Digital Tokens and Platform Building *

Jiasun Li[†] William Mann[‡]

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Abstract

We present a model rationalizing the economic value of digital tokens for launching peer-to-peer platforms: By using the blockchain to transparently distribute tokens before the platform begins operation, a token sale overcomes later coordination failures between transaction counterparties during the platform operation. This result follows from forward induction reasoning, under which the costly and observable action of token acquisition credibly communicates the intent to participate on the platform. Our theoretical framework demonstrates the applications of digital tokens to entrepreneurship, including initial coin offerings (ICOs), and offers guidance for both practitioners and regulators.

Keywords: blockchain, coordination, entrepreneurship, FinTech, ICO, platform, tokenomics

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[†]George Mason University, 4400 University Drive, MSN 5F5, Fairfax, VA 22030. jli29@gmu.edu.

[‡]Emory University, 1300 Clifton Road NE #512, Atlanta, GA 30322. william.giles.mann@emory.edu.

With the rise of blockchain technology, digital tokens have gained popularity in entrepreneurship. Media attention particularly spiked during 2017 and 2018, when token sales, including most notably initial coin offerings (ICOs), attracted over $5 billion and $11 billion, respectively (CB Insights; CoinTelegraph). This volume far surpassed equity investments in blockchain startups during the same time, and was undeterred by the significant drop in cryptocurrency prices in 2018. However, as with any disruptive innovation, the rise of tokens has also provoked controversy. While enthusiasts see token sales as valuable tools, detractors see them simply as disguised security issuance with no value beyond regulatory arbitrage, and further point to examples (unsurprising in a new market) of frivolous or even fraudulent deals.[1] Amid fears of regulatory backlash and concerns over market integrity, token sales declined to $4.1 billion in the first ten months of 2019 (PwC), and media attention abated.

The digital token concept nevertheless demonstrates enduring appeal. Many jurisdictions continue to introduce regulatory safe harbors for token sales, while practitioners continue to develop modifications to the ICO structure in hopes of better compliance with existing regulation. These efforts have revealed a tension as to whether existing securities law forms the appropriate regulatory framework for digital tokens: While some recent tokens that carry cash flow or voting rights explicitly label themselves as "security tokens," many market participants and observers continue to argue that other so-called "utility tokens" serve operational functions that would be undermined if simply treated as securities.[2]

Is there an economic basis for this argument? What explains the appeal of digital tokens

[1] For example, the SEC has prosecuted cases such as REcoin, AriseBank, and Centra Tech.

[2] As the most recent example of regulatory safe harbor, France approved its first regulated ICO in December 2019. Modifications to ICOs include Simple Agreements for Future Tokens (SAFTs) and initial exchange offerings (IEOs). Both of them use a centralized intermediary for token issuance (rather than a blockchain as in vanilla ICOs), presumably to better fit existing U.S. securities laws, even though the token will still fully operate on a blockchain once issued. While it is unclear yet if they are any better than vanilla ICOs for projects' long-term operational success, some have seen success with regulators. For example, in July 2019, the SEC approved a regulated token offering by Blockstack via the intermediary CoinList (WSJ). ICOs broadly-defined include all such modifications, as well as security token offerings (STOs), although no widely-accepted definition prevails.

to entrepreneurship, and can they serve a purpose that is fundamentally distinct from that of traditional securities? We address these questions in the context of a large class of tokens which has remained popular since ICOs first appeared, in which an entrepreneur pre-sells a token on a blockchain which will later serve as the medium of exchange on a peer-to-peer platform.[3] We show that these tokens indeed serve a non-financial purpose: They prevent a coordination failure that can otherwise arise when the platform is launched. Building on this basic insight, we then draw implications for regulation and practice in this market.

We study the problem of an entrepreneur launching a peer-to-peer platform, on which two users can repeatedly provide each other a service. Each attempt to buy or sell the service incurs a utility cost. A coordination problem arises: The service buyer will only find it desirable to participate if the seller also does, and vice versa. Such strategic complementarity leads to multiple equilibria, including a self-fulfilling inefficient outcome in which no one participates on the platform, even though trade is socially valuable.

We show that a platform-specific token overcomes this problem by serving as a coordination device between the two users to select the efficient equilibrium. When one user, A, purchases a token before the platform begins operation, her purchase decision is publicly observable thanks to the transparency of the blockchain implementing the token sale. She thereby communicates to the other user, B, that she plans to attempt trade on the platform, as B will reason that otherwise A would have been better off not having purchased the token, which has no use outside the platform. Here, B's reasoning is captured formally by the *forward induction* equilibrium refinement, which we discuss further in the paper. Continued application of forward induction ultimately leads to successful coordination and the efficient outcome. Our analysis thus explains why users are willing to purchase tokens that have no intrinsic value, a pattern often puzzling to outside observers. Indeed, the token is valuable *within* a specific platform precisely because it is of no *outside* use, helping the purchase

[3] See examples in Section 1.

decision to credibly communicate an intent to participate on the platform.

Having established our baseline result, we next clarify how liquidity affects the token's value creation. We distinguish between two types of liquidity: the ability for a token to change hands as part of the platform operation, and the ability for the token to be sold outside the platform. The first type of liquidity may enhance the token's coordination power, while the second may weaken that coordination power if it gives the token value outside the platform, for example by facilitating speculation. As the next two paragraphs summarize, in the paper we illustrate the first point by comparing a token with a "membership," and the second in the context of speculation.

In a membership model, a potential platform user pays an upfront fee to access the platform, and a general-use currency rather than a platform-specific token is then used as the medium of exchange. As in the token model, the payment of a membership fee communicates future platform participation via forward induction reasoning. However, this payment is a one-time event, unlike the token which must be continually re-acquired by providing the service. Because continual token acquisition eliminates inefficient outcomes in which users alternate over time between participating and not participating, a token may be a more powerful coordination mechanism than a membership.

We model speculation by augmenting the model with an additional benefit from purchasing the token but *not* participating on the platform. We confirm that the token's coordinating effect is robust as long as the expected benefit from speculation is lower than the token price. When the speculation benefit exceeds the token price, however, speculation may arise as an equilibrium outcome alongside coordination success on the platform.

Since speculation reintroduces the possibility of multiple equilibria, we further augment the model to quantify the probability of each outcome and allow comparative statics analysis. To do this, we introduce incomplete information about the speculation benefit, and combine the higher-order beliefs reasoning typical in the global games literature with forward induction to pin down a cutoff value of the speculation benefit realization below (above) which platform success (speculation) is the unique equilibrium outcome.

In sum, we demonstrate the economic value of digital tokens in resolving a classic coordination problem, and also provide a framework to analyze their power in building platforms that feature user interactions. We thus validate the concept of "utility tokens" by showing that some tokens may facilitate a successful platform launch without necessarily involving a *financing* purpose.[4] These "utility tokens" are conceptually different from "security tokens." Our results thus provide several implications for policymakers and practitioners. First, we show that blunt application of securities regulation to utility tokens may be counterproductive. Second, our analysis clarifies the importance of transparent disclosures, consistent with the SEC's recent warnings against celebrity-endorsed ICO deals that do not fully disclose compensation or other off-blockchain activities. Third, we provide suggestions concerning who should be eligible to participate in token sales. Fourth, we identify a tension between platform success and speculation, which highlights that the efforts to curb speculation may not only help sidestep legal pitfalls, but also favor a platform's long-term success.

To be clear, we do not claim that all tokens fit the description of our framework. Rather, by explaining the economic rationale behind a large class of high-profile tokens, our theory aims to inform best practices in using this novel approach to launching a business, and help design clear and effective regulation to safeguard its healthy growth. We argue that any other proposed channels by which a token could create value should be subject to a similar rigorous analysis as pursued in this paper.

Related literature Several contemporaneous papers analyze tokens theoretically. The most related to ours are Cong, Li and Wang (2018), Sockin and Xiong (2018), and Bakos and

[4] Indeed, Mastercoin's token sale, often referred to as the first ICO in history, "burned" all its proceeds so that the entrepreneur would get zero funding from the sale. (The ICO raised its proceeds in the form of Bitcoin, which can be "burned" by sending them to a verifiably unspendable address.)

Halaburda (2018). Like our analysis, each of these papers connects tokens with the possibility of multiple equilibria on platforms with strategic complementarity among users. The first two explore the interaction between user adoptions and token prices *within* the efficient equilibrium, and the latter discusses how token trading could relax capital constraints faced by entrepreneurs. Our contribution is to show that the token sale itself can select the efficient equilibrium out of this multiplicity.

Other papers focus on different features of ICOs: Catalini and Gans (2018) show that dynamic pricing can elicit consumers' willingness to pay; Chod and Lyandres (2018) show that an ICO can facilitate risk-sharing without dilution of control; Canidio (2018) studies the tension between ex-ante financing and ex-post incentives; Garratt and van Oordt (2019) investigates how ICOs change entrepreneur incentives compared to debt and venture capital financing; Malinova and Park (2018) compare tokens with equities; and Lee and Parlour (2018) show that when competition jeopardizes upfront cost recoupment, ICOs (and crowd-funding in general) mitigate underinvestment through direct funding from consumers.

Empirically, Howell, Niessner and Yermack (forthcoming) document many important features of the ICO structure. Kostovetsky and Benedetti (2018) document high ICO returns. Lee, Li and Shin (2018) confirm wisdom of the crowd in the ICO setting. Davydiuk, Gupta and Rosen (2019) investigate the extent to which token retention signals quality. Li and Yi (2019) evaluate smart beta strategies in crypto asset investment. Adhami, Giudici and Martinazzi (2018) and Amsden and Schweizer (2018) look for ICO success determinants. Deng, Lee and Zhong (2018) analyze the effect of disclosure quality, governance mechanism, and team networks on ICO project progress. Momtaz (2018) offers a description of the ICO market evolution. Hu, Parlour and Rajan (2019) provide investment characteristics of 64 ICOs. See Li and Mann (forthcoming) for a survey of the ICO literature.

Our solution concept implementing forward induction builds on several important concepts in game theory, including notably Kohlberg and Mertens (1986), Reny (1992), and

Govindan and Wilson (2009), as we detail in the discussion of the model. The incomplete-information game that we use to study speculation marries forward induction to the global games approach (e.g. Carlsson and Van Damme (1993); Morris and Shin (1998); Frankel, Morris and Pauzner (2003); Goldstein and Pauzner (2005); Shen and Zou (2018); He, Krishnamurthy and Milbradt (2019)).

Our modeling of a token's role on a platform as a medium of exchange for bilateral trade without coincidence of wants is reminiscent of the role of money in a general economy, as studied in Townsend (1980), Kocherlakota (1998), and Kiyotaki and Wright (1989), among others. However, to our knowledge the idea that a forward induction refinement helps select the unique efficient equilibrium in such settings is novel.

More broadly, pre-sales of tokens also relate to the crowdfunding literature: Strausz (forthcoming), Ellman and Hurkens (2019), Chemla and Tinn (2016), Cimon (2017), Brown and Davies (forthcoming), Li (2017), Liu (2018), Cumming, Leboeuf and Schwienbacher (2015), Chang (2015), Belleflamme, Lambert and Schwienbacher (2014), Grüner and Siemroth (2015), Kumar, Langberg and Zvilichovsky (2019), Hakenes and Schlegel (2014), Xu (2016), and Li (2015), among others. Finally, we contribute to the vast literature on platforms, e.g. Katz and Shapiro (1985) and Evans and Schmalensee (2010), as well as a literature that studies coordination problems in adopting new technologies, e.g. Farrell and Saloner (1985) and Dybvig and Spatt (1983).

The rest of the paper proceeds as follows: Section 1 enumerates examples of platforms that feature coordination problems and issued tokens. Section 2 presents our main model and explains the coordination power of a token. Section 3 includes extensions that analyze token liquidity, membership model, and speculation. Section 4 discusses practical/policy implications from the model. Section 5 concludes.

1 Coordination on platforms using tokens

To motivate the focus on coordination in our theory, in this section we highlight a few business models that feature both coordination problems and notable examples of tokens. Readers familiar with the institutional details or more interested in the model can skip this section entirely and move on to Section 2 directly.

Sharing economy A sharing economy relies on the coordination between transacting parties. For example, in the case of data storage sharing, users with demand for cloud storage and users with spare storage space form a symbiosis. Many tokens have been issued to support sharing economies. For example, decentralized data storage network Filecoin launched a token sale in August 2017.[5] Filecoin aims to provide a decentralized network for digital storage through which users can effectively rent out their spare capacity. In return, those users receive a token (also known as Filecoin) as payment. Filecoin attracted approximately $205.8 million and was the largest token sale by the time.

