De-crypto-ing Signals in Initial Coin Offerings: Evidence of Rational Token Retention

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Abstract

We provide evidence that entrepreneurs use retention to signal their type to investors in the presence of asymmetric information using the market for initial coin offerings (ICOs) as a laboratory. Using a detailed dataset on 4,524 ICOs, we show that ICOs that retain a larger fraction of their tokens are more successful in their funding efforts. Token retention is positively correlated with ex-post measures of success. We develop a model of ICO markets with asymmetric information between informed entrepreneurs and uniformed investors. In equilibrium, high-type entrepreneurs use retention to signal their quality to investors. In line with model predictions, we find that when there is more noise in the market, the correlation between token retention and ICO quality increases.

Keywords: ICOs, digital assets, crypto, signaling, asymmetric information

JEL Classifications: D82, G32, L26

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1 Introduction

A key concept in economics is that in settings with asymmetric information, a privately informed seller may attempt to signal information about his quality to uninformed buyers. Although the theoretical literature on signaling is extremely prolific, there is relatively little empirical work on the phenomena. We provide evidence of signaling in the market for initial coin offerings (ICOs). In recent years, ICOs have emerged as a novel way of financing for young firms with over $26.8 billion raised in aggregate through June 30, 2018. However, this market remains largely unregulated and has been vulnerable to frauds and scams. We believe this combination of market liquidity and concerns about ICO quality, gives us an ideal setting to study signaling by firms in the presence of buyers who face asymmetric information about their type.

ICOs can be thought of as a hybrid form of crowd-funding. In simple terms, an ICO is the sale of digital assets, "tokens", by an entrepreneur or company to fund the creation of an online platform or ecosystem that uses blockchain technology.[1] In most cases, the token being sold can be used on the platform that the issuer is creating, making ICOs similar to crowd-funding. In this way, the company both raises funds and distributes assets that provide utility for users that wish to participate in its product ecosystem. Additionally, ICOs also have an equity aspect as the token associated with an ICO may rise or fall in value over time. This draws a parallel to IPOs even though tokens are not direct equity claims in the underlying venture. Similar to a VC-backed company, most ICO ventures are early-stage projects that can be years away from a functional product.[2] However, they may offer greater liquidity as investors can often trade their tokens before the platform is complete. Additionally, retail investors are able to directly participate in ICOs, which is not the case for VC investments.

A relatively unique downside to ICOs compared to other forms of financing is their vulnerability to fraud and scams. While it is true that similar problems can and do occur

[1] We will refer to the digital assets sold in an ICO as "tokens" and reserve the word "coins" only to refer to cryptocurrencies. We realize this may seem confusing given that the word "coin" is in the term ICO, but it is growing convention to refer to these digital assets in this way. In fact, some parties in the crypto industry are pushing to replace the term ICO with either "token sale" or "token generation event" (Token Alliance, 2018).

[2] *Ernst & Young (2017)* found that only 5% of ICOs had running projects, 11% had prototypes, and 84% were merely ideas. *EY (2017)* similarly find that, at the time of the ICO, the project is usually at the idea stage and the product is expected within one to two years thereafter.

with IPOs or VC projects, the presence of regulators and underwriters reduce such behavior. In the crypto space, accounts are anonymous and there are no central counterparties. The two most common ICO scams are "hit-and-run" and "pump-and-dump." In the former, the ICO team simply runs away with the money and does not follow through with the proposed project. In the latter, insiders inflate the price of a token through false statements or coordinated purchases.

Despite these challenges, the ICO market has grown rapidly. The number of ICOs increased from 54 in 2016 to over 1,604 in 2017 and 1,894 in the first half of 2018. To date, the ICO market has raised over $26.8 billion in total. The average ICO in our dataset raised $17.8 million and the largest ICO in history, EOS, raised over $4.2 billion (see Figure 3). For reference, however, ICOs are still relatively small compared to the 2017 global figures of $189 billion for IPOs (EY, 2018) and $155 for VC investments (KPMG, 2018). Nonetheless, this rapid growth in ICOs as a form of financing for companies make them an interesting market to study in and of themselves.

