Utility Tokens Financing, Investment Incentives, and Regulation

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Abstract

We analyze a game-theoretic model, in which projects are financed by selling tokens that give access to consumption utility and the initial investors can sell their tokens in a secondary market. The efficiency of projects funded by token and equity financing is compared, and regulatory implications discussed. We then extent the model to consider the token issuer's ex-post investment incentive, which creates a gap between the size of funds raised and actual capital outlays. If the investors have a naive expectation, then the issuer can sometimes sell the entire token supply and invest nothing, so the project fails. If they have a rational expectation, then the equilibrium investment level becomes more efficient, but there can be still a room for regulatory policies such as setting a floor on the issuer's token holdings.

Keywords: utility tokens; initial coin offering; entrepreneurial financing

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1 Introduction

Digital token sales, also known as Initial Coin Offerings (ICOs), are an emerging method of raising capital for (blockchain-based) ventures.[1] Token sales/ICOs are a type of crowd-funding where the issuer often sells so-called 'utility' tokens (or agrees to distribute such tokens in the future) that can be used to gain access to goods and/or services once the proposed project is successfully launched and completed. The market for digital token sales grew rapidly in recent years, raising about \$10 billion in 2017 and \$11 billion in 2018 (Pozzi, 2019). On the other hand, ICO volume fell sharply below equity financing in 2019 to \$371 million (CB Insights, 2020).

Token issuers have frequently claimed that their tokens are utility tokens rather than securities, in an attempt to avoid the existing financial regulations. However, the U.S. Securities and Exchange Commission (SEC) has maintained that token sales are considered as securities offering under the *Howey* test (especially, when they are traded for a profit before the good or service is made available) and also has brought a handful of legal actions against unregistered digital token sales (Peirce, 2019).[2] Despite the legal uncertainties, token issuers around the world are still selling utility tokens to this date, hoping that such securities regulations can be avoided by qualifying for an exemption.

Thus, there are significant concerns over this largely unregulated market for digital token sales due to the possibility of frauds, or the general lack of governance as to the large sums of money raised in ICOs. In fact, a striking feature of many ICOs is that the issuers sometimes sell a substantial fraction (over 70 to 80 percent) of the total token supply that was created. This contrasts to the more familiar Initial Public Offerings (IPOs), where practitioners estimate that existing pre-IPO shareholders (e.g., founders, employees, and

[1] To be precise, tokens are created on existing blockchains such as the Bitcoin and the Ethereum blockchains, while a coin (e.g., Bitcoin and Ether) refers to a digital asset that is native to its own blockchain. ICOs can create either tokens or coins, though tokens are more common.

[2] The Howey case found that an "investment contract" exists when there is the investment of money in a common enterprise with a reasonable expectation of profits to be derived from the efforts of others. In 2018, SEC Chairman Jay Clayton testified "I believe every ICO I've seen is a security."

venture capitalists) retain some 70 to 80 percent of the company's shares and offer the complementary share to the public (Pearl, 2018).[3]

This paper aims to explain these phenomena in the ICO market as well as regulatory issues in a tractable model. First, we consider a base model, wherein investors derive utility from spending their tokens, abstracting away from the token issuer's investment incentive. This model illustrates the benefits from trading the tokens in the secondary market, while taking the token price as exogenous. It is the additional profit the initial investors can capture through the secondary-market trading that enables the token sales to finance projects that are inefficient, hence, would not be financed under traditional equity financing. This yields some straightforward implications for regulatory policies. We then show more nuanced results when the investors comprise heterogeneous groups.

Second, we enrich our base model to incorporate the token issuer's post-ICO investment incentives. The main argument is that if token issuers are only left with a small fraction of tokens post ICO, then the issuer's incentive to invest in the project would be greatly diminished, because the issuer's gain from liquidating the tokens is relatively small. We explain the recent ICO market using the classical concept of time inconsistency (e.g., Kydland and Prescott, 1977; Barro and Gordon, 1983), where the ICO investors' belief on the level of subsequent investment can be naively formed, rather than perfectly consistent with the issuer's behavior. The issuer then chooses a level of investment post ICO that would deviate from the naive investor's expectation, which leads to failed ICO projects.

More recently, there are a growing number of ICOs, offering a much smaller fraction of total token supply, compared to the cases in the past. This may be due to the issuer's self-regulatory attempt facing the threat of regulations, but it may be also because ICO investors now understand better the issuer's incentive problem. If indeed the investors have rational expectation, then the issuer sells a smaller fraction of token supply and also the equilibrium

[3]There are exceptional cases: A company can raise the bulk of its equity through an IPO via so-called "special purpose acquisition company", and also a company need not raise any capital from the public via direct listing (e.g., Spotify's 2018 IPO).

level of investment increases. Nonetheless, our model indicates that the equilibrium level of investment still falls short of the socially optimal level. We are thus lead to consider a regulatory scheme for setting a floor on the size of the issuer's post-ICO token holdings and show that it can sometimes increase social welfare.

This paper aims to contribute to the nascent literature on ICOs in the broader cryptocurrency market.[4] Economists have initially emphasized the role of tokens as a commitment device in solving the coordination problem in a network or platform market (e.g., Bakos and Halaburda, 2018; Cong et al., 2018; Li and Mann, 2018). The difference is that these papers analyze the network or platform market that has already been successfully developed and is susceptible to the coordination problems, while our model examines the formative stage of a project/platform in the spirit of venture financing and takes into account the issuer's investment incentives and the trading activities before and after the ICO.

The paper we found closest to ours includes Canidio (2018), where an entrepreneur exerts efforts and makes an investment in multiple periods. Canidio finds that the entrepreneur either sells the entire stock of tokens in an ICO or does not sell at all, and holds an ICO just prior to launching the platform. Thus, an overinvestment can occur in Canidio's model. While our model shares some similar features, our model introduces the possibility that the investor may hold naive expectation that the issuer can exploit. Further, we model a continuous fraction of tokens offered in the ICO and derive the market-clearing price in the secondary market, while Canidio parameterizes the demand for the tokens post ICO.