Social networks Social networks also feature multiple equilibria due to a coordination problem: One joins Facebook for the interaction with friends, and leaves MySpace for the lack thereof. Many tokens have been issued to support social networks.[6] For example, in September 2017 social media platform Kik attracted $98 million by issuing the token Kin designed as an internal currency.[7] Kik explicitly stated that it chose a token sale instead of traditional VC financing in order to foster a community. As another example, social messaging app Telegram, in an effort to expand itself into Telegram Open Network (TON), also sold a token GRAM and attracted $1.7 billion, making it the largest token sale to close in

[5]Initially issued via Simple Agreement of Future Token (SAFT) on CoinList, a joint venture between Filecoin developer Protocol Labs and startup funding platform AngelList. See Howell, Niessner and Yermack (forthcoming) for a detailed case study of Filecoin.

[6]Facebook or Myspace could not have followed this strategy, as they were founded before the rise of blockchain technology. That said, Facebook did put forward Libra in its attempt to tap into payment.

[7]Initially issued as an ERC-20 token on Ethereum.

2019. That said, the fact that Kin and Gram have utility attributes does not automatically preclude their also having security attributes, as suggested by the SEC's ongoing litigation against Kik and Telegram.

Blockchain infrastructure A permissionless blockchain, as a decentralized database, also builds on coordination: A user (such as one who sends a transaction in Bitcoin or invokes a smart contract in Ethereum) would only trust the system in the presence of miners (as in a proof-of-work blockchain such as Bitcoin) or validators (as in a proof-of-stake blockchain such as Cosmos), while a miner/validator would only find it profitable to contribute in the presence of users who generate transaction fees or valuable system-sustaining activities.

Token sales have been widely adopted by entrepreneurs to jump-start new blockchains. One classic example is Ethereum itself. As a decentralized computing platform featuring smart contract functionality, Ethereum extends Bitcoin's Turing-incomplete Script language and develops a new blockchain to support the Ethereum Virtual Machine (EVM), executing smart contracts with an international network of public nodes. Its July-August 2014 crowdsale introduced "Ether," the internal medium of exchange. In addition to being an early ICO example that inspired many later token sales, Ethereum today has also become one of the top choices for other platforms to issue tokens. Besides Ethereum, the crowdsale of Mastercoin in 2013, widely regarded as the first ICO in history, and the 2019 ICO of Algorand, designed by Turing Award winner Silvio Micali, both fall into the similar category.

As illustrated in the non-exhaustive examples above, tokens in practice come in various designs and support different business models. Therefore, no model can precisely describe every detail of a specific token. However, we can distill some common threads: In a wide range of business models that include some of the most successful cases, a token is a digital record specifically coded for exclusive use on a platform that requires coordination between users over time. Furthermore, the token is pre-sold before the platform starts operation.

These common features will form the basis of our model setup developed in Section 2.

In our model, users purchase a service with the platform's internal token. In practice, many platforms directly reward service providers with newly-minted tokens (e.g. reward miners/validators with block rewards in addition to transaction fees in a blockchain). Such system-generated rewards are essentially indirect payments from service demanders to providers through targeted inflation, and thus fit our model. By similar logic, our model also applies to new platforms that feature zero transaction fees, such as the so-called Blockchain 3.0 project EOS (which attracted $4 billion in 2018 and remains the largest ICO so far) and its social networking predecessor Steemit, as well as the latest layer-2 blockchains such as Nervos (which attracted $72 million in October 2019 through the sale of its token Common Knowledge Base, or CKB).

2 Model: ICO coordinates the efficient equilibrium

In this section, we build a model to describe a platform that is subject to a potential coordination failure. We then illustrate how this coordination failure can be avoided through the introduction of a token distributed before the platform begins operation.

2.1 Model setup

Time is discrete and infinite. An entrepreneur has the ability to launch a peer-to-peer platform that allows its users to either obtain a service from, or provide the same service to, other users starting from period 1.

There are two potential users of the platform, denoted A and B. They each alternate between demanding and providing the service: User A derives a surplus s from obtaining the service in each odd period, and can provide the same service at a cost c in each even period. User B has the opposite timing: He derives surplus s from the service in even periods, but can provide the service at cost c in odd periods. Both users apply a common discount rate $\rho \in (0, 1)$ between periods. While there are gains from trade, the timing difference in preferences creates a coincidence-of-wants problem, so that the two users never have a mutually-beneficial transaction in any single period, and must instead interact dynamically to realize the gains from trade.

On the platform, attempting to purchase or provide the service ("participate" hereafter) within any period incurs a utility cost of $u > 0$. In any period, a user can also choose to not participate and receive a zero payoff. Transactions happen only when both A and B participate in the same period, upon which the service buyer realizes the surplus s, and the service provider incurs the cost c. For tractability, throughout the paper we will restrict ourselves to stationary strategies à la Duffie et al. (1994) and Maskin and Tirole (2001), so that in every period users condition their actions (that is, to participate or not) only on payoff-relevant information.

Throughout the paper, we assume that first providing and then receiving the service is preferable to autarky, that is $-(c+u)+\rho(s-u) > 0$. This in turn implies that the reversed timing, first receiving and then providing the service, is also preferable to autarky, that is $(s-u)-\rho(c+u) > 0$. This assumption is summarized below:

Assumption 1 (Valuable platform)**.** *Providing and then receiving the service on the platform is preferable to autarky, that is* $\rho(s-u)-(c+u) > 0$.

Because of the coincidence of wants problem between user A and B, transactions require a medium of exchange. The platform specifies the medium of exchange to be either a generic currency (a fiat currency such as the US dollar or a general-use cryptocurrency such as Bitcoin), or a platform-specific token with no use outside of the platform, issued before the platform starts operation.[8] The next two subsections close the model for these two cases.

[8]Throughout the paper, we will use "generic currency" to refer to any medium of exchange that, unlike the platform-specific token, can be used outside of the platform.

2.1.1 Operation of a platform using a generic currency

When the platform uses a generic currency as its medium of exchange, in any period the service can be purchased or sold on the platform, and the buyer and seller equally split the gains from trade $(s - u) - (c + u)$. For each player the payoff-relevant information is which player demands the service (equivalently, whether t is even or odd), leading to a representation of the game as summarized by Figure 1.

Figure 1: **The Game on a Platform Using a Generic Currency**

		B: Y	B: N
A	Y	$\frac{s-c-2u}{2}$, $\frac{s-c-2u}{2}$	$-u$, 0
	N	0, $-u$	0, 0

$t = 1, 3, 5, \cdots$

A: purchase service? (Y or N)
B: provide service? (Y or N)

		B: Y	B: N
A	Y	$\frac{s-c-2u}{2}$, $\frac{s-c-2u}{2}$	$-u$, 0
	N	0, $-u$	0, 0

$t = 2, 4, 6, \cdots$

A: provide service? (Y or N)
B: purchase service? (Y or N)

The payoff matrices in Figure 1 already hint at a potential coordination failure in equilibrium: If either player believes that the other will choose N at a given state, then the only rational response is also to choose N at that state. We will derive this result in Proposition 1 below, after formally defining our solution concept.

2.1.2 Operation of a platform using a token

Next we consider the operation of a platform using exclusively a platform-specific token as the medium of exchange. The platform's protocol specifies that the service has to be purchased with the token. Without loss of generality, we assume that each unit of the service costs one token. We first formally lay out two key characteristics of a platform-specific token:

Definition 1 (Token)**.** *A token is an internal digital medium of exchange within a platform that features the following two properties:*

1. *No intrinsic value: While the platform designates the token as the medium of exchange and one unit of service costs one token, the token has no use outside the platform.*[9]

2. *Transparency: Token transfers within the platform are recorded on a blockchain and therefore observable to users.*

For a token to serve as the medium of exchange on the platform, it must be first distributed to user A before the platform operation starts in period 1. We refer to the initial token distribution event as an ICO. Note that we use the ICO label only for convenience; in practice the token distribution event may go by a different name.

Definition 2 (ICO)**.** *An ICO is a token distribution event before the platform starts operation in which user A decides whether to purchase a token from the entrepreneur for a price $P > 0$. If A does not purchase the token, the game ends with both users receiving zero payoff. If instead A purchases the token, the game then proceeds to platform operation starting from period 1. We denote period 0 as the time in which the ICO takes place. Users can observe the ICO token purchase outcome recorded on the blockchain.*

Throughout the paper, we further impose the following condition.

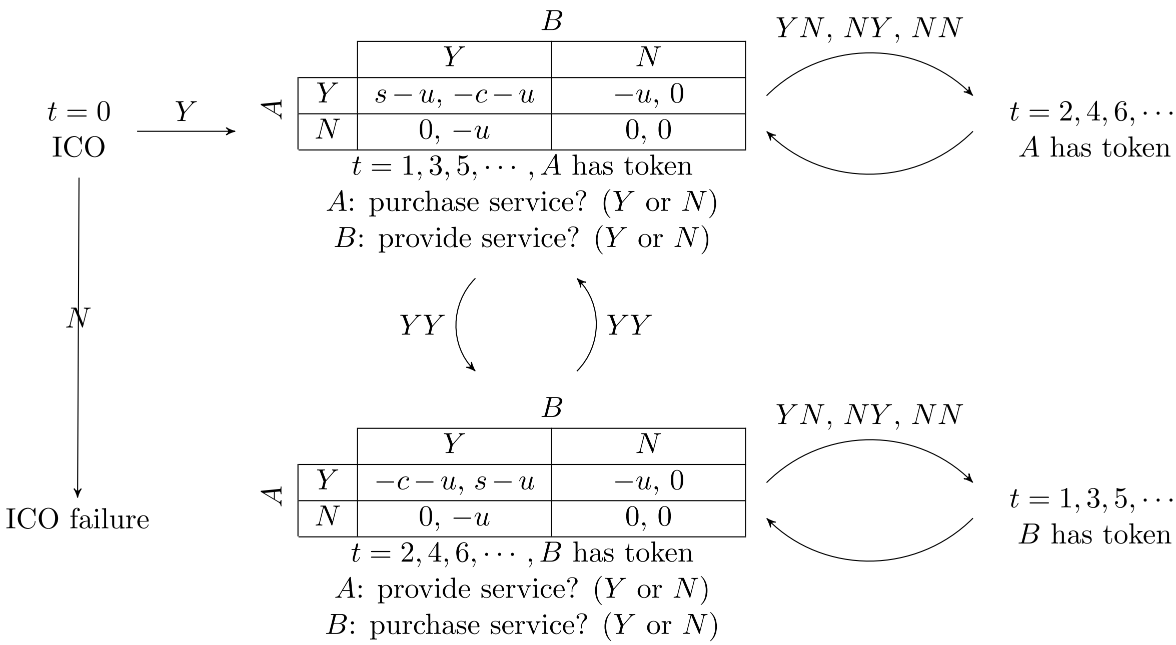
Assumption 2. $c + u < P \leq \frac{\rho}{1-\rho^2} \times [(s-u) - \rho(c+u)]$.

If $P > \frac{\rho}{1-\rho^2} \times [(s-u) - \rho(c+u)]$, the token price exceeds the present value of all possible payoffs from platform participation, and clearly no user would find it desirable to purchase the token. Assumption 2 further requires that $P > c+u$, so that it is more costly to purchase the token during an ICO than to acquire it from providing service during platform operation. Note that Assumption 2 only constrains the pricing of the token, and does not restrict the set of projects we consider.

[9] This assumption can be relaxed to state that any token value outside of the platform is sufficiently low. Section 3 further discusses the details.

If A purchases the token in the ICO, then in the game that follows, because token transfers are transparently recorded on the blockchain, the payoff-relevant information includes not only who demands and who can provide the service (as in the generic currency case), but also who holds the token. This leads to a game representation summarized in Figure 2.

Figure 2: **The Game on a Platform Using a Token**



As Figure 2 illustrates, the game starts at the ICO in period 0. If A purchases the token during the ICO (choosing Y) then the game proceeds to the first period of platform operation, $t=1$. In any period $t \geq 1$, if the user who demands the service happens to hold the token, a simultaneous-move game is played with payoff matrix given in Figure 2. If instead the user who demands the service does not hold the token, no actions are taken, both users receive stage-game payoffs of zero, and in the next period the state transitions back to the one in which the user demanding the service holds the token. Proposition 2 below will show that using a token as the medium of exchange resolves the coordination problem that arises when using a generic currency.