In our analysis, we exploit a feature of ICOs that they report the fraction of tokens insiders are retaining to potential investors. Leland and Pyle (1977) and Demarzo and Duffie (1999) show that costly retention can be used by sellers as a way of conveying information about the quality of an asset. Applying their results to our setting, it is less costly for ICO issuers with high-quality projects to retain a share of tokens because the value of their tokens is more likely to appreciate over time. Assuming issuers have superior information about their projects, those with higher-quality projects may choose to retain a larger fraction of their tokens to signal their quality to investors. In our data, we observe the fraction of tokens retained and therefore we can empirically test whether ICO issuers use this decision as means of signaling.

We believe the ICO market is an ideal laboratory to study if informed sellers use retention to signal their quality to uniformed buyers in the presence of information asymmetries. The challenge of early stage private ventures to secure financing due to asymmetric information is well known (Hall and Lerner, 2010). Moreover, the lack of regulation in this market and increased counterparty risk due to anonymity exacerbate problems of asymmetric information. The large amount of recent activity in the ICO market has allowed us to compile a dataset with over 4,524 distinct ICOs which includes data on the share of tokens retained by investors, which projects investors allocate funds to and ex-post measures of

performance. There is no public, comprehensive database available on ICOs so we create our dataset by manually aggregating information from a variety of websites which provide information about ICOs to the potential investors.

We begin our analysis with a stylized model of the ICO market. This model highlights the asymmetric information environment and formalizes the intuition for our empirical analysis. In the model, penniless entrepreneurs raise funds through an ICO from a large measure of deep-pocketed investors. There are gains from trade and, without information asymmetries, entrepreneurs choose to sell all tokens to investors. Entrepreneurs have private information about their type. A high-type entrepreneur has a greater probability of building a successful platform than a low-type entrepreneur. In the model equilibrium, high-type entrepreneurs choose to retain a larger fraction of tokens than low-type entrepreneurs to signal their quality and separate from low-type entrepreneurs. This outcome causes a negative correlation between the fraction of tokens sold to investors and the quality of the ICO. When noise in the market increases and the quality of information investors get through a public signal about ICOs decreases, this correlation becomes stronger and high-type firms retain a larger share of tokens on average.

To test whether our theoretical predictions are borne out in the data, we perform a number of tests. First, we examine whether ICOs that retain a greater fraction of tokens are more likely to fund raise successfully. When a firm announces its ICO, it usually states a "hard cap," which is the maximum amount of funds it wants to raise and is willing to accept. For each ICO in our dataset, we divide the funds they raised by this hard cap to get a continuous measure of ICO fundraising success. In line with retention as a means of signaling quality, we show that a 1 percentage point increase in the fraction of tokens sold to investors is associated with a decrease in fundraising success by 0.2-0.4 percentage points.

Second, we test if the relationship between token retention and fundraising success is stronger when the market is noisier. We measure noise in the market at the time an ICO is happening by the number of other ICOs that are happening in the same month. We show that this is highly correlated with high values of the Bitcoin-USD and Ethereum-USD exchange rates capturing a "bubble-like" market. We find that in accordance with our model predictions, the relationship between retention and fundraising success is stronger at times when many ICOs are taking place.

Third, we show that greater retention is related to better ex-post performance. In line

with Amsden and Schweizer (2018), we measure ICO success by future tradibility - if the token begins to trade on a reputable exchange following the ICO. The provision of ex-post liquidity to buyers is an important source of value and a key distinguishing feature of ICOs from venture and angel capital, the other prominent forms of early stage financing. However, only relatively successful ICOs list their token on an exchange. Exchanges engage in due diligence prior to accepting a token for listing to protect their reputation both with customers and regulators. Furthermore, the fees ICO have to pay to list on an exchange are very high and can range from $1 to $3 million.[3] We find that ICOs that retain more tokens are more likely to be listed on exchanges confirming. This effect holds even when we control for the funds raised by the ICO.