Another closely related paper is Davydiuk et al. (2019), where the entrepreneur's type is signaled via the amount of tokens retained in an ICO. A separating equilibrium results because it may be less costly for high-quality entrepreneurs to retain tokens. They also provide empirical evidence, based on a comprehensive ICO sample during 2016–2018, that ICOs that retain a larger fraction of tokens are for instance more likely to develop a product/platform.

[4] Our model assumes premined tokens (e.g., ERC-20) that are directly created by and assigned to the issuer, so we do not attempt to summarize here the broader literature on blockchain and node maintenance. For this, see, e.g., Athey et al. (2016), Huberman et al. (2017), and Cong and He (2019).

Our analysis can thus be viewed as providing a complementary theory/logic that leads to a similar conclusion. We also note that Prat et al. (2019) examines the token price based on the cash-in-advance theory and endogenizes the mass of token supply.

Another related stream of research focuses on the comparison between token financing and other traditional methods of financing. For instance, Chod and Lyandres (2018) explains that token sales lead to underproduction but ICOs may dominate equity financing when entrepreneurial effort is crucial, because token financing alleviates the moral hazard problem. Catalini and Gans (2018) shows that by revealing consumer valuation, ICOs may increase entrepreneurial returns beyond what can be achieved by equity financing, as long as the issuer can credibly commit to the original supply schedule, and also highlight a hybrid contract where both token and equity financing are used.

Garratt and van Oordt (2019) considers a model in which an entrepreneur can exert effort at a personal cost to reduce the per-period cost of operating the platform. They show the different incentives under debt, equity and token financing and also compare the net present values under the respective financing schemes, which depends on the margin the platform charges. Their main focus is on the possibility that the entrepreneur can choose to not honor the initial promise to accept the tokens as the sole means of transaction on the platform, which is different from ours where the entrepreneur's moral hazard problem arises in terms of the capital outlays from the ICO funds.

Finally, there is a growing number of empirical studies on ICOs (e.g., Amsden and Schweizer, 2018; Howell et al., 2018; Blaseg, 2018; Deng et al., 2019). Each paper uses different sets of variables, so a direct comparison across them is difficult. However, as far as the percentage of tokens sold in ICOs is concerned, Amsden and Schweizer and Deng et al. find that a higher percentage is negatively associated with post-ICO trading and development activities (on Github). Blaseg reports that the fraction of tokens sold is not significantly correlated with exchange listing; and Howell et al. finds that the fraction sold is not significantly correlated with employment proxy (on LinkedIn).[5]

2 Why Use Token Financing

2.1 Model

There are a continuum of homogeneous individuals of measure one and a penniless entrepreneur who has a project idea that requires a funding of size f to implement. In this section, we take f as given and hold it constant. If implemented, the project yields a consumption utility of $u(x)$, where $x \in [0, 1]$ normalizes the maximum individual demand to unity. We thus assume that the goods and services provided by the project are a continuous choice variable and also $u(x)$ satisfies $u(0) = 0$, $u'(x) > 0$, $u''(x) < 0$, so there is a diminishing marginal utility, and $\lim_{x\to 0} u'(x) = \infty$ to avoid the uninteresting corner solution at $x = 0$.

There are two stages of the model. In the first stage, the entrepreneur seeks funding, and there are two types of financing methods available to the entrepreneur—equity sales and token sales, which we explain below. In the second stage, she provides the goods and services at a price (in fiat currency) or in exchange for the tokens issued, respectively. Specifically, we assume that under equity financing, the firm sets the price to maximize the profit; and under token financing, one unit of token entitles the holder of the token one unit of the goods and services without a further price charge.[6] There is no variable cost of production.

First, under the equity financing model, there is a single decision-maker (i.e., Venture Capitalist) who manages a fund in which the unit measure of individuals invest their money. This can be due to a lack of deal flows available for individual investors in the absence of a decentralized form of financing. The venture capitalist is profit driven and its fund has

[5]Thus, our results are more in line with the former findings in that the issuer sells a smaller fraction of token supply in an ICO and increases the level of investment (hence, the likelihood of success) when the investors in the ICO market hold rational, rather than naive, expectation.

[6]This captures the idea that blockchain-powered (decentralized) platforms do not sell goods and services for a profit, whereas venture-financed (centralized) platforms do. In token-financed platforms, developers can retain and sell tokens for a profit (which we deal with in the next section).

an outside option of a zero economic return. We assume that the fund's equity share of the startup is determined as the ratio of f to the maximum startup equity value, which equals the maximum profit in our static model. This assumption would hold, for instance, if the entrepreneur minimizes equity dilution when negotiating the financing terms.

Second, under the token financing model (ICO), the individuals are investors as well as consumers. The entrepreneur creates a token supply, which we normalize to one, so the measures of individuals and tokens are isomorphic. The individuals are then given an opportunity to invest up to f in exchange for the token supply, which means that each individual is given an opportunity to buy an arbitrarily small, one unit of a token at a price that sets the token capitalization at ICO equal to f. If the token sales fall short of f, then the fund is returned to the investors. Also, for simplicity, we ignore the effect of any transaction costs in transferring investment funds.

A crucial difference between the two methods of financing is the liquidity provision through a secondary market trading. In the former, private equity investments are mostly illiquid at least in the short run without incurring some significant costs; hence, we assume that trading or a partial liquidation is not possible for the venture capitalist in the second stage. In the latter, tokens (especially those implemented on existing blockchains) are often listed and traded on crypto exchanges relatively shortly after the initial token sale; therefore, we assume that the ICO investors can sell any fraction of their token holdings in the second stage at an exogenous token price p.

We will endogenize the token price in the next section; however, in the short run, the token price can depend on the sentiment in the broader cryptocurrency market. Thus, one can think of this section as capturing the behavior of investors in a relatively short window after the token sale, where the token price can diverge from any theoretical value. We also abstract from having an infinite time horizon because it is the investment of the ICO investors that matters for the project financing, rather than the subsequent trading in the secondary market. That is, the (unmodeled) profit/loss of the traders from buying and selling tokens since ICO does not directly affect the project financing.