2.2 Outcomes with a generic currency versus with a token

In this section, we compare the equilibrium outcomes on a platform that uses a generic currency with that using a token. We demonstrate the advantage of the token model when users apply reasoning based on *forward induction*, which in short requires that any past action in a dynamic game is believed to be part of a rational strategy.

Our solution concept is weakly sequential equilibrium refined by forward induction, which is the same one used by Govindan and Wilson (2009) to formalize forward induction.[10] Weakly sequential equilibrium, introduced by Reny (1992), resembles the sequential equilibrium concept of Kreps and Wilson (1982) in that it also requires consistent beliefs about others' strategies, but it slightly relaxes the sequential rationality requirement by only requiring one's equilibrium strategy to specify a best response at states not excluded by that strategy, rather than at all states.[11] Forward induction further requires that, in any equilibrium, beliefs only put positive weight on others' strategies that are best responses to *some* equilibrium with the same outcome. Unless otherwise specified, we will always use "equilibrium" in the rest of the paper to refer to the solution concept described in this paragraph.

After presenting our main result (Proposition 2), we will further explain the intuition behind forward induction, and further justify why this is a natural reasoning for users to apply in our model. All technical definitions of related concepts are detailed in Appendix A.

2.2.1 Outcomes on a platform using a generic currency

When the platform uses a generic currency as its medium of exchange, coordination failure can lead to an inefficient equilibrium, as summarized in the following result:

Proposition 1 (Coordination failure on a platform using a generic currency)**.** *On a platform*

[10] As noted earlier, the equilibrium is defined within stationary strategies. In Section 3.2 where we study an incomplete information game version of our model, the solution concept is the natural Bayesian extension.

[11] Reny (1992) and Govindan and Wilson (2009) discuss the advantages of this equilibrium concept.

that uses a generic currency as the medium of exchange, there exist inefficient equilibria satisfying forward induction in which service provision fails to happen in some periods.

For example, there is an equilibrium in which both users never participate on the platform, because a unilateral deviation in a particular period incurs an additional utility cost u without changing the equilibrium outcome. This poses a serious problem for an entrepreneur launching a new platform: since non-participation was the status quo, coordination failure is likely focal. We next show that this coordination failure can be eliminated if the medium of exchange is a platform-specific token initially distributed through an ICO.

2.2.2 Outcomes on a platform using a token

When a token is used as a medium of exchange on the platform, there is a unique equilibrium outcome. This is our main result, summarized in Proposition 2:

Proposition 2. *On a platform using a token as the medium of exchange, there is a unique equilibrium outcome: A purchases the token in the ICO and service provision happens in every period during platform operation.*

Notice that there does exist a weakly sequential equilibrium in which A never purchases the token, and service provision never happens on the platform. However, this outcome does not survive forward induction.

To get intuition, recall that forward induction requires players to believe that others' past actions were rational given their plans for the future. Now consider B's decision in period 1, after having observed A's token purchase during the ICO. Clearly, B will not attempt to provide the service if he believes that A will not attempt to spend the token. However, this is exactly the belief ruled out by forward induction: B understands that for A, a strategy of purchasing the token and then not trying to spend it is strictly inferior to a strategy of not purchasing the token at all. Therefore, B believes that A will spend the token in period 1.

Given this belief, B understands that if he attempts to provide the service in period 1, he will incur a cost of $c + u$ and receive the token. Is it rational to do so? Apply an additional iteration of forward induction: If B provides the service and receives the token in period 1, A will be confident that B will attempt to spend the token in period 2, when B derives utility from the service. Knowing this, in period 2 A would find it desirable to provide the service at cost $c + u < P$, re-acquire the token, and return to the state previously seen in period 1. Both users are aware of the above conclusions. Therefore, B will attempt to provide the service in period 1, and the efficient equilibrium outcome is obtained.

The above reasoning is made rigorous in the proof of the proposition, following the framework of Govindan and Wilson (2009). In summary, thanks to the observable and costly token purchase by user A before the platform launch, forward induction selects the efficient outcome of the game instead of the inefficient one. Our model thus rationalizes the use of platform-specific tokens in platform-based startups.

Both the transparency of token transfers, and the intrinsic uselessness of the token, are important for the result in Proposition 2. If token acquisition is not transparent, the users cannot use it to communicate their future plans. If the token has value beyond its use on the platform, then this communication may not be credible. Tokens are thus useful to the platform precisely *because* they are useless outside of it. This answers the question, often puzzling to ICO observers, of how a digital token can have value when it cannot be widely used outside of a specific platform. In fact, this is the precise reason that the purchase of such a token credibly communicates future participation.

Further remarks on forward induction While the concept of forward induction dates back to at least Kohlberg and Mertens (1986), with further contributions by Battigalli and Siniscalchi (2002) and Govindan and Wilson (2009), among others, its applications in the finance literature have so far been limited. In this section we provide further motivation for applying this concept in our setting.

First, we observe that many well-known concepts in finance can be viewed as special cases of forward induction, including for example the intuitive criterion of Cho and Kreps (1987) which has been used for equilibrium selection in signaling games (see discussion in Cho, 1987 and Govindan and Wilson, 2009). Therefore, the basic idea of forward induction is more familiar than it might seem at first. While the intuitive criterion restricts players' beliefs about each other's types, forward induction restricts beliefs about strategies.

Second, experimental evidence shows that forward induction can accurately describe individual reasoning in coordination games. For example, van Huyck, Battalio and Beil (1993) conduct an experiment that resembles our model: Participants played a coordination game, and in some cases this game was preceded by an auction among a pool of potential players for the right to play the game. Without the auction, coordination failure was the most common outcome. When the auction was conducted, the resulting price was usually higher than the payoff from coordination failure, and coordination success was also usually achieved in the subsequent game. Crawford and Broseta (1998) relate this finding to forward induction, and Kogan, Kwasnica and Weber (2011) and Avoyan and Ramos (2017) provide more recent experimental evidence.

Forward induction has historically been viewed by some researchers as controversial because it occasionally conflicts with backward induction. However, in these conflicts it is not always clear that backward induction is the more natural concept than forward induction. For example, in the centipede game of Rosenthal (1981) and similar examples in later literature, backward induction often predicts outcomes that seem unreasonable based on both introspection and experimental evidence, while forward induction predicts the more natural outcome. Reny (1992) gives a specific example in his Figure 1 and accompanying discussion.

Reny (1992) also shows that the tension between the two induction concepts is resolved by slightly relaxing sequential rationality à la Kreps and Wilson 1982, which corresponds to backward induction in games with imperfect information, leading to his development of the weakly sequential equilibrium concept. One can then refine the set of weakly sequential equilibria to impose the stronger concepts of backward or forward induction. Govindan and Wilson (2009) build on this motivation, and show that, for a large class of games, forward induction is satisfied by any sequential equilibrium with the invariance property.[12]

Related, Kohlberg and Mertens (1986) point out that forward induction effectively interprets past actions as a form of preplay communication. In some games, the opportunity for preplay communication can yield controversial results: For example, a player may obtain higher payoffs if she merely has the ability to "burn money", even if she does not actually do so (e.g. Ben-Porath and Dekel, 1992). However, the main reason this result appears pathological is that the superior payoff results from *inaction*. In our view, forward induction reasoning is a more reasonable assumption when applied to costly *actions* taken deliberately, as is the case in our model and in the experimental evidence cited above.

In our view, the ICO structure has a natural interpretation as an attempt by the entrepreneur to harness forward induction reasoning among potential platform users. Our model builds on this idea and demonstrates the conditions under which it can be effective.

3 Token liquidity and coordination power

The intuition of our main result is that a user who acquires a token effectively communicates the future intent to participate on the platform. Would the strongest communication come from a token that could never be separated from its original purchaser? In other words, does liquidity weaken the token's coordinating power? To tackle this question, we distinguish between two types of liquidity, which we label *inside* and *outside* liquidity.

[12] While we adopt the weakly sequential equilibrium concept following Govindan and Wilson (2009), in our model all weakly sequential equilibrium outcomes are also sequential equilibrium outcomes, so forward induction does not conflict with sequential equilibrium in our model but rather sharpens its predictions.

By inside liquidity, we refer to the ability for the token to change hands from period to period between the two users within the platform. We will show that inside liquidity does not weaken the token's coordinating power, and in fact may strengthen it. We illustrate this point in Section 3.1 below, by comparing the pricing requirements for a token with that for a "membership", which may also coordinate platform participation by taking advantage of forward induction, but does not feature inside liquidity.

By outside liquidity, we refer to the ability for the token to be traded outside of the platform for external products/services or for speculation. In this case, the token may provide a payoff to a token holder even if he or she does not intend to participate on the platform. This type of liquidity may violate the requirement for the token to be worthless outside the platform, and may indeed weaken its coordinating power within the platform. To illustrate this point, we study the potential negative effect of speculation in Section 3.2.

3.1 Comparing a token and a membership

To illustrate the role of inside liquidity, we compare a token, which can change hands between users every period, with a non-transferable membership. Specifically, consider a platform using a generic currency as the medium of exchange, as described in Section 2.1.1, which in addition charges users an upfront membership fee: Any user must first make this one-time payment at $t = 0$ in order to be eligible to participate on the platform starting in $t = 1$.

This membership model may also exploit forward induction reasoning to prevent coordination failure just like the token model does, provided that the payment of the membership fee can be made observable like the token purchase, and that the fee is high enough so that its payment can credibly communicate a user's intent to participate on the platform.

However, a membership is not a perfect substitute for a token, as the required membership fee to achieve efficient coordination differs from the required token price. This result is summarized in Proposition 3.

Proposition 3. *For a sufficiently valuable platform, to ensure that forward induction uniquely selects the most efficient equilibrium outcome, the minimum membership fee required is higher than the minimum token price required.*

To understand Proposition 3, notice that in a membership model, there exist equilibria in which trade happens only in even or odd periods, and thus the up-front membership fee must be greater than the lifetime payoff from any one of these equilibria in order for forward induction to guarantee the efficient outcome. Hence, the required membership fee for efficient coordination is increasing in s. In the token model, by contrast, outcomes with service provision in only even or odd periods are ruled out, as users must acquire the token in even periods in order to spend it in odd periods or vice versa. On the other hand, the token model does require $P > c + u$ to rule out the outcome in which A only obtains a one-time service from B in period $t = 1$, and does not reciprocate afterwards. Notice that this token price requirement is independent of s. Therefore, for a sufficiently-valuable platform, a token requires a lower price to eliminate all inefficient equilibria than a membership does.

3.2 Speculation and coordination power

During the 2017–2018 ICO boom, many token purchases seemed to be motivated by expectations of potential speculation benefits rather than sincere intent to use the platform, raising a robustness concern over our main result: One may worry that in this case the purchase of the token does not reflect intent to use the platform, and may thus erode the token's power to select the efficient equilibrium. This section considers this concern.

We introduce a speculation benefit to our baseline model in Section 2.1.2: At $t = 1$, a token purchased during the ICO gives a benefit of r if the token is not used to acquire the service on the platform. We assume that r is drawn from an atomless distribution, and its realization is common knowledge (we will relax the common knowledge assumption after

Proposition 4 below). Our baseline model in Section 2.1.2 then corresponds to the special case of $r = 0$. Proposition 2 has established that in this special case, the inefficient equilibrium outcome of ICO failure does not satisfy forward induction, and the efficient equilibrium outcome of coordination success in every period is the unique outcome satisfying forward induction. Proposition 4 confirms the former result for any value of r, and shows that the latter result remains true for sufficiently small r, but it is overturned for large r.

Proposition 4. *The ICO succeeds almost surely when the token carries a speculation benefit* r. *Furthermore,*

- *If* $\rho r < P$, *the unique equilibrium outcome satisfying forward induction is for service provision to happen every period on the platform.*
- *If* $\rho r > \frac{\rho}{1-\rho^2}(s - u - \rho(c + u))$, *the unique equilibrium outcome satisfying forward induction is for* A *to purchase the token in the ICO only for speculation.*
- *If* $P < \rho r < \frac{\rho}{1-\rho^2}(s - u - \rho(c + u))$, *the above two outcomes are the only two equilibrium outcomes satisfying forward induction.*

Proposition 4 shows that as long as the platform is value creating, the ICO succeeds almost surely even in the presence of speculation concerns. Furthermore, for an adequately small speculation benefit, the token's coordination power is also robust. However, when the speculation benefit r is large, speculation may indeed crowd out efficient coordination in platform operation, even though the token sale remains successful.

