function of network size) and their coordination bias with respect to the platform. The willingness to pay and the coordination bias are common knowledge; and so are the numbers of potential users expected to arrive in each of the two periods.

(4) Potential users that acquire a token in the first period also join the platform; these users can stay on the platform for the second period as long as they keep possession of the token; alternatively they may exit the platform in the second period and trade their token.

We find that tokens can provide a novel mechanism to help solve the coordination problem faced by a new platform. This mechanism works by allowing early users to share the benefit of platform success, as they can sell their tokens at a higher price when the platform is successful. Early users essentially acquire an equity interest in the platform and thus become vested in its success. As a result lower incentives are needed to get early users to adopt, reducing the cost of addressing the coordination problem. With tokens, revenue is higher in period 1 and lower in period 2: the platform is moving revenue from period 2 to period 1. In our model, parameter α determines the amount of revenue that can be moved, and ϕ_1 determines the discounting of the revenue moved to compensate potential users in period 1 for the risk of platform failure.

While token sales to early adopters result in higher revenues in period 1, they are offset by loss of revenue in period 2 as these early adopters sell their tokens to future potential users. If the platform faces no financial constraints, then traditional financing of addressing the coordination problem (such as a subsidy for early users) will lead to higher total profits for the platform.

If, however, the platform is capital constrained, tokens provide a mechanism to avoid the cost of subsidizing period 1 users, and thus finance the solution of the coordination problem faced by the platform. The benefit of issuing tokens increases when the platform is viewed by the market as more risky, or when its cost of capital is higher.

While our assumptions are intended to simplify the analysis and emphasize the central focus of the model, which is using tokens to address the coordination problem of potential adopters, it would be interesting to explore the implications of relaxing them and this suggests several extensions and variations to our work. For example, our setting can be extended to more than two periods. Another extension would be to allow for heterogeneity of the potential users in their coordination bias with respect to the platform, and in their willingness to pay as a function of network size. Yet another extension would allow for investors and speculators in the token market: such agents might acquire one or more tokens with the intent to trade their tokens at some future date. Finally it would be interesting to combine the coordination features of our model with related work that considers the use of tokens as a means for financing the development of a platform or to gauge the demand for its services, which would allow us to explore possible strategic interactions.

Appendix – Discounting the future

Suppose that the platform and potential users in period 1 discount the future (i.e., period 2) with discount factor δ. Platform profits under the token and no token scenarios are

$$\Pi^T(\delta) = \bar{p}_1(\delta)n_1 + \delta\, p_2(1)\,(n_2 - \alpha\, n_1)$$
$$\Pi^{NT}(\delta) = \bar{p}_1^{NT}(\delta)n_1 + \delta\, p_2(1)\, n_2$$

The second period choices by the platform or the users are not affected by δ, as this the last period. But $\bar{p}_1$ and $\bar{p}_1^{NT}$ depend on δ, because $V_1(s_1)$ and $V_1^{NT}(s_1)$ do.

$$V_1(1|\delta) = u(n_1) + \delta\left(\alpha p_2(1) + (1-\alpha)EU_2^{stay}(1)\right)$$
$$V_1(0|\delta) = u(0) + \delta\left(\alpha p_2(0) + (1-\alpha)EU_2^{stay}(0)\right)$$

$\bar{p}_1(\delta) = \phi_1\, V_1(1|\delta) + (1-\phi)\, V_1(0|\delta)$, and

$$\bar{p}_1^{NT}(\delta) = \bar{p}_1(\delta) - \delta\alpha\left(\phi_1\, p_2(1) + (1-\phi_1)\, p_2(0)\right).$$

By issuing a token the platform gains $n_1 \cdot \delta\alpha\left(\phi_1\, p_2(1) + (1-\phi_1)\, p_2(0)\right)$ in period 1. The difference between the first period prices is increasing with δ. As δ gets smaller, the present value of the loss from leaving the market in the absence of a token is smaller, and hence the option to avoid this loss becomes less valuable.

If the platform issues a token, the present value of the second period revenue loss is

$$n_1 \cdot \delta\alpha p_2(1) > n_1 \cdot \delta\alpha\left(\phi_1\, p_2(1) + (1-\phi_1)\, p_2(0)\right)$$

.

Cost of financing and discounting the future. Suppose $\bar{p}_1^{NT}(\delta) < 0 < \bar{p}_1(\delta)$

$$\Pi^{NT}(\delta,\, r) = \bar{p}_1^{NT}(\delta) n_1 + \delta\, p_2(1)\, n_2 + \delta$$

Then $\Pi^T(\delta) > \Pi^{NT}(\delta,\, r)$ iff $r > \bar{r}(\delta)$, where

$$\bar{r}(\delta) = \frac{\alpha(1-\phi_1)\big(p_2(1) - p_2(0)\big)}{-\bar{p}_1^{NT}(\delta)}\,.$$

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