Related Literature: Our paper contributes to several strands of literature. First and foremost, our paper is an empirical application of a classic question in finance and economics regarding equity retention and signaling. Recent empirical work explores the role of signaling in other settings. Adelino et al. (2018) provide direct evidence of a signaling mechanism through trade delays in the residential mortgage market. Ahlers et al. (2015) study the effectiveness of signaling in the equity crowd-funding market. Schultz and Zaman (2001) study the information contained by retention and sales of insiders during the 1996-2000 dotcom boom. Going back further, Downes and Heinkel (1982) and Ritter (1984) study signaling through equity retention in the IPO market.

The theoretical literature has long established that an informed seller can use retention as a signal of quality. In their seminal paper, Leland and Pyle (1977) argue that financing a project with more debt (retaining more equity) provides a signal of high quality because debt is less costly to high-quality types. Other notable theoretical contributions include Demarzo and Duffie (1999) and Hartman-Glaser (2017).

Despite the recency of their rise, there is growing interest in what drives ICO success.[4] Broadly speaking, these papers rely on the same data sources as we do but they focus on a different goal: uncovering the set of key factors associated with ICO success. A consistent

[3] `https://www.bloomberg.com/news/articles/2018-04-03/crypto-exchanges-charge-millions-to-listtokens-autonomous-says`.

[4] See Adhami et al. (2018); Amsden and Schweizer (2018); Boreiko and Sahdev (2018); Bourveau et al. (2018); Deng et al. (2018); Fisch (2019); Jong et al. (2018); Howell et al. (2018). These papers use various measures of ICO success. Similar to us, some use the achievement of stated funding goal or listing on an exchange. Others use the amount of funds raised as a measure of success. Howell et al. (2018) uniquely focus on ex post trading measures (liquidity and volume).

message is their results is that disclosure and transparency are important. Instead of focusing on success, we use the ICO market to empirically study retention as a means of signaling in an environment with high information asymmetry. In the end, we contribute to this literature by showing that greater token retention is, in fact, associated with ICO fundraising success and higher quality issuers. Moreover, we find that this relationship is stronger during periods in which there is a flurry of ICO activity (more noise).

In addition to empirical studies, researchers have begun to analyze the properties of ICOs in a theoretical setting. In general, these papers highlight channels through which the novel aspects of an ICO can improve or worsen outcomes relative to traditional financing. Catalini and Gans (2018) highlight that the ICO mechanism can elicit the value that consumers place on the underlying project. Both Li and Mann (2018) and Sockin and Xiong (2018) find that an ICO can solve the coordination failure problem in creating a new platform. In a dynamic setting, Cong et al. (2018) highlight endogenous user adoption in ICOs. Cong and He (2018) point out the nonlinear relationships between equilibrium values for token price, platform productivity, and network size. Sanchez (2017) proposes an optimal ICO mechanism to improve upon the current set of models. As part of our analysis, we develop a simple model to formally evaluate the intuition behind our key empirical findings. Compared to the concurrent theoretical work, our analysis differs in highlighting how ICOs are similar to other forms of financing in the presence of large information asymmetries between sellers and buyers rather than the theoretical ways in which ICOs are distinct.

There are also some empirical papers that study post-ICO returns in the spirit of the initial public offering (IPO) literature. Benedetti and Kostovetsky (2018) observe an average first-day return of 179%. They find that cryptocurrency prices and social media activity are significant determinants of ICO underpricing. While they believe their results could indicate an irrational bubble, they conclude that the observed ICO underpricing is also consistent with high compensation for risk. Momtaz (2018a) and Momtaz (2018b) explore both short-term and medium-term returns after an ICO. He argues that his results are consistent with a "market liquidity hypothesis" that proposes ICO issuers want to underprice to generate ex post market liquidity for the token.

Finally, several papers study the asset pricing properties of digital currencies, commonly referred to as "cryptocurrencies." Some papers focus on the largest and most liquid digital currencies. For example, Liu and Tsyvinski (2018) find that the returns of the largest

cryptocurrencies are not driven by stock market and macroeconomic factors. Instead, these returns are driven by market specific factors including momentum and investor attention to crypto. Other papers consider the cross-section of returns across all digital currencies. As an example, Hu et al. (2018) find that the return on Bitcoin is a strong factor in explaining the returns on all others. We incorporate these findings into our analysis by using the prices of the two largest cryptocurrencies as measures of market sentiment. Our results show that investors appear to adjust for elevated market sentiment by focusing more on signal quality, consistent with our theoretical predictions.