The intuition for Proposition 4 is the following: When r is so low that the cost to acquire the token exceeds the benefit from speculation, forward induction implies that past token acquisition communicates future platform participation. In this case, the efficient outcome remains the only equilibrium outcome that satisfies forward induction, by the same logic as in Proposition 2. On the other hand, when r is so high that it exceeds the lifetime benefit from participating on the platform, A is strictly better off to purchase the token only for speculation. For intermediate r values, strategic complementarity permits both outcomes: If A believes B will use (not use) the platform, the benefit from using the platform exceeds (falls short of) that from speculation. Similarly, if B believes A will use the platform (speculate), the benefit from using the platform exceeds (falls short of) that from not using it.

Forward induction within a global game Proposition 4 establishes that there are multiple equilibria for intermediate values of r, but unique equilibria for extreme values. This observation suggests an opportunity to apply results on equilibrium selection in global games with strategic complementarities (Frankel, Morris and Pauzner, 2003; Goldstein and Pauzner, 2005). Inspired by this literature, in this section we explore an incomplete-information extension of our game.[13]

Instead of assuming r as common knowledge, assume that each player only has a noisy private signal $s_i = r + \epsilon_i$ where $\epsilon_i \sim \mathcal{N}(0, \sigma^2)$. We focus on the limiting case in which the players' signals become infinitely precise ($\sigma \to 0$). Lemma 5 summarizes the resulting equilibrium outcomes.

Lemma 5. *Suppose each player $i \in \{A, B\}$ has a noisy private signal $s_i = r + \epsilon_i$ where $\epsilon_i \sim \mathcal{N}(0, \sigma^2)$. In the limit as $\sigma \to 0$, the ICO succeeds almost surely, and the unique equilibrium outcome is service provision happening in every period when $\rho r < \max\{P, \rho r^*\}$ and speculation when $\rho r > \max\{P, \rho r^*\}$, where*

$$r^* = \frac{1}{1-\rho^2}\left(\frac{\rho(s-u)-c-u}{\rho(s-u)-c}\left(s-\rho(c+u)\right)-u\right). \tag{1}$$

Both forward induction and the higher order beliefs reasoning typical to standard global games are important for obtaining Lemma 5, as it is the joint force of the two that restricts

[13] We thank Itay Goldstein for encouraging us to explore potential application of global games to our setting, and Zhiguo He for extensive discussions on the global games literature.

beliefs and thus eliminates strategies.[14] As r varies, the game almost surely pins down a unique equilibrium outcome: The outcome of successful platform adoption is robust as long as the speculation benefit is adequately low. When the speculation benefit is too high, however, speculation may crowd out platform adoption, such that the ICO is "successful" but platform adoption fails. It is readily verified that the cutoff $\max\{P, \rho r^*\}$ derived in Proposition 5 lies between the two cutoffs P and $\frac{\rho}{1-\rho^2}(s-u-\rho(c+u))$ derived for the common-knowledge case in Proposition 4.

The key advantages of studying the incomplete information game, besides equilibrium uniqueness, are that it quantifies the probability of a successful platform launch and allows comparative statics analysis, as summarized in Proposition 6.

Proposition 6. *Ceteris paribus, the probability of a successful platform launch (service provision happening in every period on the platform) is higher for a platform with higher social value (higher s, lower c, and lower u) or a higher-priced token.*

Proposition 6 shows that speculation is more likely to happen to platforms with low intrinsic value (assuming all tokens have the same distribution of speculation benefits and signals). The entrepreneur can also set a higher token price to discourage speculation.

The fact that speculation may crowd out efficient coordination in platform operation suggests that it may be desirable to limit speculation to a certain extent. Section 4 discusses policy implications based on this fact. This finding echoes some recent reflections in the blockchain community that ICO success does not necessarily equal platform success, and that ICO promotions focused on maximizing token sales in the short term may not be optimal for a platform's ultimate adoption.[15] In other words, regulators and entrepreneurs may not necessarily be at odds with each other on the goal of limiting speculation.

[14] One might wonder if we can also apply global games to our baseline model and thus eliminate multiple equilibria without forward induction. However, relaxing common knowledge of the baseline model parameters (s, c, u, or ρ) is not helpful on this front, as without forward induction multiple equilibria persist even for an extremely valuable platform.

[15] This perspective has been gaining ground in the blockchain community; see e.g. Wang et al. (2018).

4 Implications for practitioners and regulators

We illustrate the relevance of our analysis with several immediate takeaways toward best practices and effective regulation of token sales.

Utility tokens and securities regulation Having validated the concept of a "utility token" with our model, we can shed light on the complicated question of whether a utility token should automatically be subject to existing securities laws such as the Securities Act of 1933 and the JOBS Act/Regulation Crowdfunding.[16] Indeed, our analysis shows why this question has been so difficult. On the one hand, a token may fit legal precedents for defining securities such as the Howey test.[17] On the other hand, our theory demonstrates that a token sale may not have a *financing* purpose. In our model, while the token sale does result in cash inflow at a time when the entrepreneur likely needs funding, its purpose is instead to build up user interactions as an integrated part of the platform's operational process.

This perspective is corroborated by several empirical facts: First, some token sales have been designed to cryptographically "burn" all their proceeds so that the entrepreneurs get zero funding from the sale, highlighting that fundraising was not their primary objective. An example is Mastercoin's token sale, commonly known as the first ICO in history. Second, many startups that conduct token sales also get significant funding from traditional sources such as venture capital (Howell, Niessner and Yermack, forthcoming). Finally, practitioners have long emphasized that token sales can be useful for community building.[18]

Because utility tokens are not necessarily aimed at the purpose of traditional securities,

[16]In a Senate hearing on February 6, 2018, the SEC chairman Jay Clayton claimed "Every ICO I've seen is a security." On June 14, 2018, William Hinman, SEC Director of the Division of Corporation Finance, stated that Ether and Bitcoin are not securities.

[17]The Howey test specifies a security as "investment of money in a common enterprise with a reasonable expectation of profits to be derived from the efforts of others" (SEC.gov).

[18]For example, Ryan Zurrer, Principal and Venture Partner of Polychain Capital, stated in a keynote speech at the Toronto FinTech Conference that ICOs are about fostering a community and "tokens act like rocket fuel for network effects."

compliance with existing securities regulations may inadvertently hinder their functioning (for examples in the context of our model, see below). Our theory therefore justifies carving out a special regulatory category for tokens that support platforms facing credible coordination problems, even if they meet existing tests for security status. This approach is already taken by certain jurisdictions including Switzerland and Singapore, and is currently being discussed within the SEC.[19] Such efforts may also require involvement from lawmakers.

Finally, the identification of a utility token should be based on the economic role it plays in the project it supports, not necessarily on the label attached by entrepreneurs themselves, in keeping with the SEC's stated goal of emphasizing substance over form in token regulation. Tokens that fail to justify their economic value, through either a coordination function as described in our theory or some other channels based on similarly rigorous analyses, should indeed face skepticism. That said, a universal ban on ICOs – as implemented by China and South Korea today – risks throwing the baby out with the bathwater.

Transparency The value of a token in our framework – its ability to credibly communicate future actions – relies on the transparency of token transactions. To a large extent, transparency is guaranteed for tokens issued on blockchains (e.g. ERC20 tokens on Ethereum) with near-real-time transaction records. This fact helps explain why token sales have grown in tandem with advances in the blockchain technology. That said, actions not recorded on the blockchain may interfere with this transparency. For example, a dishonest entrepreneur may manipulate "on-chain" activities by offering undisclosed "off-chain" bribes for participation in the token sale. In response, our theory suggests strict disclosure requirements for off-chain activities or compensations, as required in the SEC's warning against undisclosed compensation for celebrity endorsements of ICOs.[20]

On the other hand, while a blockchain readily provides the required transparency for the

[19]See SEC commissioner Hester Peirce's speech on February 6, 2020.

[20]See https://www.coindesk.com/sec-celebrity-ico-endorsements-illegal/.

token to facilitate coordination, the same level of transparency is likely more costly for a centralized intermediary to provide. Since existing crowdfunding/private placement regulations under the JOBS Act framework require all deals to go through a centralized funding portal (rather than directly through a blockchain), recent efforts to bring all ICOs in compliance with existing security regulations via the introduction of centralized intermediaries may have inadvertently hurt the market for utility tokens, as may be suggested by the relative decline of utility token sales in the U.S. in the second half of 2019.[21]

Eligibility Our theory also raises the question of who should be eligible to participate in a token sale. Due to current regulatory uncertainty in the US, a utility token may still be classified as a security. If that happens, a token sale larger than $50 million (under JOBS Act Title IV A+ Tier 2) must be restricted to "accredited investors," with stringent income and personal wealth constraints. Such requirements may render many valuable platforms infeasible, as these rules would exclude many of the very users that a platform services.

Some recent regulatory changes in the U.S. may be an appropriate step toward striking the balance between the security and utility attributes of tokens. On December 18, 2019, the SEC proposed to update the accredited investor definition to "allow more investors to participate in private offerings by adding new categories of natural persons that may qualify as accredited investors based on their professional knowledge, experience, or certifications."[22] This new rule may help certain projects to better reach out to their potential users and to allow ICOs to better coordinate platform building.

Limiting speculation in utility tokens As highlighted by Proposition 4 and Lemma 5, a token becomes less effective at coordinating user participation when it facilitates speculation.

[21] In addition to the SEC-sanctioned Blockstack token sale, many notable tokens with strong utility features in the second half of 2019 also eventually opted to go through the third-party security token funding portal CoinList – including Algorand – developed by Turing Award winner Silvio Micali.

[22] https://www.sec.gov/news/press-release/2019-265

Hence, practices that limit the benefit from speculation in utility tokens should be supported by entrepreneurs and regulators alike. To accomplish this, the entrepreneur could for example enhance disclosure to reduce information asymmetry, or introduce a vesting period for newly sold tokens before the platform launches. Another practice gradually gaining popularity is for an entrepreneur who seeks both fundraising and platform building to issue "security" tokens (or just traditional securities) compliant with existing securities law, separately from "utility" tokens, in hope that speculators will be drawn to the former rather than the latter. Finally, as so-called "stablecoins" continue to develop, it may become possible to incorporate some of those features into utility token designs so as to limit room for speculation.[23]

5 Conclusion

This paper creates a framework to understand the role of tokens in developing platforms for peer-to-peer transactions. We focus on the economic value of token sales, and highlight how tokens can serve to prevent inefficient coordination failure, rather than as alternatives to traditional securities. Both the transparency provided by the blockchain supporting a token, and the token's lack of use outside of the platform, contribute to the token's coordination power. Our analysis demonstrates the value of digital tokens in entrepreneurship, and also provides theoretical support for several best practices in practice and regulation, including the validity of utility tokens, the imposition of disclosure requirements, clear distinction of security and utility aspects of tokens, and limitations on speculation.

We hope that our analysis paves the path towards a comprehensive rule-based regulatory framework for digital tokens, and potentially other future innovations in entrepreneurship driven by blockchain technology. Currently, regulators in many major economies including the United States still follow a case-by-case approach toward regulation of token sales.[24]

[23] Wang et al. (2018) echo this vision.

[24] For example, the SEC has stated that "depending on the facts and circumstances of each individual

While some ambiguity is inevitable when initially dealing with a completely new market, over time a case-by-case approach may create its own problems: A lack of clear rules *ex ante* adds another source of risk to startups, market participants, and other stakeholders in the already-risky early stage entrepreneurship space. Our analysis of how tokens create economic value thus contributes to the development of a rule-based regulatory framework to help regulators and practitioners separate the wheat from the chaff in this emerging market and safeguard its future development.

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Appendix

A Forward induction à la Govindan and Wilson (2009)

The definition of forward induction follows Govindan and Wilson (2009), who in turn build on weakly sequential equilibrium defined by Reny (1992).

Weakly sequential equilibrium: A weakly sequential equilibrium of an extensive form game is a pair (b, μ) of players' behavioral strategies and beliefs. At each information set h_n of player n, his behavioral strategy specifies a distribution $b_n(\cdot|h_n)$ over his feasible actions, and his belief specifies a distribution $\mu_n(\cdot|h_n)$ over profiles of Nature's and other players' pure strategies that enable h_n to be reached.[25] These profiles are required to satisfy the following conditions:

[25] Note that our baseline model does not involve nature's move, so beliefs are only over others' strategies.

