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.

Keywords: economics of IS, ICOs, blockchain, platforms, network effects

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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. The volume of ICOs has been increasing rapidly. Between January 2014 and June 2018, ICOs raised over \$18 billion (Howell, Niessner and Yermack 2018); in the first 5 months of 2018 alone a total of 537 ICOs with a volume of \$13.7 billion have been closed successfully, which is more than twice 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 another aspect of tradable digital tokens that may provide a legitimate benefit when employing them in the context of platforms: to the extent that

[1]See, for instance, Halaburda and Sarvary (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.

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.

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.

This work is directly relevant to researchers and practitioners affected by financial technology, as ICOs are becoming an important element of the FinTech ecosystem and token offerings by platforms employ blockchain technology to create technology-based strategic and financial options. Our analysis and findings illustrate the strategic alternatives for platform adoption enabled by blockchain technology, which are important for platforms, as addressing the associated coordination problems and engaging potential participants is central to platform success.

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

2 Related Literature

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 a user's utility increases as more other users buy the same product or service. As a result, potential users want to join the same network as other users and thus multiple outcomes can constitute an equilibrium as long as potential users coordinate on the same one. For instance, a potential user may forgo joining an otherwise attractive network if he does not believe that other potential users will join as well, or join a network he otherwise wouldn't because he believes that will be the choice of other users.

Platforms are strategic players and can use attractive pricing to overcome unfavorable beliefs when they try to entice potential users to adopt, or when they compete against other platforms (e.g., Caillaud and Jullien, 2001; Hagiu and Spulber, 2013). 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).

In this paper we study the coordination problem in the context of cryptographic tokens and ICOs. There is a rapidly growing literature on ICOs but most of it is not concerned with their role in settings with network effects.[4] There is also 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 (Sockin and Xiong, 2018; Cong, Li, and Wang, 2018).

Network effects are central in Sockin and Xiong (2018) and Cong, Li, and Wang (2018). In these analyses, however, 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

[4] For example, Howell, Niessner and Yermack (2018) provide comprehensive overview of ICOs characteristics, and investigate relation between these characteristics and success of ICO. Chod and Lyanders (2018) consider agency problems that may arise when funding venture with tokens. Malinova and Park (2018) analyze optimal contact structure when funding venture with tokens. Lyanders, Palazzo and Rabetti (2018) investigate the dynamics of token prices, and compare them to securities. Bakos and Halaburda (2019) illustrate how ICOs may help crowdsource due diligence in funding new projects.

coordination problem by issuing a token rather than with a traditional user subsidy. Moreover, the coordination issue is not a problem in their settings, as these papers assume that in case of multiple equilibria the users will coordinate on the efficient equilibrium.

Catalini and Gans (2018) focus on the role of tokens in demand discovery, but they also discuss the possibility to use 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 the token price as is the case in our setting. In their model 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 tokens in that setting depends on a large enough stand-alone value of the product or service offered by the platform; and on the ex-ante heterogeneity of users, which leads to sequential increase in demand. In their setting tokens would not solve the coordination problem for ex-ante homogeneous users or for pure network goods, i.e., goods (or services) that have no value if no other user adopts.

Li and Mann (2018) consider how platform-specific tokens help overcome the coordination problem in platform adoption.[5] They consider a two-sided market with a single potential user on each side. The platform offers tokens to each side in turn, and purchase of a platform-specific token allows each side's commitment to trade on the platform to be observed by the other side; this effectively transforms the setting into a sequential game and resolves the coordination problem for adoption across the two sides. The heterogeneity of the potential users in the sense that they can be separately targeted by the platform to purchase a token is necessary for their mechanism to work. The coordination problem reappears within each side if there are multiple potential users for that side. In this case, Li and Mann (2018) implicitly follows the literature and assume the market coordinates on the efficient equilibrium for each side when multiple equilibria are available.

[5] Li and Mann (2018) also considers the problem of how to sustain the value of tokens, which is outside the scope of our paper.

Mechanisms like the ones in Catalini and Gans (2018) and Li and Mann (2018) illustrate an important aspect of tokens, namely the ability to make token purchases (which in the case of platform-specific tokens correspond to adoption decisions) observable by market participants—sometimes referred to as "transparency." This transparency can affect the resulting equilibria by changing the information structure and therefore the sequence of moves, and this can eliminate the coordination problem in certain settings.

Our work is complementary to the above literature as we focus on a different characteristic of tokens—their tradability. We show that tradability makes tokens a valuable tool in overcoming coordination problem even if the information about token purchases is missing or not reliable (i.e., they lack transparency). Distinguishing the impact of different features of cryptographic tokens, such as tradability and transparency, in addition to its theoretical interest can have practical implications. Since these tokens are programmable, it is possible to design them with customized features, and thus take advantage of an understanding of the contexts in which particular features are valuable, and the benefits they provide.

Furthermore, while existing literature leverages the heterogeneity of potential users to transform platform adoption into a sequential game, our approach allows platform to overcome the coordination problem even when potential users are ex-ante identical and move simultaneously. We find that the coordination problem can be overcome because of the tradability of tokens even when direct subsidies are infeasible or too costly. This offers the early potential users a stake in the success of the platform and makes it more attractive for them to join, and their joining makes it more likely for the platform to indeed succeed. We derive conditions under which the platform prefers to issue a tradable token to solve the coordination problem and 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 that offers 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 the issuance of cryptographic tokens to traditional price-based strategy options such as subsidizing early adopters.

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 potential users that arrive in two periods that we denote with $t = 1, 2$. In each period, n_t 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."[6] While potential users are *ex-ante* identical, they differ in terms of their realized utility from the platform, which is determined by a type k that is learned only after experiencing the platform. Type k is distributed with a continuous pdf $g(k)$ on support $[A, B]$ with the utility u_k weakly decreasing in the type k.

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 and join the platform have the option to leave in period 2 after observing their realized utility from the platform; they will do so if staying in the platform for period 2 offers lower expected utility than their outside option.

[6] 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.

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 $u_k(\omega) > u_k(\omega')$ for all types k. Furthermore, to make the coordination problem nontrivial, we assume that $E[u_k(0)] < 0$ and $E[u_k(n_1)] > 0$; that is, joining an empty platform yields on expectation negative utility (e.g., due to adoption cost), and joining a successful platform yields on expectation positive utility.

Digital tokens. Platform access requires possession of a digital token issued by the platform. Tokens are offered for sale by the platform each period $t = 1, 2$ at a price it chooses, provide access to the platform for both periods, 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.

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 *ex-ante* 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.[7]

Focality. In coordination games, players' beliefs frequently result in one equilibrium being more salient than others, a concept known as *focality* (Schelling, 1960). Focality has been used to address selection among the multiple possible equilibria in the context of platform adoption and platform competition (Fudenberg and Tirole, 2000; Caillaud and Jullien, 2001, 2003).[8] When a platform enters a market with network effects, frequently there are two equilibria for potential users: *adopting* or *not adopting*; in these cases, focality can help determine the resulting outcome.

For instance, suppose first that the focal equilibrium is *adopting*. In this case we will say that the platform enjoys "full focality of adoption," as potential users fully expect other

[7]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.

[8]The terminology in the platforms literature varies. Fudenberg and Tirole (2000) assume that in the presence of two equilibria, *adopting* and *not adopting*, the market will coordinate on *adopting* as the focal equilibrium—although they do not explicitly use the "focality" label. Caillaud and Jullien (2001, 2003) use "favorable beliefs" to denote a focal equilibrium with successful adoption, and "unfavorable" or "pessimistic beliefs" to denote a focal equilibrium without adoption.

potential users to adopt. Potential users will thus adopt provided the platform sets a price that is acceptable *in the case that the other potential users adopt as well.* 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 a platform enjoying full focality can charge a price $p = V(1)$. At this price all potential users adopt, and correctly believe that all other potential users will also adopt. This scenario is the most desirable for the platform in the sense that it maximizes the price it can charge. Several papers on platform competition, such as Fudenberg and Tirole (2000), assume that the market will coordinate on the equilibrium with adoption, and thus the platform will enjoy full focality of adoption. This approach, however, essentially assumes away the coordination problem that platforms face.