The rest of this paper is arranged as follows. Section 2 gives an overview of blockchain technology and the ICO market. Section 3 describes the model and empirical predictions. Section 4 describes our data and provides summary statistics about the ICO market. Section 5 describes our results. Section 6 concludes.

2 Background: Blockchain, Cryptocurrencies, and Initial Coin Offerings

In this section, we provide key institutional details, a brief history, and an overview of the regulatory treatment for ICOs. First, however, we describe the basics of the crypto space because ICOs would not exist without blockchain technology and cryptocurrencies.

A blockchain is a digital, decentralized, distributed ledger for a specified digital asset. It is a file that contains the sequential list of transactions for that digital asset. Blockchain technology refers to the combination of this file with a network of computers (nodes) and software that dictates how the blockchain is monitored and updated. Using cryptography and an incentive scheme to reward participation on the network[5], this technology enables the direct and secure transfer of the underlying digital asset without a central authority to verify the transfer of ownership.[6] A cryptocurrency is a digital asset that is intended to be used as a medium of exchange. Although they may differ in technical details, all cryptocurrencies exist and are traded on a blockchain. In 2008, Bitcoin was the first cryptocurrency ever created (Nakamoto, 2008).

[5]Mining refers to a process in which participants use computers to solve mathematical puzzle and compile recent transactions are compiled into blocks.

[6]For a more detailed description, see, e.g., Narayanan et al. (2016).

As discussed in the introduction, the tokens that are sold in an ICO have a functional purpose in the product or platform that the issuer is creating. This "utility" aspect is the key differential between cryptocurrencies and tokens. It is also an important characteristic in the current regulatory debate (discussed more below). To provide a concrete example, let us consider the STORJ token (`https://storj.io/`). The underlying product is a blockchain-based decentralized cloud storage solution that allows users to store their data in the otherwise unused storage space owned by other people. One can either rent space on the devices of others using the STORJ token or lease out their own space in exchange for STORJ tokens. In this example, it is easy to see how the token is an integral part of the blockchain-based platform. This example also highlights the early-stage nature of platforms that choose to ICO. The Storj project issued STORJ tokens in May 2017. As of October 2018, the company's website promises that the Storj network is launching in early 2019.

ICOs are a relatively new phenomenon. In 2013, a software developer named J.R. Willett launched a social media fundraising campaign that promised 100 newly created MasterCoins for every Bitcoin received. He used the approximately $500,000 of funds raised to both develop the software and build an exchange to trade the newly created tokens. The success of MasterCoin encouraged other similar campaigns between 2013-2015. Campaigns during this time period did not actually use the term "ICO" but instead used terms such as "crowd sale", "donations", or "presale" (Boreiko and Sahdev, 2018).

The ICO market did not begin to resemble its existing form until 2016 after the development of the Ethereum blockchain. The Ethereum blockchain, which is denominated in the cryptocurrency Ether, was itself funded through a crowdfunding-style ICO in 2014. Ethereum was the "world's first programmable blockchain" that allowed users to design "smart contracts." As a result, users could easily create proprietary tokens that existed on a platform on top of the Ethereum blockchain. Before this advancement, an ICO would have to build and maintain their own blockchain. In September 2015, Augur was the first ICO to issue a token that ran on the Ethereum blockchain.

Since 2016, the stylized process for an ICO is as follows:

1. **Conception.** A team of entrepreneurs conceives a blockchain-based project that requires funds and users

2. **Announcement.** The team announces project details and the planned sale date on

cryptocurrency forums/websites

3. **Payment.** On the ICO date, prospective buyers submit orders by sending cryptocurrency payments to the issuer

4. **Distribution.** At the sale's conclusion, the token contract automatically sends the purchased tokens to successful buyers

Despite their relatively short history, ICOs have evolved to a relatively standardized procedure in many ways to reduce investor uncertainty (Massey et al., 2017). First off, ICOs typically produce a "white paper" that describes project in detail and provides key aspects of the sale such as token supply and pricing. This document effectively serves like a prospectus in an initial public offering. Second, most ICOs choose to sell a certain number of tokens on a first-come, first-served basis at a fixed price. This pricing mechanism means that there is a cap on the amount of money to raise. Third, most ICOs set a time limit for the sale to occur.