(i) Consistency: There exists a sequence $\{b^k\}$ of profiles of completely mixed behavioral strategies converging to b and a sequence $\{\sigma^k\}$ of completely mixed equivalent normal-form strategies such that for each information set of each player the conditional distribution specified by μ is the limit of the conditional distributions obtained from $\{\sigma^k\}$.

(ii) Weak sequential rationality: For each player n and each information set h_n that b_n does not exclude, each action in the support of $b_n(\cdot|h_n)$ is part of a pure strategy that is an optimal response to $\mu_n(\cdot|h_n)$ in the continuation from h_n.

Equilibrium outcome: The outcome of an equilibrium of an extensive form game is the induced probability distribution over the *paths* of the game tree. Note that Govindan and Wilson (2009) only consider finite horizon extensive form games and therefore define outcomes over terminal *nodes* of the game tree. Our definition is a natural extension that accommodates infinite horizon extensive form games.

Relevant strategy: A pure strategy of a player is relevant for a given equilibrium outcome if there is a weakly sequential equilibrium with that outcome for which the strategy at every information set it does not exclude prescribes an optimal continuation given the player's equilibrium belief there.

Relevant information set: An information set is relevant for an outcome if it is not excluded by every profile of strategies that are relevant for that outcome.

Forward induction: An outcome satisfies forward induction if it results from a weakly sequential equilibrium in which, at every information set that is relevant for that outcome, the support of the belief of the player acting there is confined to profiles of other players' strategies that are relevant for that outcome.

B Outcomes on a platform using a generic currency

Proof of Proposition 1. Consider the following strategy profiles:

- Both A and B participate on the platform every period;
- Neither A nor B participates on the platform in any period;
- Both participate on the platform in even periods and neither does in odd periods;
- Both participate on the platform in odd periods and neither does in even periods.

For each of these strategy profiles, we can construct a weakly sequential equilibrium by specifying each player's belief to coincide with the other's equilibrium strategy. Then beliefs are consistent by construction, and no player has a profitable unilateral deviation given her belief about the other's strategy, satisfying the requirements of weakly sequential equilibrium.

Moreover, all the equilibrium outcomes comply with forward induction: In each of the four cases, neither player's equilibrium strategy excludes any state of the game, so their equilibrium strategies are automatically relevant to the respective equilibrium outcome. Hence, players' beliefs in each equilibrium are restricted to strategies that are relevant to the equilibrium outcome. □

C Outcomes on a platform using a token

Proof of Proposition 2. For ease of exposition, we first label the payoff-relevant states:

- State 0 is the ICO.
- State 1 is the one in which A demands the service and has the token.
- State 2 is the one in which B demands the service and has the token.
- State 3 is the one in which B demands the service and A has the token.
- State 4 is the one in which A demands the service and B has the token.

We then summarize both users' stationary strategies as follows:

- A chooses Y with probability π at state 0 (ICO), δ at state 1, and β at state 2.
- B chooses Y with probability γ at state 1 and α at state 2.

We further make several definitions to be used extensively in the rest of the proof:

- s_A^Y denotes A's strategy that specifies Y at states 0, 1, and 2, i.e. $\pi = \delta = \beta = 1$.
- s_B^Y denotes player B's strategy that specifies Y at states 1 and 2, i.e. $\gamma = \alpha = 1$.
- "Always-trade" denotes the outcome in which A purchases the token at the ICO, and service provision takes place on the platform (both players participate) in every period. Note that this will be the outcome if both players play strategy s_i^Y ($i \in \{A, B\}$).
- "ICO-failure" denotes the outcome in which A does not purchase the token in the ICO.

We proceed with the proof of Proposition 2 in multiple steps as separate lemmas.

Lemma 7. *Always-trade and ICO-failure are the only two weakly sequential equilibrium outcomes on a platform with tokens distributed through an ICO.*

Proof of Lemma 7. First we construct a weakly sequential equilibrium $(\hat{b}, \hat{\mu})$ in which the outcome is always-trade: $\hat{b}$ specifies that $\pi = \alpha = \beta = \gamma = \delta = 1$, and each belief in $\hat{\mu}$ coincides exactly with the probabilities specified in $\hat{b}$. It is readily verified that:

- $(\hat{b}, \hat{\mu})$ satisfies consistency because players believe correctly about others' actions.

- $(\hat{b}, \hat{\mu})$ satisfies weak sequential rationality: The equilibrium payoff to each player is the maximum theoretical payoff from the game. Any unilateral deviation from Y to N during the platform's operation will lead to two periods of autarky, costing a flow utility of at least $\rho(s-u)-(c+u)>0$ compared to the equilibrium, so any such deviation would be suboptimal.

Next we construct a weakly sequential equilibrium $(\overline{b}, \overline{\mu})$ in which the outcome is ICO-failure: $\overline{b}$ specifies that $\pi=\alpha=\beta=\gamma=\delta=0$, and each belief in $\overline{\mu}$ coincides exactly with the probabilities in $\overline{b}$. It is readily verified that:

- $(\overline{b}, \overline{\mu})$ satisfies consistency because players believe correctly about others' actions.
- $(\overline{b}, \overline{\mu})$ satisfies weak sequential rationality: Given the other player always chooses N, deviating to Y at any period loses strictly positive flow utility of P or u.

Finally, we demonstrate that always-trade and ICO-failure are the only two possible equilibrium outcomes on a platform with token and ICO:

- For any equilibrium outcomes other than ICO-failure, we have $\pi>0$, that is, A purchases the token at ICO with strictly positive probability. Therefore state 1 is not excluded by A's equilibrium strategy, which implies $\delta=1$, as otherwise A has a profitable deviation to not purchase token at the ICO. In turn, equilibrium must feature $\gamma>0$, as otherwise A again has a profitable deviation to not purchase the token at the ICO. Finally, this in turn implies $\alpha=1$, as otherwise B has a profitable deviation to not purchase token at state 1.
- We prove by contradiction that $\gamma=1$. Otherwise, $0<\gamma<1$. In this case, for B, the continuation payoff from choosing N at state 1, which is 0, is equal to the continuation payoff from choosing Y at state 1, which is $-c-u+\rho\frac{\beta s-u-\beta\rho(c+u)}{1-\rho^2}$. Therefore $\beta=\frac{(1-\rho^2)(c+u)+\rho u}{\rho(s-\rho(c+u))}\in(0,1)$. Thus, for A, the continuation payoff from choosing N at state 2, which is 0, is equal to the continuation payoff from choosing Y at state 2, which is $-c-u+\rho\frac{\gamma s-u-\gamma\rho(c+u)}{1-\rho^2}$. Therefore $\gamma=\frac{(1-\rho^2)(c+u)+\rho u}{\rho(s-\rho(c+u))}$. In this case, A's payoff from choosing Y at the ICO state (with some simplification) turns out to be $-P+c+u<0$, so she is better off choosing N at ICO, contradicting $\pi>0$.
- Given that $\gamma=\alpha=1$, A's optimal strategy must be $\pi=\delta=\beta=1$, leading to the equilibrium outcome of always-trade. Therefore always-trade and ICO-failure are the only two possible equilibrium outcomes on a platform with token and ICO.

$\square$

Lemma 8. *The always-trade outcome satisfies forward induction.*

Proof of Lemma 8. Consider the weakly sequential equilibrium $(\hat{b}, \hat{\mu})$ defined in the proof of Lemma 7 in which the outcome was always-trade. The equilibrium strategies of A and B are s_A^Y and s_B^Y, respectively. By the definition of equilibrium, these two strategies must be best responses to the equilibrium for each of the two players. Therefore, s_A^Y and s_B^Y are relevant to the equilibrium outcome of always-trade. Since beliefs are consistent with s_A^Y and s_B^Y in this equilibrium, and are thus at every information set confined to these relevant strategies, the outcome of this equilibrium, always-trade, satisfies forward induction. □

Lemma 9. *s_A^Y is relevant to the ICO-failure outcome.*

Proof of Lemma 9. We first show that the following strategy and belief profile constitutes a weakly sequential equilibrium:

- A chooses $\pi = 0$, $\delta = \frac{u}{\rho(s-u)-c}$, and $\beta = 1$. Because $\rho(s-u) > c+u$, $0 < \delta < 1$.
- B chooses $\gamma = \frac{(1-\rho^2)P+\rho u}{\rho(s-\rho(c+u))}$ and $\alpha = 1$. Because $P < \frac{\rho}{1-\rho^2}(s-u-\rho(c+u))$, $0 < \gamma < 1$.
- Both players' beliefs are consistent with the strategy profile above.

Clearly the outcome of this equilibrium is ICO-failure.

We proceed to verify that

- B's strategy gives a best response at state 1:
  - Since $\gamma > 0$, U_1, the present value of B's continuation payoffs at state 1 from the equilibrium strategy equals that from choosing Y at state 1, and satisfies
  $$U_1 = -u + \delta(-c + \rho(s-u+\rho U_1)) + (1-\delta)\rho^2 U_1.$$
  Therefore $U_1 = \frac{\rho\delta(s-u)-\delta c-u}{1-\rho^2}$, which is exactly zero when $\delta = \frac{u}{\rho(s-u)-c}$.
  - The present value of the continuation payoff from deviating to any strategy that specifies N at state 1 is zero.
  - Therefore B does not have a strictly profitable deviation at state 1, and any mixture of Y and N at state 1, including the specified strategy, could constitute a best response.
- B's strategy gives a best response at state 2:
  - U_2, the present value of B's continuation payoffs at state 2 from the equilibrium strategy satisfies
  $$U_2 = s - u + \rho U_1,$$
  which is strictly positive when $\delta = \frac{u}{\rho(s-u)-c}$.
  - The present value of the continuation payoff from deviating to any strategy that specifies N at state 2 is zero.
  - Therefore B strictly prefers Y at state 2, rationalizing $\alpha = 1$.

- A's equilibrium strategy, as well as the alternative strategy s_A^Y, both give best responses at state 0:
  - The present value of A's continuation payoff to any strategy that specifies Y at state 0, including the equilibrium strategy, is zero.
  - The present value of A's continuation payoff to any strategy that specifies Y at state 0 and N at state 1 is $-P < 0$.
  - The present value of A's continuation payoff to a strategy that specifies Y at state 0, Y at state 1, and N at state 2 is $-P + \frac{\rho(\gamma s - u)}{1-(1-\gamma)\rho^2}$. Given $\gamma = \frac{(1-\rho^2)P+\rho u}{\rho(s-\rho(c+u))}$, this payoff can be restated as $\frac{\gamma\rho^2(c+u-P)}{1-(1-\gamma)\rho^2}$, which is strictly negative given $P > c + u$.
  - V_{ICO}, the present value of A's continuation payoff at state 0 from the strategy s_A^Y satisfies

$$V_{ICO} = -P + \rho V_1 \tag{2}$$
$$V_1 = -u + \gamma(s + \rho(-c - u + \rho V_1)) + (1-\gamma)\rho^2 V_1. \tag{3}$$

    Therefore $V_{ICO} = -P + \frac{\rho}{1-\rho^2}(\gamma s - u - \gamma\rho(c+u))$, which is equal to zero when $\gamma = \frac{(1-\rho^2)P+\rho u}{\rho(s-\rho(c+u))}$.
  - Any other possible strategy is a mixture of the strategies above and hence gives a payoff (weakly) less than zero. Hence any strategy that yields a payoff of zero, including s_A^Y, is a best response for A.
- Note that we do not need to check that A's strategy is a best response at any state other than state 0, because these other states are all excluded by A's equilibrium strategy that specifies N at state 0.

We have thus constructed a weakly sequential equilibrium in which the outcome is ICO-failure and s_A^Y is a best response to this equilibrium for A. Therefore, s_A^Y is relevant to ICO-failure. □

Lemma 10. *s_A^Y is the only strategy of A's that is relevant to the ICO-failure outcome and specifies Y at the ICO.*

Proof of Lemma 10. Denote s_A as an arbitrary strategy for A that is relevant to the ICO-failure outcome and specifies Y at the ICO.

- First, observe that s_A must also specify Y at state 1: Otherwise, it could not be a best response to any weakly sequential equilibrium, since the only possible surplus for A from choosing Y at the ICO is realized at state 1. Put differently, A's payoff from choosing Y at ICO and N at state 1 is $-P < 0$, which cannot be a best response as choosing N at the ICO gives a higher payoff of 0.