2.2 Analysis

First, let us consider the equity financing. If the VC fund manager invests f, then the startup can maximize the profit in the second stage by charging a two-part tariff, $a + bx$, for the individual consumption quantity $x \in [0, 1]$. Each consumer would then maximize an objective function $u(x) - a - bx$ given an outside option value of zero. It follows that the startup maximizes its profit by setting $a = u(1)$ and $b = 0$. That is, each individual pays a fixed price that extracts all their surplus and consumes the maximal amount ($x^* = 1$) in equilibrium; and the firm makes a profit of $u(1)$ from the unit measure of consumers. The fund manager's first-stage decision rule is straightforward: VC will invest f if and only if $f \leq u(1)$.

This decision rule coincides with the socially efficient decision rule as long as the social planner puts an equal weight on consumer surplus and firm profit. To see this, notice that the consumer surplus is zero and the firm profit is given by $\max\{0, u(1) - f\}$ in equilibrium. The fund manager's first-stage decision rule is socially efficient because only those projects that yield a gross utility greater than the investment cost, f, will be financed. Hence, the government cannot improve upon the equilibrium outcome by imposing a constraint on the VC fund manager's behavior. Notice that a complete surplus extraction from homogeneous consumers by a monopolist via a two-part tariff is efficient, solely based on the producer's surplus.

Second, consider the token financing. If the investors collectively invest f, then they will receive the unit supply of tokens, which can be used to purchase one unit of the goods for each individual. However, any fraction of the token can be sold at a price of p in the secondary market. Hence, each individual maximizes $u(x) + p(1 - x)$ in the second stage. For any positive token price $p > 0$, there is a unique interior equilibrium $x^* \in (0, 1)$ such that the initial token holder spends x^* in exchange for the goods and sells $1 - x^*$ tokens in exchange for money. The trading opportunity strictly increases the initial investor's indirect utility, compared to the one without the opportunity (see Figure 1).

Therefore, the unit measure of identical investors are willing to buy the tokens as long as the token capitalization, f, is less than $u(x^*) + p(1 - x^*)$.[7] This implies that a socially inefficient project (e.g., f' in Figure 1) as well as an efficient project (e.g., f in Figure 1) can be financed by ICOs. The social planner, concerned with the social welfare, can then consider the following regulation: The government bans the token trading post ICO at least for a sufficiently long time.[8] This policy will basically restore the equilibrium to the outcome under equity financing, where the main difference is that even without an intermediary, the individuals would only purchase ICO tokens if and only if $f \leq u(1)$.

Proposition 1. Assume as a tie-breaker that entrepreneurs prefer to do the project than not do so when indifferent. Entrepreneurs with an efficient project prefer equity financing to token sales, and entrepreneurs with an inefficient project prefer token financing. Banning secondary market trading can be efficiency-enhancing.

A less restrictive policy is to allow secondary market trading only if the token price p is sufficiently low. Note that for any project with f', where $f' > u(1)$, there is a threshold value $\bar{p} > 0$ such that the investors will not purchase the ICO tokens if $p < \bar{p}$. Equivalently, the regulator may allow trading if the utility derived from the usage of the token, relative to that of the trading, is sufficiently high. This is because there is an inverse relationship between p and $u(x^*)$ given a concave utility function. Thus, a threshold value $\bar{u} > 0$ exists, where $\bar{u} < u(1)$, such that the ICO investors will not fund a socially inefficient project if the consumption utility is sufficiently high, $u(x^*) > \bar{u}$.

The latter can shed light on the policy debate on 'security' versus 'utility' tokens. Our

[7]Since there is a continuum of investors, however, there is always another equilibrium where no investor invests because each individual thinks that no one else will participate in the ICO. We abstract from such equilibrium because any ICO can fail for this reason.

[8]This may be achieved by regulating decentralized crypto exchanges (e.g. Uniswap), where any issuer can list their tokens by providing a liquidity pool, whereas centralized exchanges (e.g., Coinbase) take much longer to list tokens that pass a due diligence process.

simple model illustrates that the dichotomy is not well defined, when the tokens are divisible and tradable, because the investors can always choose to spend some of their token holdings for goods and others for trading. However, our model suggests that if the utility from token usage falls below a certain level, then the token price would be high enough to finance some projects that should not have been financed from the social planner's standpoint. This inefficiency can be seen by assuming an arbitrarily high post-ICO token price p, which yields an indirect utility greater than any finite $f > 0$.[9]

2.3 Heterogeneity

In the above, we assumed a homogeneous population. Here, we relax this assumption by considering two groups of individuals with different subjective beliefs about the project's utility. Specifically, in the first stage, a measure 1/2 of individuals ('optimists') think that the utility function will be $u_H(x)$, while the other measure 1/2 of individuals ('pessimists') think that it will be $u_L(x)$, where $u_L(x) < u_H(x)$ for all $x \in [0, 1]$, $u_i(0) = 0$, $u_i'(x) > 0$, $u_i''(x) < 0$, and $\lim_{x \to 0} u_i'(x) = \infty$ for $i = L, H$. Everything else remains the same as in the base model. In particular, under token financing, the unit measure of individuals are offered an opportunity to purchase the unit supply of tokens at the same nondiscriminatory price and quantity, having capitalization f.[10]

Under equity financing, we assume that (through an unmodeled process) the two groups of individuals are represented by two different VC fund managers who share their group's subjective beliefs; hence, the two managers 'agree to disagree' in the first stage. We also assume that each fund manager is unable or unwilling to invest f all alone, but instead they must make investment decisions jointly. (Equal sized investments are not necessary for our results, because $u_L(x)$ and $u_H(x)$ are freely chosen, but it helps simplify our exposition.)

[9] After a successful ICO and the listing of the digital token on various exchanges, the token price can overshoot its fundamental value at least in the short to medium run, driven by speculators as well as the so-called ICO pumpers who manipulate crypto market prices (e.g., Baydakova, 2019).

[10] Price discrimination over individual investors is not common in blockchain communities. For instance, Buterin (2017) said "If an ICO does volume bonuses ("buy at least \$50000 of coins, get 20% more") then they do not understand the first thing about the egalitarian spirit of crypto."