Now suppose that the focal equilibrium is *not adopting*, i.e., that the market is fully biased against the new platform in the coordination game. This does not mean that the platform will never get adopted; however, in order for potential users to adopt, the price set by the platform needs to be low enough so that a potential user would want to adopt *even in the case that nobody else adopts*, i.e., $p = V(0)$. Entry under unfavorable beliefs was first explored by Caillaud and Jullien (2001, 2003).

In our setting $V(0) < 0$, and thus the platform must charge a negative price, i.e., *subsidize* potential users in order to foster adoption. Beliefs are rational in the sense they are consistent with the actions taken, the observed outcomes, and Nash equilibrium: at this price, potential users know that just as they are enticed to join the platform, so will all other potential users, and thus they correctly expect all potential users to adopt, and thus expect to enjoy utility $V(1) > p = V(0)$. Drawing on Caillaud and Jullien (2001, 2003), even though all users will join the platform, and they all expect that to happen at $p = V(0)$, the platform cannot charge a higher price $p > V(0)$ to capture some of the resulting surplus; if it were to do so, potential users would expect that other potential users would not adopt given that *not adopting* is focal, and thus they themselves would not adopt as well, leading to failed adoption. Thus, with focality against the platform the highest price at which all users will adopt is $p = V(0)$, and this outcome also complies with rational expectations.

The focality of different adoption equilibria may change the resulting outcome for the platform. It is possible that the platform will not find it profitable to overcome the coordination problem if it faces an unfavorable situation where not adopting is focal, in which case the platform will not be adopted, while it would have been profitable to do so if the focal equilibrium would favor adoption, which would have led to successful platform adoption.

Partial focality. Full focality favoring the *adopting* equilibrium and full lack of focality for that equilibrium (which corresponds to full focality favoring the *not adopting* equilibrium) are the two extreme possibilities in terms of determining the conditions under which users are willing to join the platform; a more realistic scenario is the intermediate case of partial focality (e.g., see Halaburda and Yehezkel, 2016, 2019).[9] We say that *adopting* is partially focal equilibrium with degree $\phi \in (0, 1)$, if in order for a potential user to adapt the platform, the price needs to be low enough that adoption would be attractive *even in the case when other potential users would join only with probability* ϕ, i.e., $p(\phi) = \phi V(1) + (1 - \phi)V(0)$. The fully favorable and fully unfavorable focality cases that we discussed earlier correspond to $\phi = 1$ and $\phi = 0$ respectively.

Under focality of degree ϕ, the highest price the platform can charge and entice potential users to adopt is $p(\phi) = \phi V(1) + (1 - \phi)V(0)$. As Halaburda and Yehezkel (2016, 2019) point out, this is consistent with rational beliefs. At price $p(\phi) = \phi V(1) + (1 - \phi)V(0)$, each potential user knows that just as he is enticed to join the platform, so will all other potential users, and correctly expects everyone to adopt, providing utility $V(1) > p(\phi)$. The platform

[9] Halaburda and Yehezkel (2016) are the first to formally analyze and apply partial focality (calling it "coordination bias") in a specific two-sided setting. Halaburda and Yehezkel (2019) extend that formulation, introduce the term "partial focality" that we use in this paper, and provide a more general formalization linked to the established concept of focal equilibrium.

cannot set a higher price, however, by the same logic as described above for the case of fully unfavorable focality, corresponding to $\phi = 0$, where the platform can charge at most $V(0)$. The more favorable the market coordination bias for the platform, i.e., the higher the value of ϕ, the higher the price it can charge and still enjoy successful adoption.

The focality of degree ϕ can be interpreted as the trust the market places on the platform that the latter will be able to overcome the coordination problem. Given that history may affect this trust, the degree of focality in the second period may be affected by the outcome of the first period. While for simplicity we focus our analysis on the case that ϕ_2 does not depend on the period 1 outcome, our results persist if we allow ϕ_2 to be a function of success at $t = 1$, with $\phi_2(s_1 = 1) > \phi_1$ if the platform succeeds in period 1 and $\phi_2(s_1 = 0) < \phi_1$ if the platform fails in period 1.

4 Coordination without tokens

We first consider the platform's optimal pricing strategy in the base case scenario, when no digital tokens are issued. This provides a benchmark for exploring the impact of tradable tokens, which we analyze in the next section.

4.1 Timing of the game

Potential users arrive to the market in each period t ($t = 1, 2$) and can decide to join the platform in the period they have arrived, in a later period, or not at all. Upon joining the platform, users learn their type k and realize their utility. Users who joined the platform in period 1 realize the utility $u_k(\omega_1)$, and subsequently may choose to leave the platform in period 2.

The detailed timing of the game is as follows:[10]

[10]Figure 2 in the Appendix provides visual representation of the timeline of agents' decisions.

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, knowing n_1 and ϕ_1, sets a price for access, p_1^{NT}.
- The n_1 potential users decide whether to join the platform based 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 $s_1 \in \{0, 1\}$ with a successful outcome for the platform denoted by $s_1 = 1$. Users that joined the platform learn their type k and realize period 1 benefit $V_k^{NT}(s_1)$, which includes their utility from participating in the period 1 network, $u_k(\omega_1)$, and their expected payoff in period 2.

Period 2:

- In the beginning of period 2, n_2 new potential users arrive to the market.
- The market coordination bias is ϕ_2.
- The platform, knowing s_1, n_2 and ϕ_2, sets a price for access, $p_2^{NT}(s_1)$, depending on whether first period adoption was successful.
- Users who joined the platform in period 1 decide whether to stay or leave the platform based on their type k and their expectations for period 2. Users that leave the platform receive continuation payoff 0,[11] and we denote the fraction of such users as α^{NT}.

[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.

– Users who have not joined the platform 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 subgame perfect equilibrium using backward induction, starting with period 2:

If the platform failed in period 1 ($s_1 = 0$), the highest price the platform can charge in period 2 and still attract everyone is $\bar{p}_2(s_1 = 0, \phi_2) = \phi_2 E[u_k(n_1 + n_2)] + (1 - \phi_2)E[u_k(0)]$. By earlier assumptions, $E[u_k(0)] < 0$ and $E[u_k(n_1 + n_2)] > 0$.

In our main analysis, we focus on the case where the platform can charge a positive price at $t = 2$ and still attract users only if it succeeded at $t = 1$, i.e., $\bar{p}_2^{NT}(s_1 = 1, \phi_2) > 0$ and $\bar{p}_2(s_1 = 0, \phi_2) < 0$.[12,13] Since $\bar{p}_2(s_1 = 0, \phi_2) < 0$, the platform will set $p_2(s_1 = 0, \phi_2) = 0$, resulting in no potential user to adopt in period 2 as well, i.e., $s_2 = 0$. Everyone's payoffs, including the platform, are 0 and $\Pi(s_1 = s_2 = 0) = 0$.

If the platform succeeded in period 1 ($s_1 = 1$), we denote by α^{NT} the fraction of period 1 users that will leave the platform, based on their type k and their expectations about their second period payoffs in and out of the platform. These are users that after experiencing the platform at $t = 1$ and discovering their type, are better off to leave the platform given their expectations for period 2. The n_2 new potential users decide whether to join the platform, based on the adoption strategy's focality of degree ϕ_2, the price p_2^{NT} set by the platform at $t = 2$, and their expectation that $(1 - \alpha^{NT})n_1$ period 1 users will remain.