- Next, we prove by contradiction that s_A must also specify Y at state 2. Suppose otherwise: s_A specifies Y at the ICO, Y at state 1, and N at state 2. As a relevant strategy, s_A must be a best response to some weakly sequential equilibrium with ICO-failure as its outcome. Denote such a weakly sequential equilibrium as $(\hat{b}, \hat{\mu})$.

- If N is a best response to $(\hat{b}, \hat{\mu})$ for A at state 2, then $(\hat{b}, \hat{\mu})$ must specify $\alpha < 1$: Otherwise with $\alpha = 1$ and $P > c + u$, the continuation payoff to A from choosing Y at state 2 is strictly greater than the continuation payoff from choosing Y at the ICO, so a weak preference for N at state 2 would imply a strict preference for N at ICO, contradicting our assumption that s_A is a relevant strategy that specifies Y at the ICO.

- $(\hat{b}, \hat{\mu})$ must also specify $\alpha > 0$. Otherwise if $\alpha = 0$, $\hat{b}$ must specify that B chooses N at state 1, as choosing Y would not be sequentially rational. With $\gamma = 0$, it would not be a best response for A to choose Y at the ICO, again contradicting our assumption.

- B must be indifferent between Y and N at state 2 in order to rationalize his decision to mix between them with probability $\alpha \in (0, 1)$. So the continuation payoff U_2 to B from being in state 2, and from choosing Y at that state, must both be equal to the continuation payoff from choosing N at that state, which is 0.

- Now consider the value of γ under equilibrium $(\hat{b}, \hat{\mu})$. Since $\alpha < 1$, the continuation payoff U_1 to B from choosing Y at state 1 satisfies

  $$U_1 = -u - \delta c + \delta\rho U_2 + (1-\delta)\rho^2 U_1 = -u - \delta c + (1-\delta)\rho^2 U_1,$$

  leading to $U_1 = \frac{-u-\delta c}{1-(1-\delta)\rho^2} < 0$, while the continuation payoff to B from choosing N at state 1 is zero. Therefore $\gamma = 0$, which means that it cannot be a best response for A to choose Y at the ICO, a contradiction. Hence s_A must specify Y at state 2.

We thus conclude that s_A^Y is the only strategy of A's that is relevant to the ICO-failure outcome and specifies Y at the ICO. □

Lemma 11. *State 1 is relevant to the ICO-failure outcome.*

Proof of Lemma 11. We construct a profile of relevant strategies that do not exclude this state. Consider the following profile: for player A, the strategy s_A^Y; and for player B, the strategy $\gamma = \alpha = 0$. Player A's strategy is relevant to the ICO-failure outcome by Lemma 9. Player B's strategy is relevant to the ICO-failure outcome because it is a best reply to the weakly sequential equilibrium in which A chooses N at the ICO and $\delta = \beta = 0$. Since A's strategy specifies Y at ICO, this profile of strategies does not exclude state 1, and therefore state 1 is relevant to the game over outcome. □

Lemma 12. *The ICO-failure outcome does not satisfy forward induction.*

Proof of Lemma 12. Proof by contradiction.

- Suppose there exists a weakly sequential equilibrium (b, μ) in which the outcome is ICO-failure, and players' beliefs only put weight on strategies that are relevant to the ICO-failure outcome at every relevant state.
- By Lemma 11, state 1 is relevant. Therefore, at this state, μ must specify that all players put weight only on other players' strategies that are relevant to the ICO-failure outcome, and that specify Y at the ICO. By Lemmas 9 and 10, the only such strategy for A is s_A^Y. Therefore, B must assign probability 1 to A's strategy s_A^Y once the game reaches state 1.
- Given this belief, B's best response at state 1 is Y at both states 1 and 2, as this yields a payoff of $\frac{1}{1-\rho^2}[\rho(s-u)-(c+u)] > 0$, compared to the payoff of zero from choosing N. Since state 1 cannot be excluded by any of B's strategies, by sequential rationality, the equilibrium strategy profile b must specify that B plays the best-response of Y at state 1. Given this, B's strategy also does not exclude state 2, and again sequential rationality b must specify that B plays the best-response of Y at state 2, too.
- Consistency requires μ to specify that A's equilibrium belief is that B will play Y at states 1 and 2. Given this belief, A has a profitable deviation to strategy s_A^Y. This contradicts the assumption that (b, μ) is a weakly sequential equilibrium whose outcome is ICO-failure.

We thus prove that the ICO-failure outcome does not satisfy forward induction. □

Lemma 8 and 12 has already shown that always-trade satisfies forward induction, while ICO-failure violates. Therefore, only the always-trade equilibrium outcome satisfies forward induction, proving Proposition 2. □

D Comparison with a membership model

Proof of Proposition 3. We prove by contradiction that when a platform runs a membership model, it must charge a membership fee F higher than $\frac{\rho}{1-\rho^2}(\frac{s-c-2u}{2})$ to ensure that forward induction uniquely selects the most efficient equilibrium outcome.[26]

Suppose otherwise: $F \leq \frac{\rho}{1-\rho^2}(\frac{s-c-2u}{2})$. Consider the following strategy profile: Both A and B pay F in period 0 so as to be eligible to participate on the platform, and both choose Y at odd periods and N at even periods afterwards. A's and B's expected payoffs at period 0 are both $\frac{\rho}{1-\rho^2}(\frac{s-c-2u}{2}) - F \geq 0$. It is easy to verify that the presented strategy profile and a consistent belief profile constitutes a weakly sequential equilibrium that satisfies forward induction, contradicting the assumption that always-trade is the only outcome satisfying forward induction.

[26]Notice that this cutoff for F is a *necessary* condition to select the efficient outcome in the membership model. We do not pursue sufficient conditions.

Furthermore, we have $\frac{\rho}{1-\rho^2}(\frac{s-c-2u}{2}) > c+u$ when $\rho(s-u) > (2+\rho-2\rho^2)(c+u)$, which represents a platform with high value. From Proposition 2, an ICO selects the efficient equilibrium when $P > c+u$, so the necessary price for the membership model is higher. $\square$

E Speculation

Proof of Proposition 4. We proceed with separate discussions for each case.

When $\rho r < P$, the cost of acquiring the token during the ICO strictly exceeds the benefit from speculation. Therefore, A purchasing the token for speculation is not a relevant strategy. By forward induction, when A participates in the ICO, B believes that A will also attempt to buy the service on the platform (i.e. $\pi > 0 \Rightarrow \delta = 1$). With this belief, B's continuation payoff at state 1 from N is 0, which is higher than that from first choosing Y at state 1 and then N at state 2 (continuation payoff $-c-u$). Therefore we have $\gamma > 0 \Rightarrow \alpha = 1$. In state 2 (when B demands the service and has the token), $\alpha = 1$ indicates that A prefers Y (which gives a continuation payoff of $\frac{1}{1-\rho^2}(s-u-\rho(c+u))$ than N (which gives a continuation payoff of $s-u$). Therefore $\beta = 1$, and given $s_A < \frac{1-\rho}{\rho}P$, A's pure strategy of $\pi = 1, \delta = 0$ is strictly dominated by $\pi = 0$, leading to $\delta = 1$. Therefore, upon a successful ICO, B's continuation payoff from $\gamma = 0$ is 0, and that from $\gamma = \alpha = 1$ is $\frac{1}{1-\rho^2}\left(\rho(s-u)-(c+u)\right)$, leading to $\gamma = 1$. Therefore, always-trade is the only equilibrium that satisfies forward induction.

When $\rho r > \frac{\rho}{1-\rho^2}(s-u-\rho(c+u))$, the benefit from speculation strictly exceeds that from using the platform (and thus the cost to purchase the token during the ICO). Therefore it is a strictly dominant strategy for A to purchase the token and speculate (rather than using the platform). Therefore, "A speculating" is the unique equilibrium outcome of the game. It also satisfies forward induction as the consistent beliefs within the equilibrium ($\pi = 1, \delta = \gamma = 0$) are all restricted to relevant strategies.

Similarly, when $P < \rho r < \frac{\rho}{1-\rho^2}(s-u-\rho(c+u))$, we have that it is strictly dominated to not participate in the ICO (by speculation, or $\pi = 1, \delta = 0$). Therefore $\pi = 1$. Then from B's incentives we have that either $\gamma = 0$ or $\gamma > 0, \alpha = 1$. A's incentives give that $\delta = 0$, or $\delta > 0, \beta = 1$. Therefore we get that always-trade and "A speculating" are both equilibrium outcomes that satisfy forward induction. $\square$

F Comparative statics with a global game setup

Proof of Lemma 5. Our proof marries the standard global game approach and forward induction, both heavily making use of higher order beliefs. We will show that any pure strategies other than the ones stated in the lemma are eliminated from this reasoning.

First, we consider the case of sufficiently high signals:

A's payoff from speculation is monotonically increasing in s_A, while the payoff from any other strategy is bounded by the maximum value attainable on the platform. Therefore, there exists some $\overline{r}_A < +\infty$ such that A chooses to speculate ($\pi = 1, \delta = 0$) when $s_A > \overline{r}_A$.

For B, upon a successful ICO, the pure strategy of trying to acquire the token but not spend it ($\gamma = 1, \alpha = 0$) is always strictly dominated by not trying to acquire the token at all ($\gamma = 0$). Furthermore, B's continuation payoff from choosing $\gamma = 0$ is 0, while that from ($\gamma = 1, \alpha = 1$), taking into account A's strategy as described above, is no greater than

$$\mathbb{P}[s_A > \overline{r}_A | s_B] \underbrace{\left(-\frac{1}{1-\rho^2}u\right)}_{B\text{'s payoff if } A \text{ chooses } \pi=1,\delta=0} + \mathbb{P}[s_A < \overline{r}_A | s_B] \underbrace{\left(\frac{1}{1-\rho^2}(\rho(s-u) - (c+u))\right)}_{B\text{'s maximal payoff otherwise}}. \quad (4)$$

B prefers to not use the platform ($\gamma = 0$) upon a successful ICO if (4) is negative, which is true if and only if $\mathbb{P}[s_A > \overline{r}_A | s_B] > \frac{\rho(s-u)-(c+u)}{\rho(s-u)-(c+u)+u}$. Therefore, there also exists some $\overline{r}_B < +\infty$ such that B chooses $\gamma = 0$ when $s_B > \overline{r}_B$.

(4) gives that upon a successful ICO, the difference between B's expected payoff from $\gamma = \alpha = 1$ minus that from $\gamma = 0$, conditional on s_B, is no greater than $\Delta_B(s_B, \overline{r}_A)$, where

$$\Delta_B(s_B, r_A) \equiv \mathbb{P}[s_A < r_A | s_B] \left(\frac{1}{1-\rho^2}(\rho(s-u) - c)\right) - \frac{1}{1-\rho^2}u.$$

Similarly, the difference between A's expected payoff from other strategies over speculation ($\pi = 1, \delta = 0$), conditional on s_A, is no greater than $\overline{\Delta}_A(s_A, \overline{r}_B)$ where

$$\overline{\Delta}_A(s_A, r_B) \equiv \max\left\{\mathbb{P}[s_B < r_B | s_A] \left(\frac{\rho}{1-\rho^2}(s - \rho(c+u))\right), P + \frac{\rho}{1-\rho^2}u\right\} - \rho s_A - \frac{\rho}{1-\rho^2}u.$$

It is readily verified that both $\Delta_B(s_B, r_A)$ and $\overline{\Delta}_A(s_A, r_B)$ are increasing (strictly decreasing) in their respective r-arguments (s-arguments), and take positive and negative values for extreme values of the s-arguments. We can thus uniquely define $b_B(r_A)$ and $\overline{b}_A(r_B)$ so that $\Delta_B(b_B(r_A), r_A) = 0$ and $\overline{\Delta}_A(\overline{b}_A(r_B), r_B) = 0$.

Therefore, B prefers $\gamma = 0$ over $\gamma = \alpha = 1$ if $s_B > b_B(\overline{r}_A)$ while A prefers speculation ($\pi = 1, \delta = 0$) over other strategies if $s_A > \overline{b}_A(\overline{r}_B)$.

Iterating this logic for $n \geq 1$ rounds, any surviving strategy specifies that B prefers $\gamma = 0$ over $\gamma = \alpha = 1$ if $s_B > (b_B \circ \overline{b}_A)^{(n)}(\overline{r}_B)$, while A prefers speculation over other strategies if $s_A > (\overline{b}_A \circ b_B)^{(n)}(\overline{r}_A)$.