Thus, the entrepreneur now needs to obtain both fund managers' agreement in order to start her project under equity financing. There are three cases to consider: (i) $f > u_H(1)$; (ii) $u_L(1) < f < u_H(1)$; and (iii) $f < u_L(1)$.

Case (i): Under equity financing, both fund managers will decline to invest because they think that the startup will not generate a consumption utility higher than f given their respective belief. Under token financing, however, it is possible that individuals in both groups may agree to purchase the tokens sold at the capitalization f, if the second-stage token price, p, is sufficiently high. To be precise, p has to satisfy $u_L(x_L^*) + p(1 - x_L^*) > f$ for individuals in the pessimistic group to purchase the ICO tokens. Hence, inefficient projects can be still financed, but a smaller range of them are financed compared to the scenario where all individuals are optimistic.

Regulatory implications are similar to those discussed in the previous subsection: If the government bans secondary-market trading, then none of the projects from this case would be financed. In terms of the token price-based regulation, the threshold token price below which trading activity can be allowed without financing any given inefficient project now increases. This is because individuals in the pessimistic group believe that their payoff would be strictly negative given a price, p, at which individuals in the optimistic group are indifferent. Thus, the second-stage token price, p, would have to be sufficiently high in order for the pessimists to invest.

Case (ii): Under equity financing, the fund manager holding the optimistic belief will finance his share of the investment, but the pessimistic fund manager will not, given their respective beliefs about the project's utility. Thus, the project will not be financed. The ex-ante efficiency implication of this outcome is however slightly more nuanced because, while individuals hold different subjective beliefs regarding the utility of the project, the social planner may put an weight on both of them. For instance, if the social planner maximizes $u_H(1)/2 + u_L(1)/2 - f$, then the social surplus of a project could be ex ante positive if f is closer to $u_L(1)$ than to $u_H(1)$ but it could be negative if the opposite holds true.

Under token financing, a project from this case can be potentially funded. For the optimistic group, the token is undervalued relative to $u_H(1)$, so they are willing to participate regardless of the second-stage token price p. For the pessimistic group, the gross utility can be made higher than f if the second-stage token price is above a certain value. Hence, an efficiency-enhancing policy is contingent on whether the project's social surplus is positive or negative. If it is positive, then the token sales can fund an efficient project that would not be financed under equity financing, so the trading market should not be shut down. If it is negative, then the similar regulatory implication as above would hold.

Proposition 2. Suppose some of the ICO investors become more pessimistic than others regarding the project's utility. Then it becomes less likely that the token sales will finance an inefficient project. There exists a range of ex-ante efficient projects that can be financed under token financing but not under equity financing.

3 Ex-post Investment Incentives

3.1 Enriched Model

In the previous section, we showed how token sales may finance (in)efficient projects and how a regulatory policy on secondary-market trading may change the results. In this section, we extend the baseline model in two ways. First, we allow the entrepreneur (i.e., token issuer) to hold a certain fraction of the token supply and liquidate them in the secondary market for a profit. Second, and more important, we endogenize the size of project investment and show that the issuer's incentive could constrain the investment far below the fund size. This reflects the fact that ICO projects do not often have a strong enough governance to ensure that the entire funds raised are spent on developing the project.

There are a continuum of investors (cum users) who arrive in two waves. Specifically, the first wave of investors arrives when the entrepreneur issues and sells the tokens in the initial offering. Later on, when the token gets listed on an exchange, a second wave of investors arrives, and the first wave of investors as well as the token issuer can sell their token holdings to the second wave of investors. As before, it suffices for this paper's purpose to focus on the trading activity involving the initial tokenholders, so we do not model the repeated nature of the trading. Instead, we close the model by assuming that both sets of investors spend their token holdings in the last period in exchange for the goods.

After the initial token sales but before the exchange listing, the entrepreneur can invest a certain amount out of the funds into developing the project. Importantly, the entrepreneur need not invest the entire funds raised, but she can invest any amount less than or equal to the funds. This captures the entrepreneur's moral hazard and is due to the lack of governance mechanism for most ICO-funded projects. This includes a broader set than outright fraud cases because even if the entrepreneur has no intention of deceiving any investor, she can still decide on the capital outlay in a self-interested manner, as long as the ICO governance rules do not restrict the entrepreneur's access to the ICO funds.[11]

Let us now introduce some notations and assumptions. We normalize the size of each wave of investors to one. In general, the size of the first and the second wave of investors can differ; in fact, keeping the group sizes equal to each other is not necessary for our qualitative results, but doing so would make our exposition much more straightforward. We normalize the total supply of tokens to one, which are continuously divisible. As in the previous section, all tokens are premined on an existing blockchain, so we abstract from mining rewards. In the ICO stage, the token issuer can keep a fraction $y < 1$ of the token supply and offer to sell the complementary fraction $1 - y$ to the first set of investors.

Since investors are atomless, we focus on symmetric equilibrium in which each investor belonging to the same wave chooses the same pure strategy and derives the same utility of $u(x)$ from spending tokens, x, if the project is successful. Further, we keep the two groups'

[11] According to the data compiled by Deng et al. (2019), only 28 percent of all ICOs conducted up to mid-2018 mentions an escrow or custodian account and 30 percent stipulate voting rights of tokenholders; and the aggregate governance index is also generally low.

preferences identical, to illustrate the main mechanism without confounding it with heterogeneous preferences, but doing so is not essential for the qualitative results. In addition, the project succeeds with a probability $\theta(f) \in [0, 1]$, where f is the issuer's investment, $\theta(0) = 0$, $\theta'(f) > 0$, $\theta''(f) < 0$, and $\lim_{f \to 0} \theta'(f) = \infty$.[12] $u(x)$ also satisfies the same curvature conditions as before. As is standard, all investors as well as the token issuer are assumed to be risk neutral.

The timing of the game is as follows. First, the issuer decides on the fraction, y, of tokens to withhold given an initial capitalization. Second, the issuer offers the first-wave investors an equal amount of the tokens, and the investors simultaneously decide whether to buy the tokens. Third, the issuer decides how much to invest, f, not exceeding the funds raised from the token sales. Fourth, the second wave of the investors arrives and the trading market opens. The first wave of investors can sell any fraction of their initial token holdings (however, we do not allow for short selling); and the issuer liquidates all her set-aside tokens. Fifth, if the project succeeds, then all token holders spend their tokens to gain utility from the goods.