The highest price the platform can charge and still attract the potential users that arrive at $t = 2$ is $\bar{p}_2^{NT}(s_1 = 1, \phi_2) = \phi_2 E[u_k(n_2 + n_1(1 - \alpha^{NT}))] + (1 - \phi_2)E[u_k(n_1(1 - \alpha^{NT}))]$. Since

[12] In the appendix we relax this assumption and allow for $\bar{p}_2^{NT}(s_1 = 1, \phi_2) \leq 0$ and $\bar{p}_2(s_1 = 0, \phi_2) \geq 0$. While it complicates the analysis, it does not change the qualitative results about the value of token tradability.

[13] If platform adoption fails at $t = 1$, period 2 outcomes are identical whether tokens are employed or not as there are no tokens purchased in period 1, hence we do not need to distinguish the two cases and we do not employ corresponding superscripts in the notation for $\bar{p}_2(s_1 = 0)$.

$\bar{p}_2^{NT}(s_1 = 1, \phi_2) > 0$, the platform will optimally set $p_2^{NT} = \bar{p}_2^{NT}(s_1 = 1, \phi_2)$. At this price, all new potential users join, i.e., $\omega_2 = n_2 + n_1(1 - \alpha^{NT})$.

Early adopter's utility if he stays is $u_k(n_2 + n_1(1 - \alpha^{NT}))$. Or he can leave and get zero payoff. Since $u_k(\omega)$ is decreasing with k, users with low k, prefer to stay; while users with high k prefer to leave and get the outside option zero payoff. The threshold $\hat{k}^{NT}$ is defined by

$$u_{\hat{k}^{NT}}(n_2 + n_1(1 - \int_{\hat{k}^{NT}}^{B} g(k)dk)) = 0\,.$$

All $k > \hat{k}^{NT}$ leave, i.e., $\alpha^{NT} = \int_{\hat{k}^{NT}}^{B} g(k)dk$.

Now we can solve for the period 1 equilibrium: Potential users that arrive in period 1 know that if the platform fails in period 1, it will also fail in period 2, and if is succeeds in period 1, it will also set such a price in period 2 to attract new users. They also know that once they join and learn their type k, they will be able to leave at $t = 2$, obtaining the outside option payoff of 0.

The highest price the platform can charge and attract users in period 1 is

$$\bar{p}_1^{NT}(\phi_1) = \phi_1 V^{NT}(s_1 = 1) + (1 - \phi_1)V(s_1 = 0)$$

where the expected individual benefit of joining the platform if the platform ends up failing is $V(s_1 = 0) = E[u_k(0)] < 0$, and the expected individual benefit of joining the platform if the platform succeeds is

$$V^{NT}(s_1 = 1) = \int_{A}^{\hat{k}^{NT}} [u_k(n_1) + u_k(n_2 + n_1(1 - \alpha^{NT}))]g(k)dk + \int_{\hat{k}^{NT}}^{B} [u_k(n_1)]g(k)dk > E[u_k(n_1)] > 0$$

For the platform to overcome the coordination problem, it must set $p_1^{NT} = \bar{p}^{NT}(\phi_1)$. This price could 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 if it expect to recover the subsidy in period 2, i.e., if $\Pi^{NT} = \bar{p}^{NT}(\phi_1)n_1 + \bar{p}^{NT}(s_1 = 1, \phi_2)n_2 > 0$. In case $\bar{p}^{NT}(\phi_1)n_1 + \bar{p}^{NT}(s_1 = 1, \phi_2)n_2 < 0$, the platform sets $p_1^{NT} = 0$, does not enter the market (i.e., nobody joins) and collects no profit.

We focus our discussion later in the paper on the more interesting former case, where it would be profitable for the platform to overcome the coordination problem and enter the market.

5 Coordination with digital tokens

5.1 Timing of the game

The timing of the game is similar to the setting without tokens, in the sense that n_1 potential users arrive at $t = 1$ and n_2 potential users arrive at $t = 2$; they can decide to join the platform in the period they have arrived, in a later period, or not at all; upon joining the platform, users learn their type k and realize their utility; and users who joined the platform in period 1, realize the utility $u_k(\omega_1)$, and subsequently may choose to leave the platform in period 2.

Furthermore, in each period the platform sells tokens that are required to access to its services for the present and any future periods; users can either use a token they acquired in previous periods to access the platform in the present period, or can sell that 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 that decides to leave 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 tokens available for sale in period 1 at price p_1.
- 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 platform denoted by $s_1 = 1$. Users that joined the platform learn their type k and realize period 1 benefit $V_k^T(s_1)$, which includes their benefit from participating in the period 1 network $u_k(\omega_1)$, and their expected payoff in period 2.

Period 2:

- In the beginning of period 2, n_2 new potential users arrive.
- The market coordination bias is ϕ_2.
- The platform makes additional tokens available for sale in period 2 at token price p_2.
- Users who joined in period 1 decide whether to leave the platform based on their type k and their expectation for period 2 payoff on and out of the platform.
- Users leaving the platform can sell their token to new users 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 favorability bias ϕ_2 in period 2.
- At the end of period 2, everybody realizes their period 2 payoffs.

5.2 Equilibrium with tokens

As before, we solve for the equilibrium using backward induction, starting with period 2:

If the platform failed in period 1 ($s_1 = 0$) we obtain the same outcome as in the case with no tokens, because no tokens were sold in period 1, and there are no future periods, and thus no opportunity for future token trading. As before, focusing on the case that $\bar{p}_2(s_1 = 0, \phi_2) < 0$ and $\bar{p}_2^T(s_1 = 1, \phi_2) > 0$, everyone's payoffs, including the platform, are 0; specifically, $\Pi(s_1 = s_2 = 0) = 0$, as in the case without tokens.

If the platform succeeded in period 1 ($s_1 = 1$), we denote by α^T the fraction of period 1 users that will leave the platform in period 2. These are users that after experiencing the platform at $t = 1$ and discovering their type k, are better off to leave the platform and sell their token to potential users that arrive in period 2. The n_2 new potential users decide whether to join the platform, based on the focality of degree ϕ_2 for the adoption strategy, the token price p_2^T set by the platform at $t = 2$, and their expectation that $(1 - \alpha^T)n_1$ period 1 users will remain.

The highest price the platform can charge and still attract the potential users that arrive at $t = 2$ is $\bar{p}_2^T(s_1 = 1, \phi_2) = \phi_2 E[u_k(n_2 + n_1(1 - \alpha^T))] + (1 - \phi_2)E[u_k(n_1(1 - \alpha^T))]$. Since $\bar{p}_2^T(s_1 = 1, \phi_2) > 0$, the platform will not want to set $p_2^T > \bar{p}_2^T(s_1 = 1, \phi_2)$. For $p_2^T \leq \bar{p}_2^T(s_1 = 1, \phi_2)$, all new potential users join, i.e., $\omega_2 = n_2 + n_1(1 - \alpha^T)$.

A user that joined the platform at $t = 1$ will get utility $u_k(n_2 + n_1(1 - \alpha^T))$ by staying at $t = 2$, or can sell its token for p_2^T and leave. Since $u_k(\omega)$ is decreasing with type k, users with low k will have a stronger preference to stay, while users with high k are more likely to sell their token for p_2^T and leave. The threshold $\hat{k}^T$ is defined by

$$u_{\hat{k}^T}(n_2 + n_1(1 - \int_{\hat{k}^T}^{B} g(k)dk)) = p_2 \,.$$

All $k > \hat{k}^T$ leave, i.e., $\alpha^T = \int_{\hat{k}^T}^{B} g(k)dk$.