Lemma 13. *$b_B \circ \overline{b}_A$ has a unique fixed point* $\max\{r^*, \frac{P}{\rho}\} - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$, *and $\overline{b}_A \circ b_B$ has a unique fixed point* $\max\{r^*, \frac{P}{\rho}\}$.

Proof. $\Delta_B(b_B(r_A), r_A) = 0$ gives $b_B(r_A) = r_A - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$.

Denote $\overline{r}_B^{(\infty)}$ as the fixed point of $b_B \circ \overline{b}_A$, if any, then $\overline{r}_B^{(\infty)} = b_B \circ \overline{b}_A(\overline{r}_B^{(\infty)}) = b_B(\overline{b}_A(\overline{r}_B^{(\infty)})) = \overline{b}_A(\overline{r}_B^{(\infty)}) - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$, and thus

$$\overline{b}_A(\overline{r}_B^{(\infty)}) = \overline{r}_B^{(\infty)} + \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right). \quad (5)$$

$\overline{\Delta}_A(\bar{b}_A(\bar{r}_B^{(\infty)}), \bar{r}_B^{(\infty)}) = 0$ gives

$$\max\left\{\Phi\left[\frac{\bar{r}_B^{(\infty)} - \bar{b}_A(\bar{r}_B^{(\infty)})}{\sqrt{2}\sigma}\right](s - \rho(c+u)), \frac{1-\rho^2}{\rho}P + u\right\} = (1-\rho^2)\bar{b}_A(\bar{r}_B^{(\infty)}) + u.$$

Plug in (5) and further simplify we get $\bar{r}_B^{(\infty)} = \max\left\{r^*, \frac{P}{\rho}\right\} - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$.

Denote $\bar{r}_A^{(\infty)}$ as the fixed point of $\bar{b}_A \circ b_B$, if any, then $\bar{r}_A^{(\infty)} = \bar{b}_A \circ b_B(\bar{r}_A^{(\infty)}) = \bar{b}_A(b_B(\bar{r}_A^{(\infty)})) = \bar{b}_A\left(\bar{r}_A^{(\infty)} - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)\right)$. Denote $y \equiv \bar{r}_A^{(\infty)} - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$, then

$$\bar{b}_A(y) = y + \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right) = \bar{r}_A^{(\infty)}. \quad (6)$$

$\overline{\Delta}_A(\bar{b}_A(y), y) = 0$ gives $\max\left\{\Phi\left[\frac{y-\bar{b}_A(y)}{\sqrt{2}\sigma}\right](s-\rho(c+u)), \frac{1-\rho^2}{\rho}P + u\right\} = (1-\rho^2)\bar{b}_A(y) + u$. Plug in (6) and further simplify we get $\bar{r}_A^{(\infty)} = \max\left\{r^*, \frac{P}{\rho}\right\}$. □

Lemma 14. *Both $(b_B \circ \bar{b}_A)^{(n)}$ and $(\bar{b}_A \circ b_B)^{(n)}$ converge to their respective fixed points as $n \to \infty$.*

Proof. We only need to show that both $b_B \circ \bar{b}_A$ and $\bar{b}_A \circ b_B$ are contraction mappings, that is, they satisfy the Lipschitz conditions: $\exists\ \kappa \in [0,1)$ s.t. $|b_B \circ \bar{b}_A(x) - b_B \circ \bar{b}_A(y)| < \kappa|x-y|$ and $|\bar{b}_A \circ b_B(x) - \bar{b}_A \circ b_B(y)| < \kappa|x-y|$, $\forall x \geq y$. Since $b_B \circ \bar{b}_A(x) - b_B \circ \bar{b}_A(y) = \bar{b}_A(x) - \bar{b}_A(y)$ while $\bar{b}_A \circ b_B(x) - \bar{b}_A \circ b_B(y) = \bar{b}_A\left(x - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)\right) - \bar{b}_A\left(y - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)\right)$, we only need to show that $|\bar{b}_A(x) - \bar{b}_A(y)| < \kappa|x-y|$.

$\overline{\Delta}_A(\bar{b}_A(t), t) = 0$ yields $\max\left\{\Phi\left(\frac{t-\bar{b}_A(t)}{\sqrt{2}\sigma}\right)(s-\rho(c+u)), \frac{1-\rho^2}{\rho}P + u\right\} = (1-\rho^2)\bar{b}_A(t) + u$, and thus $\bar{b}_A(t) = \frac{1}{\rho}P$ when $\Phi\left(\frac{t-\frac{1}{\rho}P}{\sqrt{2}\sigma}\right)(s-\rho(c+u)) \leq \frac{1-\rho^2}{\rho}P + u$, or equivalently $t \leq z$ where $z \equiv \frac{P}{\rho} + \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{\frac{1-\rho^2}{\rho}P+u}{s-\rho(c+u)}\right)$; and $\Phi\left(\frac{t-\bar{b}_A(t)}{\sqrt{2}\sigma}\right)(s-\rho(c+u)) = (1-\rho^2)\bar{b}_A(t) + u$ otherwise. Therefore,

- When $y \leq x \leq z$, $\bar{b}_A(x) - \bar{b}_A(y) = 0$.
- When $z \leq y \leq x$, $\bar{b}_A(x) - \bar{b}_A(y) = \int_y^x \bar{b}'_A(t)dt$, where by the implicit function theorem

$$\bar{b}'_A(t) = -\frac{\Phi'(\cdot)|_{\frac{t-\bar{b}_A(t)}{\sqrt{2}\sigma}}}{\Phi'(\cdot)|_{\frac{t-\bar{b}_A(t)}{\sqrt{2}\sigma}} + \sqrt{2}\sigma\frac{1-\rho^2}{s-\rho(c+u)}} \in (-1, 0). \quad (7)$$

Hence $|\int_y^x \bar{b}'_A(t)dt| \leq \int_y^x |\bar{b}'_A(t)|dt < \kappa|x-y|$, where $\kappa < 1$ is the maximum absolute value of the right hand side of (7), a continuous function, over $t \in [y, x]$.

- When $y \le z \le x$, then $|\bar{b}_A(x) - \bar{b}_A(y)| = |\bar{b}_A(x) - \bar{b}_A(z)| = |\int_z^x \bar{b}'_A(t)dt| \le \kappa|x - z| \le \kappa|x - y|$.

$\square$

Therefore, in any equilibrium B chooses $\gamma = 0$ if $s_B > \max\left\{r^*, \frac{P}{\rho}\right\} - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$, while A speculates ($\pi = 1, \delta = 0$) if $s_A > \max\left\{r^*, \frac{P}{\rho}\right\}$.

Next, we establish what strategies are followed for sufficiently *low* signals:

Upon observing a successful ICO, by forward induction B attaches zero probability to A's pure strategy of $\delta = 1, \beta = 0$, by the same logic of Proposition 2, which is unchanged in the presence of r. Furthermore, when $s_A < \frac{1}{\rho}P$, A's pure strategy of speculation ($\pi = 1, \delta = 0$) is strictly dominated by $\pi = 0$. Thus, conditional on the event $s_A < \frac{1}{\rho}P$, again by forward induction B attaches zero probability to A's pure strategy of speculation and thus probability 1 to A's only remaining pure strategy $\delta = \beta = 1$. Conditional on s_B, this event happens with probability $\mathbb{P}[s_A < \frac{1}{\rho}P|s_B]$. Therefore, after observing an ICO success, B's expected continuation payoff from $\gamma = \alpha = 1$ is at least

$$\mathbb{P}\left[s_A < \frac{1}{\rho}P\middle|s_B\right]\underbrace{\left(\frac{1}{1-\rho^2}\left(\rho(s-u) - (c+u)\right)\right)}_{B\text{'s payoff if } A \text{ chooses } \pi=\delta=\beta=1} + \mathbb{P}\left[s_A > \frac{1}{\rho}P\middle|s_B\right]\underbrace{\left(-\frac{1}{1-\rho^2}u\right)}_{B\text{'s minimal payoff otherwise}},$$

which is large than 0, B's continuation payoff from $\gamma = 0$ upon a successful ICO, if and only if $\mathbb{P}\left[s_A < \frac{1}{\rho}P\middle|s_B\right] > \frac{u}{\rho(s-u)-(c+u)+u}$. Therefore there exists some $\underline{r}_B > -\infty$ such that

$$\Phi\left(\frac{\frac{1}{\rho}P - \underline{r}_B}{\sqrt{2}\sigma}\right) = \frac{u}{\rho(s-u) - (c+u) + u}, \tag{8}$$

and B chooses to use the platform ($\gamma = \alpha = 1$) when $s_B < \underline{r}_B$.

Given knowledge of B's strategy as described above, A's expected payoff from $\pi = 0$ is 0, that from $\pi = 1, \delta = 0$ is $-P + \rho s_A$, and that from $\pi = \delta = 1$ is at least

$$-P + \frac{\rho}{1-\rho^2}\left(\mathbb{P}[s_B < \underline{r}_B|s_A]\left(s - \rho(c+u)\right) - u\right). \tag{9}$$

Hence there exists some $\underline{r}_A > -\infty$ such that

$$-P + \frac{\rho}{1-\rho^2}\left(\mathbb{P}\left[s_B < \underline{r}_B|s_A = \underline{r}_A\right]\left(s - \rho(c+u)\right) - u\right) = \max\{0, -P + \rho\underline{r}_A\}, \tag{10}$$

and A chooses to use the platform ($\pi = \delta = 1$) when $s_A < \underline{r}_A$.

The following observation will be used later in the proof:

Lemma 15. *When $P > \rho r^*$, we have $\underline{r}_A < \frac{1}{\rho}P$. When $P = \rho r^*$, $\underline{r}_A = \frac{1}{\rho}P$.*

Proof. Notice that the left (right) hand side of (10) decreases (increases) in $\underline{r}_A$, and when $P \geq \rho r^*$, at $s_A = \frac{1}{\rho}P$ the left hand side of (10) equals

$$-P + \frac{\rho}{1-\rho^2}\left(\Phi\left(\frac{\underline{r}_B - \frac{1}{\rho}P}{\sqrt{2}\sigma}\right)(s - \rho(c+u)) - u\right) \overset{\text{by (8)}}{=} -P + \rho r^* \leq 0,$$

while the right hand side of (10) equals 0. $\square$

After observing a successful ICO, B's expected payoff from playing $\gamma = \alpha = 1$ is at least $\Delta_B(s_B, \underline{r}_A)$. The difference between A's expected payoff from participation, and A's best expected payoff from other strategies, is at least $\underline{\Delta}_A(s_A, \underline{r}_B)$ where

$$\underline{\Delta}_A(s_A, r_B) \equiv \mathbb{P}[s_B < r_B | s_A]\left(\frac{\rho}{1-\rho^2}(s - \rho(c+u))\right) - \max\{\rho s_A, P\} - \frac{\rho}{1-\rho^2}u.$$

It is readily verified that $\underline{\Delta}_A(s_A, r_B)$ is increasing (strictly decreasing) in r_B (s_A) and takes positive and negative values for extreme values of s_A. We can thus uniquely define $\underline{b}_A(r_B)$ so that $\underline{\Delta}_A(\underline{b}_A(r_B), r_B) = 0$. Observe that B prefers $\gamma = \alpha = 1$ over $\gamma = 0$ if $s_B < b_B(\underline{r}_A)$, while A prefers participation $\pi = \delta = \beta = 1$) over other strategies if $s_A < \underline{b}_A(\underline{r}_B)$. Iterating this reasoning for $n \geq 1$ rounds, any surviving strategy specifies that B prefers $\gamma = \alpha = 1$ over $\gamma = 0$ if $s_B < (b_B \circ \underline{b}_A)^{(n)}(\underline{r}_B)$, while A prefers participation over other strategies if $s_A < (\underline{b}_A \circ b_B)^{(n)}(\underline{r}_A)$.

For the rest of the proof, we distinguish the two cases $P < \rho r^*$ and $P \geq \rho r^*$.

Lemma 16. *When $P < \rho r^*$, $b_B \circ \underline{b}_A$ has a unique fixed point $r^* - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$, and $\underline{b}_A \circ b_B$ has a unique fixed point r^*.*

Proof. The proof strategy is similar to that of Lemma 13. Recall that $\Delta_B(b_B(r_A), r_A) = 0$ gives $b_B(r_A) = r_A - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$.