3.2 Naive Expectation

Our solution concept is the Subgame Perfect Nash Equilibrium with the additional requirement that the secondary trading market clears. Since the time horizon is finite, we can solve for the equilibrium by using the one-deviation property, whereby players cannot be made better off after any history by choosing an action that differs only in that period. We first show what happens in equilibrium when investors do not realize that the ICO projects have weak governance; that is, investors naively believe that the entire funds will be spent on developing the project. This may capture the state of affairs at the beginning of the ICO boom (e.g., starting around from mid-2017).

[12] The success probability, $\theta(f)$, can exhibit an increasing return to scale as f increases from zero and then become concave in f after some inflection point. This would not affect the solution as long as the optimal investment occurs in the range where $\theta(f)$ is concave in f.

In the second to last period, suppose that the initial offering size, $1-y$, and the issuer's investment size, f, are given. Since investors are identical, if the first-wave investors demand x_1 tokens for consumption in the last period, then they will supply $1-y-x_1$ tokens to the secondary market if $1-y > x_1$, or they will purchase additional $x_1-(1-y)$ tokens from the market if $1-y < x_1$. To be more specific, each individual's preference is represented by the sum of consumption utility and trading profit: $\theta(f)u(x_1)+p(1-y-x_1)$, where p is the token price (in units of the numeraire good). Each investor takes the token price, p, as given because an individual demand is a measure zero.

The second wave of investors does not have any token holding, because they just arrived at the market. Thus, if each of them demands x_2 tokens for consumption, then their preference is represented by $\theta(f)u(x_2)-px_2$. On the other hand, the token issuer liquidates her entire set-aside tokens, y, in the secondary market. Doing so is optimal and without loss because, even if the entrepreneur derives utility from spending the tokens, she can satisfy her individual consumption demand by purchasing ICO tokens as one of the first-wave investors. But for the set-aside token holding y, liquidating it for a profit py is the optimal solution because an individual cannot consume it all.

Since all investors have the same utility function, the unique interior solution (x_1^*, x_2^*) can be characterized by the usual first-order conditions: $\theta(f)u'(x_1^*)=p$ and $\theta(f)u'(x_2^*)=p$ for any given investment f and token price p. Hence, the consumption demands for tokens are the same across the two groups; however, since the first wave of investors holds $1-y$ tokens, the aggregate excess demand for tokens is $x_1^*+x_2^*-(1-y)$. Given that the issuer's supply of tokens is y, the market clearing condition requires $x_1^*+x_2^*=1$. Since the investors have identical preferences, it follows that $x_1^*=x_2^*=1/2$, and the market clearing token price is given by $p^*=\theta(f)u'(1/2)$ for an arbitrary f.

Moving to the investment stage, the issuer decides how much to invest, f, out of the ICO funds, knowing that the token price in the next stage would be p^*. Suppose that the issuer sold $1-y$ tokens in an ICO with a token capitalization φ. Then, the issuer maximizes $\varphi(1-y) - f + p^*y$ subject to the constraint $f \leq \varphi(1-y)$. The optimal solution to this problem, f^*, is implicitly characterized by $\theta'(f^*)u'(1/2)y = 1$ when the constraint $f \leq \varphi(1-y)$ is non-binding, and $f^* = \varphi(1-y)$ when the constraint is binding (and thus $\theta'(f^*)u'(1/2)y > 1$). In the former, it can be readily shown that $\partial f^*/\partial y > 0$; and in the latter, it is clearly $\partial f^*/\partial y < 0$ (as long as $\varphi > 0$). Therefore, the optimal level of investment, f^*, for the issuer is a nonlinear function of the issuer's retention of tokens, y, holding an initial token capitalization, φ, constant.

This is illustrated in Figure 2. The optimal investment is implicitly defined by $\theta'(f^*)u'(1/2)y = 1$, which is the line connecting the origin to B and C, when the issuer's budget constraint is non-binding or just binding. When the constraint starts binding, the optimal investment decreases from C to zero as the share y reaches 1. Thus, the maximum incentive-compatible investment occurs at a point labelled as C, where the constraint is just binding. If, however, y were less than $\widehat{y}$, then it is clear that the issuer invests less than the funds raised. This ex-post investment incentive may well diverge from the ICO investor's expectation on the level of investment. As long as the issuer has access to the ICO funds and freely determines its capital outlay, the funds raised will not be entirely spent on project development unless y exceeds a certain threshold value, $\widehat{y}$.

Now, consider the stage in which the first wave of investors decides whether to buy the tokens, when the issuer offers to sell $1 - y$ tokens at an implied token capitalization of φ. Assuming that the investor's outside option value is normalized to zero, each investor will participate in the ICO if and only if the utility from investing is nonnegative, that is, $\theta(f^e)u(x_1^*) + p^*(1 - y - x_1^*) - \varphi(1-y) \geq 0$, where $x_1^* = 1/2$ and $p^* = \theta(f^e)u'(1/2)$ on the equilibrium path. The probability of success, $\theta(f^e)$, depends on the investor's expectation on the issuer's subsequent investment, which we denote as f^e. The reason why we consider the case that the investor's expectation may diverge from the ex-post optimal investment level is that the ICO market has seen a large number of unsuccessful projects and sometimes a lack of development activities.[13]

To see this, suppose that the issuer offers to sell $1 - y^\circ$ tokens at a valuation of φ (see Figure 2). If the ICO investors naively believe that the issuer will invest the entire funds raised, $\varphi(1-y^\circ)$, into project development, then $f^e = f^\circ$, as indicated by point A. However, post ICO, the issuer will invest strictly less than the funds raised, as indicated by point B. Since the secondary market price is $p^* = \theta(f)u'(1/2)$, this means that while the ICO investors initially think that they can sell their token holdings at a high price (given $f^e = f^\circ > f^*$), the token price will be considerably lower than their expectation, as indicated by the gap between points A and B in the figure. Holding the initial capitalization, φ, constant, the gap is larger the more tokens, $1 - y$, the issuer sells; and similarly, the gap is larger the higher the initial token capitalization is.