Note that α^T is a function of p_2^T, and the platform may find it optimal to set $p_2^T < \bar{p}_2^T(s_1 = 1, \phi_2)$. This is because the platform faces a trade-off: As p_2^T increases, it collects higher price per each token sold in $t = 2$, but it sells fewer tokens. This is because at higher p_2 more early users find it attractive to sell. Thus, α^T is an increasing function of p_2^T. The platform maximizes its second period profit, $\pi_2 = p_2^T(n_2 - n_1\alpha^T(p_2^T))$, with

$$\frac{\partial \pi_2}{\partial p_2^T} = (n_2 - n_1\alpha^T(p_2^T)) - p_2^T n_1 \frac{\partial \alpha^T(p_2^T)}{\partial p_2^T},$$

which may be either positive or negative for $p_2^T = \bar{p}_2^T(s_1 = 1, \phi_2)$ as in that case $n_2 - n_1\alpha^T(p_2^T) > 0$ and $p_2^T n_1 \frac{\partial \alpha^T(p_2^T)}{\partial p_2^T} > 0$. Since the platform cannot charge more than $\bar{p}^T(s_1 = 1, \phi_2)$, this implies that $p_2^T \leq \bar{p}^T(s_1 = 1, \phi_2)$.

Now we can solve for the period 1 equilibrium: Potential users that arrive in period 1 know that if the platform fails in period 1, it will also fail in period 2, and if is succeeds in period 1, it will set such a price in period 2 to attract new users and thus succeed as well. They also know that once they join and learn their type k, they will be able to sell their token for p_2^T at $t = 2$ and leave.

The highest price the platform can charge and attract users in period 1 is

$$\bar{p}^T(\phi_1) = \phi_1 V^T(s_1 = 1) + (1 - \phi_1)V(s_1 = 0)$$

where the expected individual benefit of joining the platform if the platform fails is $V(s_1 = 0) = E[u_k(0)] < 0$, and the expected individual benefit of joining the platform if the platform succeeds is

$$V^T(s_1 = 1) = \int_A^{\hat{k}^T} [u_k(n_1) + u_k(n_2 + n_1(1 - \alpha^T))]g(k)dk + \int_{\hat{k}^T}^B [u_k(n_1) + p_2^T]g(k)dk > E[u_k(n_1)] > 0.$$

The highest price the platform can get and overcome the coordination problem is $p_1^T =$

$\bar{p}^T(\phi_1)$.[14] Total platform profit is

$$\Pi^T = \max\{\bar{p}^T(\phi_1)n_1 + p_2^T n_2, 0\}$$

as when $\bar{p}^T(\phi_1)n_1 + p_2^T n_2 < 0$, the platform sets $p_1^T = 0$ and collects 0, effectively giving up on the market.

6 Tokens *vs.* no tokens

6.1 Impact of introducing tradable tokens

The coordination problem arises when potential users will not adopt the platform unless other potential users also adopt; if they all adopt, the platform succeeds, otherwise it fails. In order to succeed in period 1, the platform must set a low enough price so that given the expected utility of potential participants (who are ex-ante homogeneous) and the market bias in favor of the platform as captured by the degree of focality, potential users are induced to adopt. Even though users are ex-ante homogeneous, they differ in how much they benefit from joining the platform, and users with the least favorable types in terms of benefiting from the platform (which they learn after they join in period 1) will choose to leave the platform in period 2.

If the platform succeeds in period 1 it acquires a user base, a fraction of which will remain with the platform in period 2, thus making the platform more attractive for new potential users that arrive in period 2. As a result, the platform may face an easier coordination problem in period 2.[15]

[14] As in the case without tokens, p_1^T can 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 if the subsidy will be recovered though the expected profit in period 2.

[15] The platform may also improve the market's bias in its favor as a result of its period 1 success, which also makes the coordination problem in period 2 easier.

Providing access through platform-specific digital tokens offers the platform new possibilities in terms of its entry and pricing strategy, which in certain circumstances may be more attractive to the platform. There are several aspects to platform-specific tokens, and in this paper we focus on tradability. In our context tradability is manifested as user's ability to sell his future access rights, if that user chooses to leave the platform.

Lemma 1 shows that providing platform access via tradable tokens results in a larger fraction of period 1 users leaving the platform:

Lemma 1 *After successful adoption in period 1 (i.e., $s_1 = 1$), more users leave in period 2 under tokens: $\hat{k}^T < \hat{k}^{NT}$, i.e., $\alpha^T > \alpha^{NT}$.*

Proof: The proofs of Lemmas and Propositions are in the Appendix.

Leaving the platform is more attractive for period 1 users if they can sell their token; while more attractive to departing users, this will reduce the platform's user base in period 2. Lemma 2 shows that as a result the platform needs to charge a lower price in period 2 when it employs tokens:

Lemma 2 *Period 2 price is weakly lower under tokens, i.e., $p_2^T(s_1 = 1) \leq \bar{p}_2^{NT}(s_1 = 1)$.*

There are two reasons the price in period 2 is lower in the case of tokens: First, the maximum price that the platform can charge and still have successful adoption, $\bar{p}_2^T$, depends on the value it offers potential participants when it is successful in period 2. In the setting with tokens, more users will leave per Lemma 1, and the platform's period 2 network will be smaller, offering less utility to users that join, and thus reducing $\bar{p}_2^T$. Second, while without tokens the platform will set p_2^{NT} at $\bar{p}_2^{NT}$, the maximum price it can charge and still succeed in period 2, in the case with tokens the platform has less incentive to raise p_2^T all the way to $\bar{p}_2^T$. This is because as p_2^T increases, the fraction of users that leave in period 2 increases as well; as a result new period 2 users buy more tokens from departing period 1 users rather than the platform, which reduces the platform revenue in period 2.

While the above Lemmas imply that the platform earns higher revenue at $t = 2$ without tokens, issuing tradable tokens allows the platform to increase its period 1 revenue compared to the case without tokens. This is because potential users at $t = 1$ are willing to join the platform at a higher price when they obtain a token which they can sell in period 2 if they decide to leave the platform. Thus issuing tokens can allow the platform to overcome the coordination problem while increasing its period 1 revenue — at the cost of decreasing its period 2 revenue. It turns out that the revenue loss in period 2 is higher than the revenue gain in period 1, resulting in lower total profits as shown in Proposition 1:

Proposition 1 *Tokens bring higher revenue at $t = 1$, i.e., $\bar{p}_1^T > \bar{p}_1^{NT}$, but total profits for the platform are lower when it issues tokens, i.e., $\Pi^T < \Pi^{NT}$.*

The platform sets its period 1 price to overcome the coordination problem. In the case of tokens, the platform also indirectly sells in period 1 some of the access it will provide to period 2 users, as tokens can be resold to period 2 users if the early adopters leave the platform. Essentially, with tokens the platform gives early adopters an equity stake in the future success of the platform, and shares part of the period 2 profits with them. This increases period 1 revenue, and decreases period 2 revenue and total revenue.

Since total revenue is higher without tokens, in the absence of capital constraints the platform will prefer to overcome the coordination problem by subsidizing period 1 users rather than by issuing tradable tokens. On the other hand, the ability to reduce or eliminate the need for a subsidy by issuing tradable tokens will be valuable to the platform if a subsidy is costly enough or infeasible. As shown in the Appendix, Proposition 1 continues to hold if both the platform and the period 1 potential users discount the future at the same rate.

6.2 Costy financing

An important case arises when the platform faces a coordination problem that it cannot overcome unless it subsidizes adoption, i.e., sets a negative price in period 1. In that case, while per Proposition 1 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 $p_1^{NT} < 0 < p_1^T$, then overcoming the coordination problem without tokens requires a subsidy in period 1, but the subsidy can be avoided by issuing tokens. If the platform faces capital constraints, or a negative price is otherwise not feasible,[16] token issuance may be the preferred strategy.