Denote $\underline{r}_B^{(\infty)}$ as the fixed point of $b_B \circ \underline{b}_A$, if any, then $\underline{r}_B^{(\infty)} = b_B \circ \underline{b}_A(\underline{r}_B^{(\infty)}) = b_B(\underline{b}_A(\underline{r}_B^{(\infty)})) = \underline{b}_A(\underline{r}_B^{(\infty)}) - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$, and thus

$$\underline{b}_A(\underline{r}_B^{(\infty)}) = \underline{r}_B^{(\infty)} + \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right). \tag{11}$$

$\underline{\Delta}_A(\underline{b}_A(\underline{r}_B^{(\infty)}), \underline{r}_B^{(\infty)}) = 0$ gives $\Phi\left[\frac{\underline{r}_B^{(\infty)} - \underline{b}_A(\underline{r}_B^{(\infty)})}{\sqrt{2}\sigma}\right](s - \rho(c+u)) = \max\left\{(1-\rho^2)\underline{b}_A(\underline{r}_B^{(\infty)}), \frac{1-\rho^2}{\rho}P\right\} + u$. Plug in (11) and simplify gives $r^* = \max\left\{\underline{r}_B^{(\infty)} + \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right), \frac{1}{\rho}P\right\}$. Therefore, given $P < \rho r^*$ we have $\underline{r}_B^{(\infty)} = r^* - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$.

Denote $\underline{r}_A^{(\infty)}$ as the fixed point of $\underline{b}_A \circ b_B$, if any, then $\underline{r}_A^{(\infty)} = \underline{b}_A \circ b_B(\underline{r}_A^{(\infty)}) = \underline{b}_A(b_B(\underline{r}_A^{(\infty)})) =$

$\underline{b}_A\left(\underline{r}_A^{(\infty)} - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)\right)$. Denote $y \equiv \underline{r}_A^{(\infty)} - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$, then

$$\underline{b}_A(y) = y + \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right) = \underline{r}_A^{(\infty)}. \tag{12}$$

$\underline{\Delta}_A(\underline{b}_A(y), y) = 0$ gives $\Phi\left[\frac{y-\underline{b}_A(y)}{\sqrt{2}\sigma}\right](s-\rho(c+u)) = \max\left\{(1-\rho)^2\underline{b}_A(y), \frac{1-\rho^2}{\rho}P\right\} + u$. Plug in (12) and further simplify gives $r^* = \max\left\{\underline{r}_A^{(\infty)}, \frac{1}{\rho}P\right\}$. Therefore, when $P < \rho r^*$ we have $\underline{r}_A^{(\infty)} = r^*$. □

Lemma 17. *When $P < \rho r^*$, both $(b_B \circ \underline{b}_A)^{(n)}$ and $(\underline{b}_A \circ b_B)^{(n)}$ converge to their respective fixed points as $n \to \infty$.*

Proof. $\underline{\Delta}_A(\underline{b}_A(t), t) = 0$ gives $\Phi\left(\frac{t-\underline{b}_A(t)}{\sqrt{2}\sigma}\right)(s-\rho(c+u)) = \max\left\{(1-\rho^2)\underline{b}_A(t), \frac{1-\rho^2}{\rho}P\right\} + u$. Hence we have

1. when $t \le z$, $\underline{b}_A(t) = t - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{\frac{1-\rho^2}{\rho}P+u}{s-\rho(c+u)}\right)$, where $z \equiv \frac{1}{\rho}P + \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{\frac{1-\rho^2}{\rho}P+u}{s-\rho(c+u)}\right)$
2. when $t > z$,
$$\Phi\left(\frac{t-\underline{b}_A(t)}{\sqrt{2}\sigma}\right)(s-\rho(c+u)) = (1-\rho^2)\underline{b}_A(t) + u. \tag{13}$$

In case 1 where $t \le z$, $b_B \circ \underline{b}_A(t) = \underline{b}_A(t) - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right) = t - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{\frac{1-\rho^2}{\rho}P+u}{s-\rho(c+u)}\right) - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right) > t - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{(1-\rho^2)r^*+u}{s-\rho(c+u)}\right) - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right) = t$. Therefore, after finite rounds of iterated application of $b_B \circ \underline{b}_A$, we will end up in case 2.

In case 2 where $t > z$, we further separate two cases depending on if $z < t \le \underline{r}_B^{(\infty)} = r^* - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$, or if $t > \underline{r}_B^{(\infty)} = r^* - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$.

When $z < t \le \underline{r}_B^{(\infty)} = r^* - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$, $\frac{t-r^*}{\sqrt{2}\sigma} \le -\Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$. Apply $\Phi(\cdot)$ on both side we get $\Phi\left(\frac{t-r^*}{\sqrt{2}\sigma}\right) \le \Phi\left(-\Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)\right) = 1 - \frac{u}{\rho(s-u)-c}$. Multiply $(s-\rho(c+u))$, subtract u, and divide by $1-\rho^2$ on both side gives

$$\frac{1}{1-\rho^2}\left(\Phi\left(\frac{t-r^*}{\sqrt{2}\sigma}\right)(s-\rho(c+u)) - u\right) \le \frac{1}{1-\rho^2}\left(\left(1-\frac{u}{\rho(s-u)-c}\right)(s-\rho(c+u)) - u\right) = r^*,$$

or $\Phi\left(\frac{t-r^*}{\sqrt{2}\sigma}\right)(s-\rho(c+u)) \le (1-\rho^2)r^* + u$. Compare with (13) we get $r^* \ge \underline{b}_A(t)$.

Therefore, on the one hand, $\frac{1}{1-\rho^2}\left((s-\rho(c+u))\left(1-\frac{u}{\rho(s-u)-c}\right) - u\right) = r^* \ge \underline{b}_A(t) \overset{\text{by (13)}}{=} \frac{1}{1-\rho^2}\left((s-\rho(c+u))\Phi\left(\frac{t-\underline{b}_A(t)}{\sqrt{2}\sigma}\right) - u\right)$, leading to $1 - \frac{u}{\rho(s-u)-c} \ge \Phi\left(\frac{t-\underline{b}_A(t)}{\sqrt{2}\sigma}\right)$. Apply $\Phi^{-1}(\cdot)$

on both sides gives $-\Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right) \geq \frac{t-\underline{b}_A(t)}{\sqrt{2}\sigma}$, or $\underline{b}_A(t) - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right) \geq t$. Since $\underline{b}_A(t) - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right) = b_B \circ \underline{b}_A(t)$, we have $b_B \circ \underline{b}_A(t) \geq t$.

On the other hand, subtracting $\sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$ from both side of $\underline{b}_A(t) \leq r^*$ gives $\underline{b}_A(t) - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right) \leq r^* - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$. The left hand side equals $b_B \circ \underline{b}_A(t)$, and the right $\underline{r}_B^{(\infty)}$, we thus have $b_B \circ \underline{b}_A(t) \leq \underline{r}_B^{(\infty)}$.

Therefore, $\{(b_B \circ \underline{b}_A)^{(n)}(t)\}_{n=0}^{\infty}$ where $t \in (z, \underline{r}_B^{(\infty)}]$ is an increasing and bounded sequence in $\in (z, \underline{r}_B^{(\infty)}]$, and thus converges to a finite limit as $n \to \infty$.

Following the same logic, $\{(b_B \circ \underline{b}_A)^{(n)}(t)\}_{n=0}^{\infty}$ where $t \in (\underline{r}_B^{(\infty)}, +\infty)$ is an decreasing and bounded sequence in $\in (\underline{r}_B^{(\infty)}, +\infty)$, and thus also converges to a finite limit as $n \to \infty$.

Combining all cases, $\forall t \in \mathbb{R}$, $\{(b_B \circ \underline{b}_A)^{(n)}(t)\}_{n=0}^{\infty}$ converges to a finite limit as $n \to \infty$.

Finally, we show that $\{(\underline{b}_A \circ b_B)^{(n)}\}_{n=0}^{\infty}$ also converges. This is because $(\underline{b}_A \circ b_B)^{(n)}(\cdot) = (\underline{b}_A \circ (b_B \circ \underline{b}_A)^{(n-1)})(b_B(\cdot))$, $(\underline{b}_A \circ b_B)^{(n-1)}$ converges as we have just shown, and $\underline{b}_A(\cdot)$ is a finite and continuous function. □

Hence, when $P < \rho r^*$, B prefers prefers $\gamma = \alpha = 1$ over $\gamma = 0$ if $s_B < r^* - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$ while A prefers participation over other strategies if $s_A < r^*$.

Now consider the case when $P \geq \rho r^*$. The maximum expected payoff to A from purchasing the token ($\pi = 1$) is at most $\Delta_A(s_A, \underline{r}_B) =$

$$-P + \max\left\{\rho s_A, \frac{\rho}{1-\rho^2}\left(\mathbb{P}[s_B < \underline{r}_B | s_A]\,(s - \rho(c+u)) - u\right)\right\} \tag{14}$$

where the maximum compares speculation ($\pi = 1, \delta = 0$) with participation ($\pi = \delta = \beta = 1$).

Evaluating (14) at $s_A = \frac{1}{\rho}P$ yields

$$\max\left\{0, -P + \frac{\rho}{1-\rho^2}\left(\Phi\left(\frac{\underline{r}_B - \frac{1}{\rho}P}{\sqrt{2}\sigma}\right)(s - \rho(c+u)) - u\right)\right\}$$

From the definition of $\underline{r}_B$, this is equal to $\max\{0, -P + \rho r^*\}$, which equals 0 when $P \geq \rho r^*$.

Evaluating (14) at $s_A = \underline{r}_A$ yields

$$\max\left\{-P + \rho \underline{r}_A, -P + \frac{\rho}{1-\rho^2}\left(\Phi\left(\frac{\underline{r}_B - \underline{r}_A}{\sqrt{2}\sigma}\right)(s - \rho(c+u)) - u\right)\right\}$$

From the definition of $\underline{r}_A$ this simplifies to $\max\{-P + \rho \underline{r}_A, 0\}$, which is equal to 0 by Lemma 15.

Notice that (14) decreases in s_A when $s_A \leq \hat{s}_A$ and increases in s_A when $s_A \geq \hat{s}_A$, where $\hat{s}_A$ uniquely solves $(1-\rho)^2 s_A = \mathbb{P}[s_B < \underline{r}_B | s_A]\,(s - \rho(c+u)) - u$. Hence, if $P \geq \rho r^*$, A refrains from the ICO when $s_A \in \left(\underline{r}_A, \frac{1}{\rho}P\right)$. The interval is non-empty if and only if $P > \rho r^*$ (by Lemma 15).

In summary, both A and B follow cutoff strategies:[27]

1. If $P \leq \rho r^*$, B chooses $\gamma = \alpha = 1$ when $s_B < r^* - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$ and $\gamma = 0$ when $s_B > r^* - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$, while A chooses participation when $s_A < r^*$, and speculation when $s_A > r^*$.

2. If $P > \rho r^*$, B chooses $\gamma = \alpha = 1$ when $s_B < \frac{1}{\rho}P - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$ and $\gamma = 0$ when $s_B > \frac{1}{\rho}P - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right)$, while A chooses participation when $s_A < \underline{r}_A$, refraining from the ICO when $\underline{r}_A < s_A < \frac{1}{\rho}P$, and speculation when $s_A > \frac{1}{\rho}P$, where

$$\underline{r}_A = \frac{1}{\rho}P - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{u}{\rho(s-u)-c}\right) - \sqrt{2}\sigma \times \Phi^{-1}\left(\frac{\frac{1-\rho^2}{\rho}P + u}{s - \rho(c+u)}\right).$$

As $\sigma \to 0$, both A and B choose cutoff strategies, in which B chooses $\gamma = \alpha = 1$ when $s_B < \max\left\{\frac{1}{\rho}P, r^*\right\}$ and $\gamma = 0$ when $s_B > \max\left\{\frac{1}{\rho}P, r^*\right\}$, while A chooses participation when $s_A < \max\left\{\frac{1}{\rho}P, r^*\right\}$, and speculation when $s_A > \max\left\{\frac{1}{\rho}P, r^*\right\}$. □

Proof of Proposition 6. From Lemma 5, the probability of a successful platform launch is $\Psi\left(\max\left\{\frac{1}{\rho}P, r^*\right\}\right)$, where Ψ denotes the cumulative distribution function of r. Taking derivatives of (1) with respect to s, c, and u shows that r^* increases in s, increases in c, and decreases in u. Therefore, the probability (weakly) increases in s, increases in c, decreases in u, and increases in P. □

[27] Notice that we regroup the case $P = \rho r^*$ together with $P < \rho r^*$ to facilitate concise presentation.