Proposition 3. Suppose the first-wave investors have naive expectation. Then there is a value $\varphi' > 0$, such that if $\varphi \leq \varphi'$, then the issuer retains a fraction y^*, $y^* \geq \widehat{y}$, of the token supply; and if $\varphi > \varphi'$, then the issuer does not retain any token ($y^* = 0$).

Proposition 3 tells us that when the initial token capitalization is low at ICO, the issuer would sell a relatively small fraction of the token supply and invest the entire funds raised, as the naive investors believe. However, if the ICO token capitalization increases, then the issuer switches to selling the entire token supply at the ICO and retains no token, because it is now more profitable for the issuer to 'cheat' the ICO investors who have a naive expectation. That is, by not making any investment post ICO, the issuer knows that the secondary-market token price will collapse. In the real world, the issuer may nonetheless retain a small fraction of tokens and also may not siphon off the entire funds raised, because doing so runs a risk of getting caught early, so the real-world cases may not be as stark as the above proposition.

However, the result seems to be consistent with the early boom in the ICO market, where a large number of ICO projects raised a substantial amount of funds and then failed

[13] There are certainly a number of ICO projects that are successfully developing (e.g., Cardano, Chainlink, Polkadot among the top 10 list, as of January 2021). At the same time, some of the bigging ICOs have lost most of its token value (e.g., Dragon Coin, Sirin Labs).

to provide the goods and services thus far. In some occasions, it is said that the issuer sold 80 to 90 (even over 90) percent of the token supply in the ICO, and rarely those failed projects refunded any money to the investors, implying that at least some of the funds was misappropriated. Obviously, the naive expectation may not last too long as it relies on the investors being consistently fooled into thinking that the issuer will invest the entire funds raised. Rather, it is reasonable to expect that the ICO investors will come to senses over time, so that they realize the issuer's ex-post investment incentive as discussed above.

3.3 Rational Expectation

Suppose that the investors have rational expectation on the level of subsequent investment, f^e. Then, it is easy to see that the investors will not buy the ICO tokens when the issuer offers to sell the entire (or sufficiently large) token supply, because they realize the project investment will be zero (or sufficiently small) and so will be the secondary-market token price. Therefore, the initial investors will not participate in the ICO at any given capitalization if the issuer offers to sell a very large fraction of token supply. This drop in the ICO investor's utility for all $y \in [0, \hat{y}]$ constrains the issuer's choice of y^*. Specifically, $y^* = 0$ is no longer feasible, so the issuer has to withhold an $y^* > 0$.

However, the equilibrium retention size (y^*) under rational expectation need not in general be greater than $\hat{y}$. This means that, in equilibrium, the issuer may still not spend the entire funds raised into the project development. The intuitive reason is that the investor's outside option value is zero, so the issuer need not commit to spend the entire funds, but she can keep y^* as close as possible to zero because doing so can yield a higher profit. On the other hand, if the drop in the investor's utility is sufficiently large, then it is possible for the issuer to choose a $y^* \geq \widehat{y}$ because it is better to invest more, increase the secondary-market price, and liquidate her token holding later.

It turns out that the equilibrium investment level falls short of the socially efficient (first-best) level for all values of $y \in [0, 1]$, because the issuer's ex-post investment incentive limits the amount of funds the issuer is willing to spend. In Figure 2, f° could represent the first-best solution, which is not incentive compatible. Thus, the constrained efficient level of investment occurs at the point C. Although imposing a floor on investment can achieve this constrained optimum, such regulation is not often used. Instead, putting a floor on the issuer's retention of the ICO tokens can be more easily verifiable and thus implemented both by government and self-regulation.

Specifically, requiring $\underline{y} = \widehat{y}$ as the minimum can be an effective policy because the issuer will then choose to retain exactly $\widehat{y}$, when it would have chosen to retain as small a fraction of tokens as possible below $\widehat{y}$, that satisfies the investor's participation constraint. On the other hand, it is possible that the issuer, in response to the floor, may choose a y^*, $y^* > \widehat{y}$, in which case whether the investment level would increase due to the floor regulation is ambiguous. As we have previously shown, however, the latter case arises when the initial token capitalization, φ, is sufficiently low. Therefore, the floor regulation is more likely to be welfare-enhancing when φ is sufficiently high.

Proposition 4. Assume that a social planner can impose a floor, $\underline{y}$, on the issuer's retention of token supply. The constrained efficient optimum can sometimes be achieved by setting $\underline{y} = \widehat{y}$. The floor $\underline{y}$ is increasing in ICO token capitalization φ.

4 Conclusion

We presented a simple model of token financing. We showed how token financing might emerge as an alternative to equity financing, where the tokens can be subsequently traded. Our basic finding is that token financing is prone to finance inefficient projects, but in some cases it allows for an efficient project to get funded which would not be funded by equity funds. We also discussed how an outright ban on secondary-market trading and perhaps a more elaborate price-based regulation can help with eliminating some inefficient token financing.

We then considered the token issuer's ex-post investment incentive, to explain the recent ICO market experience. That is, if our assumption that the ICO investors in the recent past had naive expectation is valid, then there is a clear possibility for the issuer's moral hazard problem. The level of investment in the project may significantly fall short of the ICO fund size if the investors had a sufficiently high expectation on capital outlays such as the level of investment that would maximize the social surplus. Accordingly, the project's success probability as well as the token price collapses post ICO, which seems to be consistent with some anecdotal ICO cases.

On the other hand, as investors realize the naive expectation, it is plausible that the ICO market could somewhat improve in terms of efficiency, increasing the actual investment and reducing the size of token offering, because investors will not participate in ICOs in which the issuer retains a sufficiently small fraction of tokens. However, there is still a room for a regulation such as a floor on the issuer's token holding post ICO to increase social welfare, even if ICO investors have rational expectation.