Suppose, for instance, that $\bar{p}_1^{NT} < 0$, i.e., a subsidy $n_1\bar{p}_1^{NT}$ is needed in period 1, and the platform faces a cost of capital $r > 0$ for this subsidy. This cost affects platform profits if it needs to offer a subsidy to overcome the coordination problem:

$$\Pi^{NT}(r) = (1+r)n_1\bar{p}_1^{NT}(s_1) + n_2\bar{p}_2^{NT}(s_1 = 1) = \Pi^{NT} + rn_1\bar{p}_1^{NT}(s_1 = 1) < \Pi^{NT}$$

Proposition 2 derives conditions under which the platform would find it advantageous to issue tokens because of the cost of financing a subsidy:

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

$$\bar{r} = \frac{n_1(\bar{p}_1^T - \bar{p}_1^{NT}) + n_2(p_2^T - \bar{p}_2^{NT}) - \alpha^T n_1 p_2^T}{n_1\bar{p}_1^{NT}} > 0$$

Proposition 2 shows that the platform prefers to use tokens rather than a subsidy to overcome the coordination problem if it faces a high enough cost of capital. Lemma 3 shows that a more positive market bias towards the platform in period 1, captured by a higher partial focality in favor of adopting, increases this threshold:

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

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

Since the focus of our analysis is overcoming the coordination problem, ϕ_1 and ϕ_2 should get special attention, as they determine the severity of the coordination problem. Specifically, lower ϕ_1 and ϕ_2 indicate that the coordination problem is more difficult to overcome as the market is tilted against *adopting* as the focal equilibrium.

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 *adopting* strategy enjoys a high degree of focality at $t = 1$ 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., the market bias is increasingly against *adopting* and the platform faces a coordination problem that is increasingly more costly to overcome, financing the subsidies needed to launch the platform becomes more expensive and issuing tradable tokens may be a better option than bearing the cost to finance a subsidy, even for a relatively low cost of capital.

Figure 1 illustrates the results of Propositions 1 and 2, and shows comparative statics for the period 1 coordination bias ϕ_1. As shown in Proposition 1 the platform profit without tokens is higher than with tokens, i.e., the Π^{NT} line is above Π^T. Both Π^T and Π^{NT} are increasing with ϕ_1 but Π^T increases faster.

From Proposition 1 we know that $\bar{p}_1^T$ is above $\bar{p}_1^{NT}$. The shaded region represents the particularly interesting area where $\bar{p}_1^{NT} < 0 < \bar{p}_1^T$; i.e., the region where without tokens a subsidy is required in period 1, but with tokens the coordination problem is solved in the platform's favor while it is able to charge a positive price for its tokens.

Both $\bar{p}_1^T$ and $\bar{p}_1^{NT}$ are increasing in ϕ_1 as well, with $\bar{p}_1^T$ 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

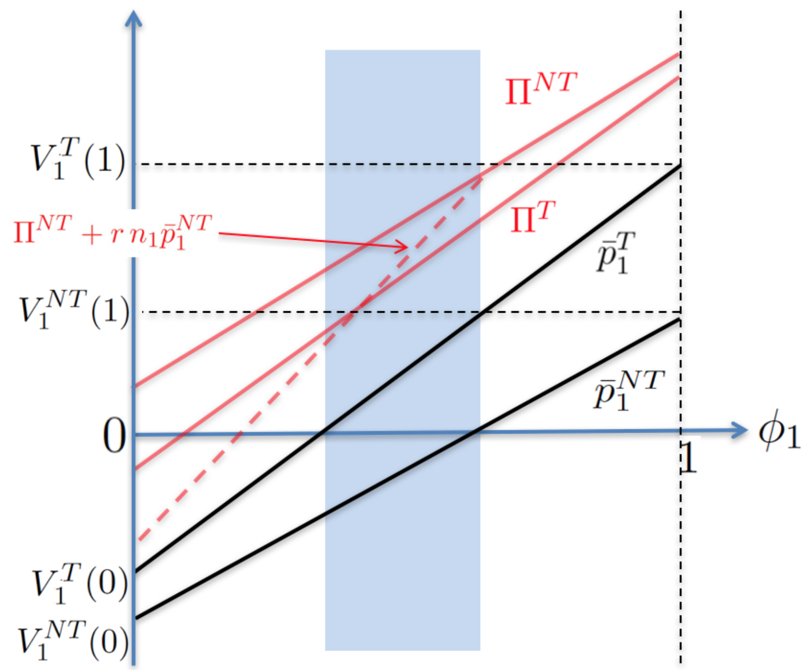

Figure 1: Coordination bias, first period price and total platform profit. The solid lines represent results of Proposition 1, and the dashed line represents Proposition 2.

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 line increases, and it crosses the Π^T line at higher ϕ_1 values, which is captured by Lemma 3.

In summary, our analysis shows that issuing tradable tokens provides a new tool for solving the coordination problem for a platform in an environment with network effects, when a direct subsidy is either undesirable or not feasible.

7 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;[17] 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 the model we assume:

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

[17] 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.

(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) The potential users expected to arrive in each of the two periods, their utility from joining the platform, and the favorability of the market towards the platform (captured by the degree of partial focality of adopting the platform) are common knowledge.

(4) Potential users that acquire a token in the first period also join the platform; these users can stay for the second period as long as they keep their 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.

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.

An important aspect of tokens is the ability to make token purchases (which in the case of platform-specific tokens correspond to adoption decisions) observable by market participants. This transparency on the platform's progress in recruiting participants can affect the resulting equilibria by changing the information structure and/or the sequence of moves in the adoption game, which in some settings can resolve the coordination problem. This mechanism, which has been studied in the literature, is distinct from the way tokens can help overcome the coordination problem in our setting, which follows from their tradability.

In our analysis we assumed that the platform's decision to issue tokens did not change the market's perception of the platform, and thus did not affect the focality of adopting the platform in either period. If the mere fact of issuing tokens biases the market in favor of adopting the platform (e.g., because offering tokens in an ICO creates favorable impression of the platform's likely success or is otherwise desirable), then this will provide still another reason why tokens can facilitate platform adoption.

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 potential strategic interactions.