In the United States, ICOs effectively remain unregulated and their future regulatory treatment is still uncertain. Since 2014, cryptocurrencies have been formally designated as commodities and, accordingly, fall under the regulatory jurisdiction of the Commodity Futures Trading Commission (CFTC).[7] The key issue for ICOs is whether the token being sold is a "security." If so, they will be regulated under existing securities laws with oversight from the Securities and Exchange Commission. As part of their 2017 investigation into the post-ICO hack of The DAO, the SEC concluded that the tokens issued were, in fact, securities.[8] This ruling put forth the notion that future ICOs could similarly be categorized as securities. Based on the limited precedent so far, it is still not clear how ICOs will be treated in the US moving forward.[9]

[7]Testimony of CFTC Chairman Timothy Massad before the U.S. Senate Committee on Agriculture, Nutrition and Forestry (Dec. 10, 2014), `http://www.cftc.gov/PressRoom/SpeechesTestimony/opamassad-6`.

[8]`https://www.sec.gov/litigation/investreport/34-81207.pdf`

[9]The SEC has only brought enforcement actions against cases involving fraud despite statements from regulators that imply almost all tokens are securities. In a December 11, 2017 "Statement on Cryptocurrencies and Initial Coin Offerings", SEC Chairman John Clayton wrote "By and large, the structures of initial coin offerings that I have seen promoted involve the offer and sale of securities and directly implicate the securities registration requirements and other investor protection provisions of our federal securities laws." (`https://www.sec.gov/news/public-statement/statement-clayton-2017-12-11`). See Token Alliance (2018) for more detailed description of the US and international regulatory environment.

The regulatory response has differed widely across the rest of the world. On one hand, China and South Korea made ICOs illegal in 2017. On the other hand, several countries including Singapore and Switzerland have adopted a much friendlier approach. Singapore puts new financial innovative ventures in a "regulatory sandbox" from which they can emerge with a government license.[10] Switzerland has been described as the world capital of cryptocurrency, with the city of Zug as the heart of "Crypto Valley."[11]

Industry participants have responded to the events of the past few years with their own forms of self-regulation. The now common practice of issuing a white paper is an early example. More recently, many ICOs are consulting with law firms to avoid potential legal issues from regulators. For example, ICOs now voluntarily comply with Know Your Customer (KYC) and Anti-Money Laundering (AML) regulations by gathering personal info from prospective buyers. These types of positive changes reduce uncertainty about future regulatory actions.

3 Theory and Testable Implications

In this section, we develop a simple model to illustrate the relationship between investor supply and how successfully a company fund raises in an ICO. In the model equilibrium, high-quality entrepreneurs retain a higher fraction of tokens than low-quality entrepreneurs to signal their type to investors. As the market becomes noisier and more "bubble-like", the quality of ex-ante information available to investors deteroriates. In such an environment, a larger number of high-type firms, facing uncertainty from investors about their type, need to retain tokens to signal their quality causing the relationship between retention and fundraising to become stronger.

3.1 The Model

The model has three dates, $t = 0, 1, 2$ and two types of risk-neutral agents - penniless entrepreneurs and deep-pocketed investors. Entrepreneurs can undertake a project at $t = 1$

[10] See Monetary Authority of Singapore, "A Guide to Digital Token Offerings" (November 14, 2017).

[11] `https://www.wsj.com/articles/switzerland-wants-to-be-the-world-capital-of-cryptocurrency-1524942058`

to build a platform using blockchain technology. At $t = 2$, the project will either succeed or fail. In the case of success, the entrepreneur receives a gross return of R per dollar invested. In the case of failure, the entrepreneur receives $\underline{R} < R$. We set $\underline{R} = 0$ without loss of generality. There are two types of entrepreneurs - a proportion q are high-type entrepreneurs and a proportion $1 - q$ are low-type entrepreneurs. A project undertaken by a high-type entrepreneur succeeds with probability p_H. A low-type entrepreneur succeeds with probability $p_L < p_H$. We assume that,

$$p_L R \geq 1$$

The above assumption implies that all entrepreneurs weakly prefer to invest a dollar in the project rather than to hold it in cash.