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Proof of Proposition 1. Under equity financing, the firm's profit is $u(1)$ if $f \leq u(1)$, and zero otherwise. If the VC fund manager invests, then the VC's equity share is $f/u(1)$. Thus, the entrepreneur's payoff is $[1-(f/u(1))]u(1) = u(1)-f > 0$ if $f < u(1)$, and zero otherwise.

Under token financing, the firm earns a zero profit regardless of whether the project is funded or not. Therefore, the entrepreneur strictly prefers equity financing if $f < u(1)$ and, given the tie-breaking condition, she weakly prefers token financing if $f \geq u(1)$. ■

Proof of Proposition 2. We only need to discuss the omitted case (iii). Under equity financing, both fund managers will invest their share of the investment given their respective belief about the utility of the project. Under token financing, individuals in both groups believe that the gross utility will be strictly larger than f, regardless of the second-stage token price p. Hence, projects in this parameter range are always funded under either financing method, and they are also efficient. Hence, banning secondary-market trading as well as any token price-based regulation on trading has no effect on the equilibrium outcome. ■

Proof of Proposition 3. Let $\widehat{y}$ denotes the point at which the issuer's budget constraint, $f = \varphi(1-y)$, and the ex-post incentive compatibility constraint, $\theta'(f)u'(1/2)y = 1$, intersect, so $\widehat{y}$ is defined by $\theta'(\varphi(1-\widehat{y}))u'(1/2)\widehat{y} = 1$. As shown in the text, $\widehat{y}$ is unique and $\widehat{y} \in (0, 1)$.

First, suppose the issuer chooses y from $[\widehat{y}, 1]$. Then, she solves the following problem:

$$\max_{y} \ \varphi(1-y) - f + \theta(f)u'(1/2)y \quad \text{s.t.} \quad f = \varphi(1-y).$$

By substitution, the problem reduces to maximizing $\theta(\varphi(1-y))u'(1/2)y$. The first-order derivative is

$$-\theta'(\varphi(1-y))u'(1/2)y\varphi + \theta(\varphi(1-y))u'(1/2),$$

and the second-order derivative satisfies

$$\theta''(\varphi(1-y))u'(1/2)y\varphi^2 - 2\theta'(\varphi(1-y))u'(1/2)\varphi < 0 \text{ for all } y,$$

because $\theta'(f) > 0$ and $\theta''(f) < 0$. Thus, the first-order condition is sufficient to solve for the optimal solution.

Evaluating the first-order derivative at $y = \widehat{y}$ and substituting in for $\theta'(\varphi(1-\widehat{y}))u'(1/2)\widehat{y} = 1$, we get $-\varphi+\theta(\varphi(1-\widehat{y}))u'(1/2) \leq 0$ for $y = \widehat{y}$ to be optimum because the objective function is concave in y. Thus, if $-\varphi+\theta(\varphi(1-\widehat{y}))u'(1/2) > 0$, then the optimal choice of y is strictly greater than $\widehat{y}$.

Second, suppose the issuer chooses y from $[0, \widehat{y}]$. Then, she solves the following problem:

$$\max_{y} \ \varphi(1-y) - f + \theta(f)u'(1/2)y \quad \text{s.t.} \quad \theta'(f)u'(1/2)y = 1.$$

Totally differentiating the constraint with y, we get $\theta''(f)(\partial f/\partial y)u'(1/2)y+\theta'(f)u'(1/2) = 0$. This implies $\partial f/\partial y > 0$ given the curvature properties of the $\theta(f)$ function. The first-order derivative is

$$-\varphi - f'(y) + \theta'(f(y))f'(y)u'(1/2)y + \theta(f(y))u'(1/2),$$

which reduces to

$$-\varphi + \theta(f(y))u'(1/2),$$

after substituting in for the incentive compatibility constraint, $\theta'(f)u'(1/2)y = 1$.

The second-order derivative is

$$\theta''(f(y))[f'(y)]^2u'(1/2)y + \theta'(f(y))f'(y)u'(1/2) + \theta'(f(y))f'(y)u'(1/2),$$

after the same substitution. This further reduces to

$$\theta'(f(y))f'(y)u'(1/2) > 0 \text{ for all } y,$$

after substituting in for the total differential, $\theta''(f)(\partial f/\partial y)u'(1/2)y + \theta'(f)u'(1/2) = 0$.

Thus, the objective function is convex in y. Evaluating the objective function at $y = 0$, we get φ; and evaluating it at $y = \widehat{y}$, we get $\theta(\varphi(1-\widehat{y}))u'(1/2)\widehat{y}$. It follows that the issuer optimally chooses $y = 0$ if $\varphi > \theta(\varphi(1-\widehat{y}))u'(1/2)\widehat{y}$, and $y = \widehat{y}$ otherwise.

Putting the solution in the two cases together, it follows that the global maximum over $y \in [0,1]$ occurs at a y^*, $y^* > \widehat{y}$, if $\varphi \leq \theta(\varphi(1-\widehat{y}))u'(1/2)\widehat{y}$; and $y^* = 0$ if $\varphi \geq \theta(\varphi(1-\widehat{y}))u'(1/2)$.

If φ is above $\theta(\varphi(1-\widehat{y}))u'(1/2)\widehat{y}$ but is arbitrarily close to it, then the profit at $y = 0$ is higher but arbitrarily close to the profit at $y = \widehat{y}$, but since $y^* > \widehat{y}$, the profit at $y = y^*$ is strictly larger. Hence, the optimum is at a $y = y^*$.

If φ is below $\theta(\varphi(1-\widehat{y}))u'(1/2)$ but is arbitrarily close to it, then y^* is arbitrarily close to $\widehat{y}$. Since φ, which is the profit at $y = 0$, is strictly greater than $\theta(\varphi(1-\widehat{y}))u'(1/2)\widehat{y}$, which is the profit at $y = \widehat{y}$, the optimum is at $y = 0$.

Since the profits at $y = 0$ and at $y = y^*$ are both increasing in φ by the envelope theorem, the intermediate value theorem implies that there exists a value, φ', below which the optimum occurs at a y^*, $y^* > \widehat{y}$ and above which the optimum occurs at $y^* = 0$.