Appendix: Game Timeline

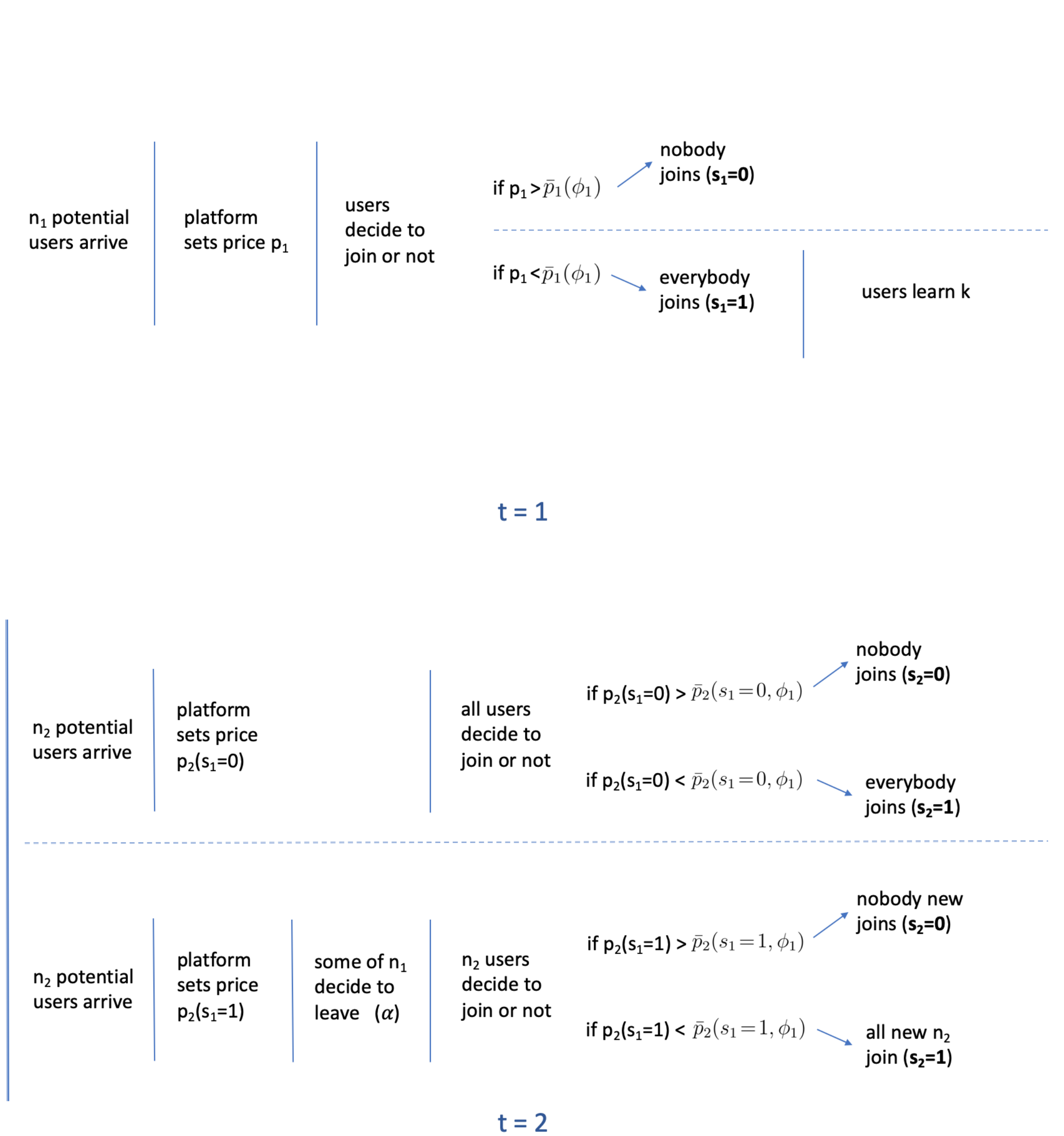

Figure 2: Game Timeline

Appendix: Proofs

Proof of Lemma 1

Suppose the platform was successful in $t = 1$, i.e., $s_1 = 1$. At the end of the period, the users learn their type k and make a decision about staying or leaving. If a user leaves, he gets the outside option, 0. And if there was a tradable token, he also gets the value of the token $p_2^T(s_1 = 1) \geq 0$.[18] Staying yields utility $u_k(\omega_2(s_1 = 1))$, where $\omega_2(s_1 = 1)$ is the size of the network in the second period, given that the platform was successful in the first period.

First, note that for any fixed network size ω leaving is a more attractive option under tokens than in the absence of tokens. Without tokens, staying is preferred when $u_k(\omega) \geq 0$. For any ω, $u_k(\omega)$ is decreasing with k. Therefore, there exists $\bar{k}^{NT}$ such that for $k < \bar{k}^{NT}$, $u_k(\omega) > 0$ and opposite for higher k. Similarly, there exists $\bar{k}^T < \bar{k}^{NT}$ such that for $k < \bar{k}^T$, $u_k(\omega) > p_2^T(s_1 = 1) > 0$, and opposite for higher k. Therefore, for the same size of the network, more users prefer to leave upon learning their type.

But as more users would be leaving in the second period, the network size in the second period will be smaller, making staying in the network even less attractive, and enforcing the inequality (for the actual $\hat{k}^T < \hat{k}^{NT}$). By definition of α:

$$\alpha^T = \int_{\hat{k}^T}^{B} g(k)dk = \underbrace{\int_{\hat{k}^T}^{\hat{k}^{NT}}}_{\hat{k}^T < \hat{k}^{NT}} \underbrace{g(k)}_{\geq 0} dk + \underbrace{\int_{\hat{k}^{NT}}^{B} g(k)dk}_{=\alpha^{NT}} \geq \alpha^{NT}$$

This completes the proof of Lemma 1.

[18] The platform will never subsidize users to join in the last period.

Proof of Lemma 2

$$\bar{p}_2^{NT}(s_1 = 1) = \phi_2 E u_k(n_2 + n_1(1 - \alpha^{NT})) + (1 - \phi_2) E u_k(n_1(1 - \alpha^{NT}))$$

$$p_2^T(s_1 = 1) \leq \bar{p}_2^T(s_1 = 1) = \phi_2 E u_k(n_2 + n_1(1 - \alpha^T)) + (1 - \phi_2) E u_k(n_1(1 - \alpha^T))$$

The inequality $\bar{p}_2^T(s_1 = 1) \leq \bar{p}_2^{NT}(s_1 = 1)$ follows directly from the fact that $\alpha^T \geq \alpha^{NT}$, i.e., from Lemma 1. More users stay to period 2 without the tokens. The platform is larger in period 2 without tokens no matter whether it succeeded to attract n_2 new users. And thus, the platform can charge higher price and still attract all the users.

This completes the proof of Lemma 2.

Proof of Proposition 1

$\Pi^T < \Pi^{NT} \iff n_1 \bar{p}_1^T + (n_2 - \alpha^T n_1) p_2^T(s_1 = 1) < n_1 \bar{p}_1^{NT} + n_2 \bar{p}_2^{NT}(s_1 = 1) \iff n_2 \left(\bar{p}_2^{NT}(s_1 = 1) - p_2^T(s_1 = 1)\right) + \alpha^T n_1 p_2^T(s_1 = 1) > n_1 \left(\bar{p}_1^T - \bar{p}_1^{NT}\right)$

We are going to show that this inequality holds in two steps.

(i) $n_2 \left(\bar{p}_2^{NT}(s_1 = 1) - p_2^T(s_1 = 1)\right) > 0$ (follows directly from Lemma 2.)

(ii) $\alpha^T p_2^T(s_1 = 1) > \bar{p}_1^T - \bar{p}_1^{NT}$

We focus on (ii) here.

$$V^{NT}(s_1 = 1) = \int_A^B u_k(n_1) g(k) dk + \int_A^{\hat{k}^{NT}} u_k(\omega_2^{NT}(s_1 = 1)) g(k) dk$$

$$V^T(s_1 = 1) = \int_A^B u_k(n_1) g(k) dk + \int_A^{\hat{k}^T} u_k(\omega_2^T(s_1 = 1)) g(k) dk + \int_{\hat{k}^T}^B p_2^T(s_1 = 1) g(k) dk =$$
$$= \int_A^B u_k(n_1) g(k) dk + \int_A^{\hat{k}^T} u_k(\omega_2^T(s_1 = 1)) g(k) dk + \alpha^T p_2^T(s_1 = 1)$$

Lemma 4 $\int_A^{\hat{k}^T} u_k(\omega_2^T(s_1 = 1))g(k)dk < \int_A^{\hat{k}^{NT}} u_k(\omega_2^{NT}(s_1 = 1))g(k)dk$.

Proof of Lemma 4:

$$\int_A^{\hat{k}^T} u_k(\omega_2^T(s_1 = 1))g(k)dk < \int_A^{\hat{k}^T} u_k(\omega_2^{NT}(s_1 = 1))g(k)dk + \int_{\hat{k}^T}^{\hat{k}^{NT}} u_k(\omega_2^{NT}(s_1 = 1))g(k)dk$$

$$\int_A^{\hat{k}^T} \left[u_k(\omega_2^T(s_1 = 1)) - u_k(\omega_2^{NT}(s_1 = 1))\right] g(k)dk - \int_{\hat{k}^T}^{\hat{k}^{NT}} u_k(\omega_2^{NT}(s_1 = 1))g(k)dk < 0$$

To complete the proof of Lemma 4, we need to prove the following claims:

(1) $u_k(\omega_2^T(s_1 = 1)) - u_k(\omega_2^{NT}(s_1 = 1)) < 0$

Proof. Since $\alpha^T > \alpha^{NT}$, $\omega_2^T(s_1 = 1) = n_2 + n_1(1 - \alpha^T) < n_2 + n_1(1 - \alpha^{NT}) = \omega_2^{NT}(s_1 = 1)$. So the inequality holds by a property of u_k for any k.

(2) $u_k(\omega_2^{NT}(s_1 = 1)) > 0$ for $k \in (\hat{k}^T, \hat{k}^{NT})$

Proof. By definition of $\hat{k}^{NT}$, for any $k < \hat{k}^{NT}$, $u_k(\omega_2^{NT}(s_1 = 1)) > 0$ (i.e. staying is more preferable than leaving without tradable tokens).