At $t = 1$, the entrepreneur can undertake an ICO to raise money for investment. The entrepreneur can issue utility tokens that can be used to purchase goods and services on the platform if successfully completed. The entrepreneur can sell a share of tokens, s, to investors. A large mass of deep-pocketed investors can purchase the tokens made available for sale by the investor. If the project succeeds, investors get utility $t^I > 0$ for the proportion of tokens they own. So, if investors own 10% of tokens, their utility in the case of success is $.1t^I$. Investors can also invest in an outside option that gives them a return of 1. An entrepreneur of type i gets utility t_i^E for the proportion of tokens they hold if the project is successful. We assume that $0 \leq t_L^E \leq t_H^E < t^I$. There are therefore gains to trade from selling tokens to investors for both types of entrepreneurs.

At $t = 0$, before entrepreneurs issue tokens, there is a public signal which perfectly reveals the entrepreneur's type with probability α. With probability $1-\alpha$ the signal is uninformative. The informativeness of the signal is the key parameter we vary when we think about markets being noisier and "bubble-like". We can interpret an increase in α as a decrease in noise in the market. For example, when a small number of ICOs are taking place, investors have more time to read up on an ICO, have time to study their whitepaper, business plan, prototype, talk to other investors etc. In the model, such a time is proxied by a high α. When many ICOs are happening simultaneously it is harder for investors to undertake such detailed due diligence - we interpret this as a low α.

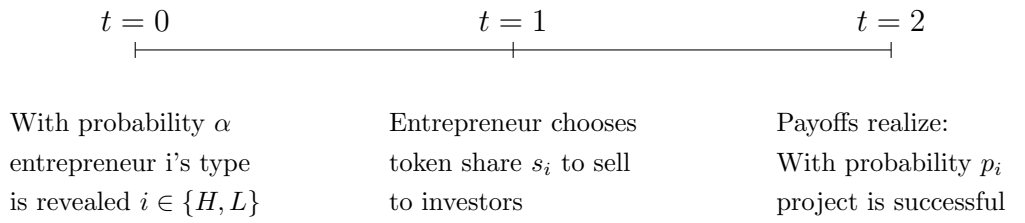


Figure 1: Model Timeline

Equilibrium Definition: A perfect Bayesian equilibrium in pure strategies of the model is given by,

1. The share of tokens, s_H^* and s_L^*, sold to investors by the high-type and low-type entrepreneur respectively whose types have not been revealed by the public signal.

2. The share of tokens, $s_{H\alpha}^*$ and $s_{L\alpha}^*$, sold to investors by the high-type and low-type entrepreneur respectively whose types have been revealed by the public signal.

3. Investor beliefs, $\mu(\theta|s)$, that an entrepreneur is of type $\theta = \{H, L\}$, if he chooses to sell share s of tokens.

4. Prices investors pay for share s of tokens sold to them s.t. their participation constraint is satisfied.
$$P(s) = \mu(H|s)p_H t^I s + (1 - \mu(H|s))p_L t^I s$$

3.2 First Best

In the absence of information asymmetries, when participating in an ICO investors know if they are buying tokens from a high- or low-type entrepreneur. Let s_H and s_L be the token shares sold to investors by a high- and low-type entrepreneur respectively. Investors will therefore pay entrepreneurs $p_H t^I s_H$ and $p_L t^I s_L$ in total for the tokens sold to them.[12] An entrepreneur of type $i = \{H, L\}$ get utility $p_i t_i^E (1 - s_i)$ from retaining a share s_i of tokens. If they instead sell the share, they receive $p_i t^I$ from investors and can invest that to earn an

[12]Since there is a large mass of deep, pocketed investors, competition between them sets token prices s.t. investors earn a return of 1, equal to their outside option.