The investor's participation constraint under naive expectation ($f^e = \varphi(1-y)$) is

$$\theta(\varphi(1-y))u(1/2) + \theta(\varphi(1-y))u'(1/2)(1/2-y) - \varphi(1-y) \geq 0,$$

where the first term is decreasing in y from $\theta(\varphi)u(1/2)$ to zero; the middle term is decreasing from $\theta(\varphi)u'(1/2)(1/2)$ to a negative value and then going back up to zero; and the last term is increasing in y from $-\varphi$ to zero.

Evaluating the investor's utility at $y = 0$, if $\theta(\varphi)[u(1/2) + u'(1/2)(1/2)] \geq \varphi$, then the investor's participation constraint is satisfied. Given the concavity of $u(x)$, $\theta(\varphi(1-\widehat{y}))u'(1/2) < \theta(\varphi)[u(1/2) + u'(1/2)(1/2)]$. Thus, $y^* = 0$ is a feasible equilibrium.

Evaluating the investor's utility at $y = \widehat{y}$, if $\theta(\varphi(1-\widehat{y}))[u(1/2) + u'(1/2)(1/2-\widehat{y})] \geq \varphi(1-\widehat{y})$, then $y^* \geq \widehat{y}$ is a feasible equilibrium. Similarly to the above, it can be shown that $\varphi \leq \theta(\varphi(1-\widehat{y}))u'(1/2)$ implies the above participation constraint. ■

Proof of Proposition 4. The aggregate surplus across the issuer and the two sets of investors is $\theta(f)[2u(1/2)] - f$. Thus, the unique solution that maximizes the joint surplus, which we denote as f°, is characterized by the first order condition, $\theta'(f^\circ)[2u(1/2)] = 1$. Since $2u(1/2) > u'(1/2)$ by concavity of u function, $1 = \theta'(f^\circ)[2u(1/2)] > \theta'(f^\circ)u'(1/2)$. Thus, the issuer's incentive constraint, $\theta'(f^\circ)u'(1/2)y = 1$, can only hold for $y > 1$. Thus, f° is greater than any incentive-compatible investment $f(y)$ within the range $y \in [0, 1]$, so the constrained social optimum is achieved at $y = \widehat{y}$. The rest follows from the text. ■

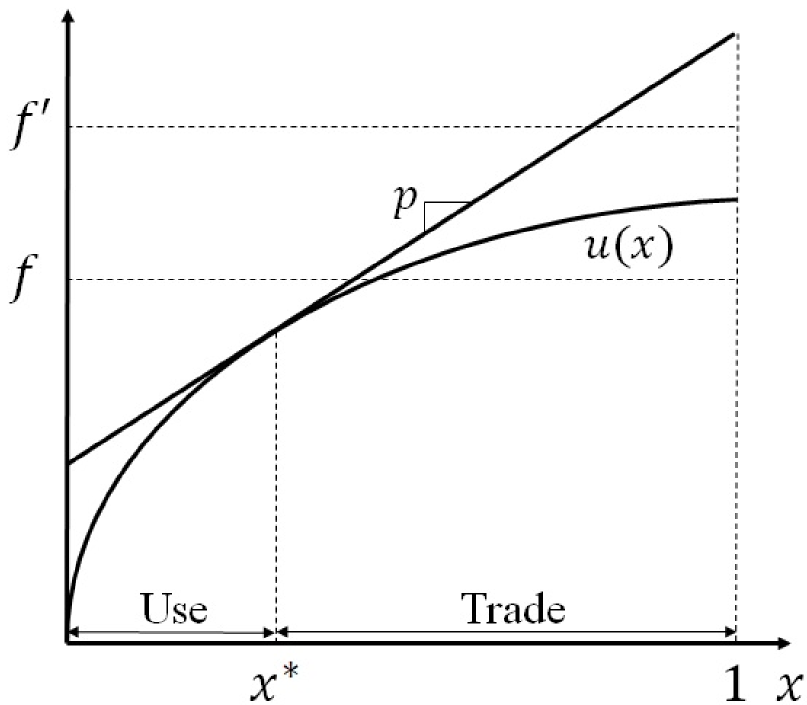

Figure 1: Optimal consumption of tokens.

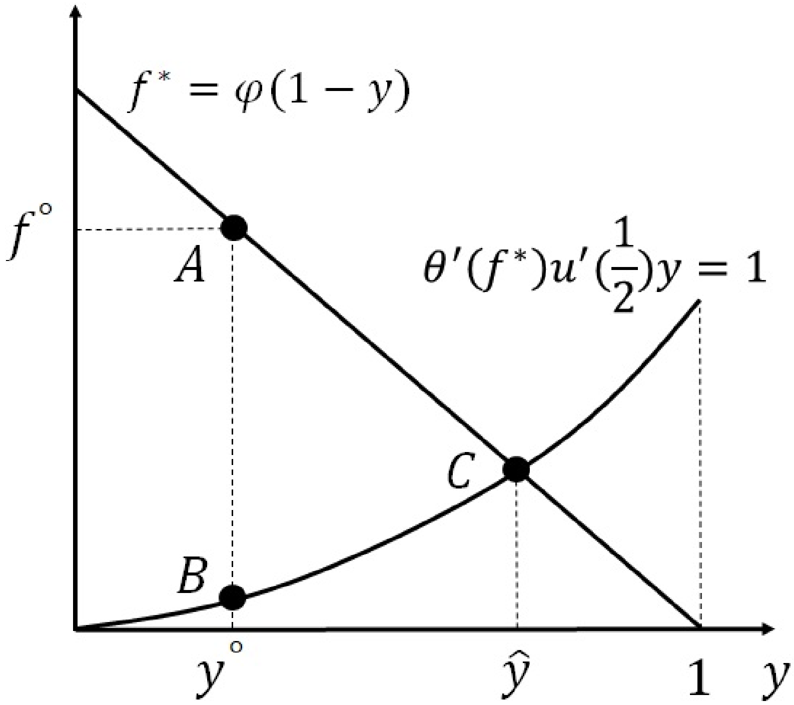

Figure 2: Optimal level of investment.