This completes the proof of Lemma 4.

Next, the lemma will be useful to observe that

$$V^T(s_1 = 1) - V^{NT}(s_1 = 1) =$$
$$= \underbrace{\int_A^{\hat{k}^T} \left[u_k(\omega_2^T(s_1 = 1)) - u_k(\omega_2^{NT}(s_1 = 1))\right] g(k)dk - \int_{\hat{k}^T}^{\hat{k}^{NT}} u_k(\omega_2^{NT}(s_1 = 1))g(k)dk}_{<0 \text{ by Lemma 5}} +$$
$$+ \alpha^T p_2^T(s_1 = 1)$$

Given coordination bias ϕ_1, $\bar{p}_1 = \phi_1 V(1) + (1 - \phi_1)V(0)$. Under the assumption that $p_2^T(s_1 = 0) = 0$ — which is the case when $\bar{p}_2(s_1 = 0) < 0$ — we directly obtain $\bar{p}_1^T - \bar{p}_1^{NT} < \alpha^T p_2^T(s_1 = 1)$.

For completeness, we also consider the case where $\bar{p}_2^T(s_1 = 0) > 0$. For that, we need to specify what is the value of joining in $t = 1$ under tokens and no tokens if the platform fails in $t = 1$. This is an off-equilibrium consideration. In case of a failure, the user joining would be the only user. We assume there is a continuum of users, so a single user does not affect the value of the network. That means that in the second period the platform will either find it optimal to attract all $n_1 + n_2$ users (if it can charge positive price) or no users (if it would need to subsidize for the users to join). But that decision is independent of this one user joining in $t = 1$ or not. Therefore, the size of the network in the second period is the same whether there are tradable tokens or not. The decision of the deviating user to stay or leave at the end of $t = 1$ will also be independent of the tokens. We will call the corresponding threshold $\hat{k}(s_1 = 0)$. Then,

Lemma 5 *$V^T(s_1 = 0) - V^{NT}(s_1 = 0) = p_2^T(s_1 = 0) \geq 0$.*

Proof of Lemma 5:

$$V^{NT}(s_1 = 0) = \int_A^B u_k(0)g(k)dk + \int_A^{\hat{k}(s_1=0)} u_k(\omega_2(s_1 = 0))g(k)dk$$

$$\begin{aligned} V^T(s_1 = 0) &= \int_A^B u_k(0)g(k)dk + \int_A^{\hat{k}(s_1=0)} u_k(\omega_2(s_1 = 0))g(k)dk + \int_{\hat{k}(s_1=0)}^B p_2^T(s_1 = 0)g(k)dk \\ &= V^{NT}(s_1 = 0) + \int_{\hat{k}(s_1=0)}^B p_2^T(s_1 = 0)g(k)dk \end{aligned}$$

This completes the proof of Lemma 5.

Lemma 6 *Some types would stay under the deviation, but they would leave if the platform was successful in the first period, i.e., $\hat{k}(s_1 = 0) > \hat{k}^T$, if $p_2^T(s_1 = 0) > 0$.*

Proof of Lemma 6: $\hat{k}(0)$ is characterized by

$$u_{\hat{k}(0)}(\omega_2(s_1 = 0)) = \bar{p}_2(s_1 = 0)\,,$$

where $\omega_2(s_1 = 0) = n_1 + n_2$. Recall that $\hat{k}^T$ is characterized by $u_{\hat{k}^T}(\omega_2^T(s_1 = 1)) = \bar{p}_2(s_1 = 1)$.

Because $\omega_2^T(s_1 = 1) = n_2 + n_1(1 - \alpha^T) < \omega_2(s_1 = 0)$, then for any k:

$$u_k(\omega_2(s_1 = 0))) > u_k(\omega_2^T(s_1 = 1))\,.$$

Moreover, $\bar{p}_2(s_1 = 0) < \bar{p}_2(s_1 = 1)$.[19] And since $u_k(\omega)$ is decreasing in k, it takes a larger $\hat{k}(0)$ to fulfill its condition than $\hat{k}^T$.

This completes the proof of Lemma 6.

With these lemmas, we continue with the proof of Proposition 1 for $p_2^T(s_1 = 0) > 0$:

$$\begin{aligned}
\bar{p}_1^T - \bar{p}_1^{NT} =& \phi_1(V^T(1) - V^{NT}(1)) + (1 - \phi_1)(V^T(0) - V^{NT}(0)) \\
<& \phi_1 \alpha^T p_2^T(s_1 = 1) + (1 - \phi_1) \int_{\hat{k}(s_1=0)}^{B} p_2^T(s_1 = 0) g(k) dk
\end{aligned}$$

[19]Otherwise, the platform would never find it worthwhile to subsidize in $t = 1$.

$$
\begin{aligned}
\bar{p}_1^T - \bar{p}_1^{NT} <& \phi_1 \int_{\hat{k}^T}^{B} p_2^T(s_1=1)g(k)dk + (1-\phi_1)\int_{\hat{k}(s_1=0)}^{B} p_2^T(s_1=0)g(k)dk = \\
&= \underbrace{\phi_1}_{\leq 1} \int_{\hat{k}^T}^{\hat{k}(s_1=0)} p_2^T(s_1=1)g(k)dk + \int_{\hat{k}(s_1=0)}^{B} [\phi_1 p_2^T(s_1=1) + (1-\phi_1)\underbrace{p_2^T(s_1=0)}_{<p_2^T(s_1=1)}]g(k)dk < \\
&< \int_{\hat{k}^T}^{\hat{k}(s_1=0)} p_2^T(s_1=1)g(k)dk + \int_{\hat{k}(s_1=0)}^{B} p_2^T(s_1=1)g(k)dk = \\
&= \int_{\hat{k}^T}^{B} p_2^T(s_1=1)g(k)dk = \\
&= \alpha^T p_2^T(s_1=1)
\end{aligned}
$$

The remaining part of the proposition, $\bar{p}_1^T > \bar{p}^{NT}$, follows directly from derivations above.

This completes the proof of Proposition 1.

Proof of Proposition 2

Directly substituting the formulas into $\Pi^T > \Pi^{NT} + rn_1\bar{p}_1^{NT}(s_1=1)$ yields

$$
\underbrace{n_1 \underbrace{(\bar{p}_1^T - \bar{p}_1^{NT})}_{+} + n_2 \underbrace{(p_2^T - \bar{p}_2^{NT})}_{-} - \alpha^T n_1 p_2^T}_{<0} > r \underbrace{\bar{p}_1^{NT}}_{<0}
$$

The LHS is negative by claim (ii) in the proof of Proposition 1 saying $\bar{p}_1^T - \bar{p}_1^{NT} < \alpha^T p_2^T$. Dividing by a negative number, $\bar{p}_1^{NT}$ reverses the inequality sign, and yields

$$
r > \bar{r} = \frac{n_1(\bar{p}_1^T - \bar{p}_1^{NT}) + n_2(p_2^T - \bar{p}_2^{NT}) - \alpha^T n_1 p_2^T}{n_1\bar{p}_1^{NT}} > 0
$$

This completes the proof of Proposition 2.

Proof of Lemma 3

To determine the sign of $\bar{r}$ with respect to ϕ_1, note that

$$\bar{p}_1^T - \bar{p}_1^{NT} = \phi_1[V^T(s_1 = 1) - V^{NT}(s_1 = 1)]$$

$$\bar{p}_1^{NT} = \phi_1 V^{NT}(s_1 = 1) + (1 - \phi_1)V(s_1 = 0) = \phi_1[V^{NT}(s_1 = 1) - V(s_1 = 0)] + V(s_1 = 0)$$

Moreover, V's, α^T and p_2's are independent of ϕ_1. Then

$$\frac{\partial \bar{r}}{\partial \phi_1} = \frac{1}{n_1}\frac{n_1[V^T(s_1{=}1) - V^{NT}(s_1{=}1)]\bar{p}_1^{NT} - [V^{NT}(s_1{=}1) - V(s_1{=}0)] \cdot [n_1(\bar{p}_1^T - \bar{p}_1^{NT}) + n_2(p_2^T - \bar{p}_2^{NT}) - \alpha^T n_1 p_2^T]}{[\bar{p}_1^{NT}]^2}$$

The sign of derivative of $\bar{r}$ with respect to ϕ_1 is the same as the sign of

$$\begin{aligned} &n_1[V^T(s_1{=}1) - V^{NT}(s_1{=}1)]\left[\phi_1[V^{NT}(s_1 = 1) - V(s_1 = 0)] + V(s_1 = 0)\right] - \\ &+[V^{NT}(s_1{=}1) - V(s_1{=}0)] \cdot [n_1(\phi_1[V^T(s_1 = 1) - V^{NT}(s_1 = 1)]) + n_2(p_2^T - \bar{p}_2^{NT}) - \alpha^T n_1 p_2^T] \end{aligned}$$

After canceling out $n_1[V^T(s_1{=}1) - V^{NT}(s_1{=}1)]\phi_1[V^{NT}(s_1 = 1) - V(s_1 = 0)]$, this expression becomes

$$\begin{aligned} &n_1[V^T(s_1{=}1) - V^{NT}(s_1{=}1)]V(s_1 = 0) - [V^{NT}(s_1{=}1) - V(s_1{=}0)] \cdot [n_2(p_2^T - \bar{p}_2^{NT}) - \alpha^T n_1 p_2^T] = \\ &= V^{NT}(s_1{=}1)[n_2(p_2^{NT} - \bar{p}_2^T) + \alpha^T n_1 p_2^T] - \underbrace{V(s_1{=}0)}_{<0} \cdot [n_2(p_2^{NT} - \bar{p}_2^T) + \underbrace{\alpha^T n_1 p_2^T - n_1[V^T(s_1{=}1) - V^{NT}(s_1{=}1)]}_{>0}] \end{aligned}$$

The latter term is positive by the result that $V^T(s_1 = 1) - V^{NT}(s_1 = 1) < \alpha^T p_2^T(s_1 = 1)$, derived in the proof of Proposition 1. Since it demonstrates that the term is positive, it proves that $\frac{\partial \bar{r}}{\partial \phi_1} > 0$.

This completes the proof of Lemma 3.

Appendix: Discounting the future

Suppose that the platform and potential users in period 1 discount the future (i.e., period 2) with discount factor $\delta \in (0, 1]$. Platform profits under the *no token* and *token* scenarios are

$$\Pi^{NT}(\delta) = n_1 \cdot \bar{p}_1^{NT}(\delta) + \delta\, n_2 \cdot \bar{p}_2^{NT}(s_1 = 1)$$
$$\Pi^{T}(\delta) = n_1 \cdot \bar{p}_1^{T}(\delta) + \delta\, (n_2 - \alpha^T n_1) \cdot p_2^{T}(s_1 = 1)$$

The second period choices by the platform or the users are not affected by δ, as this the last period. But the first period prices, $\bar{p}_1^T(\delta)$ and $\bar{p}_1^{NT}(\delta)$ depend on δ, because $V^{NT}(s_1 = 1, \delta)$ and $V^T(s_1 = 1, \delta)$ do:

$$\begin{aligned}
V^{NT}(s_1 = 1, \delta) = &\int_A^B u_k(n_1) g(k) dk + \delta \int_A^{\hat{k}^{NT}} u_k(\omega_2^{NT}(s_1 = 1)) g(k) dk = \\
=&(1-\delta) \int_A^B u_k(n_1) g(k) dk + \delta V^{NT}(s_1 = 1) = \\
=&(1-\delta) E[u_k(n_1)] + \delta V^{NT}(s_1 = 1) \\
V^{T}(s_1 = 1, \delta) = &\int_A^B u_k(n_1) g(k) dk + \delta \left(\int_A^{\hat{k}^T} u_k(\omega_2^{T}(s_1 = 1)) g(k) dk + \int_{\hat{k}^T}^B p_2^T(s_1 = 1) g(k) dk \right) = \\
=&(1-\delta) E[u_k(n_1)] + \delta V^{T}(s_1 = 1)
\end{aligned}$$

Note also that under assumption $\bar{p}_2(s_1 = 0) < 0 < \bar{p}_2^T(s_1 = 1)$, $V(s_1 = 0)$ does not depend on δ.

The next proposition shows that the result from Proposition 1 holds also in environment with future discounting.

Proposition 3 *Under future discounting, $\delta \in (0, 1]$, total profits for the platform are lower when it issues tokens, i.e, $\Pi^T(\delta) < \Pi^{NT}(\delta)$.*

Proof of Proposition 3. Note that

$$\begin{aligned}
\bar{p}_1^{NT}(\delta) =& \phi_1 V^{NT}(s_1 = 1, \delta) + (1-\phi_1) V(s_1 = 0) = \\
=& (1-\delta)\left[\phi_1 E[u_k(n_1)] + (1-\phi_1) V(s_1 = 0)\right] + \delta \bar{p}_1^{NT} = X + \delta \bar{p}_1^{NT} \\
\bar{p}_1^{T}(\delta) =& \phi_1 V^{T}(s_1 = 1, \delta) + (1-\phi_1) V(s_1 = 0) = \\
=& (1-\delta)\left[\phi_1 E[u_k(n_1)] + (1-\phi_1) V(s_1 = 0)\right] + \delta \bar{p}_1^{NT} = X + \delta \bar{p}_1^{T}
\end{aligned}$$

where $X \equiv (1-\delta)\left[\phi_1 E[u_k(n_1)] + (1-\phi_1) V(s_1 = 0)\right]$.

Then $\Pi^T(\delta) < \Pi^{NT}(\delta)$ iff

$$n_1 X + n_1 \delta \bar{p}_1^T + \delta(n_2 - \alpha^T n_1)\, p_2^T(s_1 = 1) < n_1 X + n_1 \delta \bar{p}_1^{NT} + \delta n_2 \bar{p}_2^{NT}(s_1 = 1)$$

Since $n_1 X$ on both sides cancels, and $\delta > 0$ cancels in all remaining terms, the inequality is equivalent to

$$\underbrace{n_1 \cdot \bar{p}_1^T + (n_2 - \alpha^T n_1) \cdot p_2^T(s_1 = 1)}_{\Pi^T} < \underbrace{n_1 \cdot \bar{p}_1^{NT} + n_2 \cdot \bar{p}_2^{NT}(s_1 = 1)}_{\Pi^{NT}}$$

which holds by Proposition 3.

Appendix: Relaxing assumption $\bar{p}_2(s_1{=}0) < 0 < \bar{p}_2^T(s_1{=}1)$

First, note that $\bar{p}_2^T(s_1 = 1) < 0$, the tradability of tokens brings no benefit. Even if tokens are tradable, no trade occurs in the second period, as the price $p_2^T(s_1 = 1) = 0$, and nobody buys the tokens. It also directly follows that in such a case $\bar{p}_2^T(s_1 = 1) = \bar{p}_2^{NT}(s_1 = 1) < 0$, and $p_2^T(s_1 = 1) = p_2^{NT}(s_1 = 1) = 0$.

Next, consider $\bar{p}_2(s_1 = 0) > 0$. In such a case, waiting for the second period is another profitable strategy that the platform needs to consider in comparison to entering the market in the first period with tokens or no tokens. There are two possible cases:

(1) $(n_1 + n_2)\bar{p}_2(s_1 = 0) \leq \Pi^T$. Then waiting for the second period is dominated, and our analysis applies. (Our proof of Proposition 1 accounts for this case, through Lemmas 5 and 6.)

(2) $(n_1 + n_2)\bar{p}_2(s_1 = 0) > \Pi^T$. Then tokens are dominated, and therefore technological possibility of tradable tokens does not affect the equilibrium, as they will never be adopted.

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