expected return of $p_i R$ per dollar invested. Since by assumption $t^I > t_i^E$ and $p_i R > 1$ an entrepreneur's expected utility from selling a share to investors is always higher than their expected utility from retaining that share themselves,

$$p_i t^I p_i R > p_i t_i^E \qquad i \in \{H, L\}$$

In the firm best with no asymmetric information, entrepreneurs therefore always prefer to sell all of their tokens to investors. Entrepreneurs gain more by investing each dollar they get from the investor intro the platform rather than from holding on to the token. Formally, we can establish the following proposition,

Proposition 1 *[First Best] In the first-best, with no asymmetric information, both high- and low- type entrepreneurs choose to sell all their tokens to investors, $s_H = s_L = 1$.*

Since in the first best, both types of entrepreneurs want to sell all tokens to investors, we should not see differential retention between high- and low-type entrepreneurs. Therefore, in the absence of asymmetric information about entrepreneur quality, we should see no covariance between the amount of tokens retained by an entrepreneur and the quality of an ICO.

Corollary 1 *[Retention and Quality in First Best] In the absence of asymmetric information about entrepreneur quality, there is zero covariance between the quality of an ICO and the fraction of tokens sold to investors.*

3.3 Equilibrium with Asymmetric Information

In the equilibrium with asymmetric information, with probability α an entrepreneur's type will be revealed. In this case, the entrepreneur's and investors' problems are the same as in the full information case. Both high- and low-type entrepreneurs whose type is revealed will select $s = 1$. Investors will buy all the tokens at a price of $p_i t^I$ where $i \in \{H, L\}$.

If an entrepreneur's type is not revealed, then there exists a separating equilibrium in which the high type chooses an $s_H \leq 1$ to signal his type while the low type choose $s_L = 1$. The following investor beliefs can support such an equilibrium,

$$\mu(H|s) = \begin{cases} 1 & \text{if} \quad s \leq s_H \\ \\ 0 & \text{if} \quad s > s_H \end{cases}$$

In a signaling equilibrium in which the high-type separates from the low-type, s much be small enough that the low-type doesn't want to copy the high-type,

$$\underbrace{p_H t^I s_H p_L R}_{\text{Expected Return from Funds Raised}} + \underbrace{(1-s_H) p_L t_i^E}_{\text{Expected Return from Tokens Retained}} \leq \underbrace{p_L t^I p_L R}_{\text{Expected Return from Funds Raised}}$$

Additionally, the high-type must not want to deviate to selling a larger fraction of tokens to investors,

$$\underbrace{p_H t^I s_H p_H R}_{\text{Expected Return from Funds Raised}} + \underbrace{(1-s_H) p_H t_i^E}_{\text{Expected Return from Tokens Retained}} \geq \underbrace{p_L t^I p_H R}_{\text{Expected Return from Funds Raised}}$$

Under the Intuitive Criterion, we can show that the least-cost separating equilibrium is the unique equilibrium of the model. In this equilibrium, the high type chooses to retain a strictly positive amount of tokens and sell a fraction, $s_H^* < 1$, of tokens. This fraction is set such that the low-type entrepreneur's incentive compatibility constraint is just satisfied,

$$p_H t^I s_H^* R + (1 - s_H^*) t_L^E = p_L t^I R$$

Proposition 2 *[Equilibrium with Asymmetric Information] Under the Intuitive Criterion, an equilibrium in which a high-type entrepreneur who has not had his type revealed at $t = 0$, signals his quality by retaining a fraction, $s_H^* < 1$, of tokens and a low-type entrepreneur sells all tokens, $s_L^* = 1$, exists and is unique. The equilibrium fraction of tokens sold to investors by the high-type is given by,*

$$s_H^* = \frac{p_L - \frac{t_L^E}{t^I R}}{p_H - \frac{t_L^E}{t^I R}}$$

In the presence of asymmetric information, high-type entrepreneurs retain a positive share of tokens to signal their type of investors. This will therefore cause there to be a positive relationship between investor supply and fundraising success in the ICO market. A number of factors will affect the fraction of tokens the high-type chooses to retain.

Corollary 2 *[Equilibrium Retention] The fraction of tokens a high-type entreprenur sells to investors, s_H^*, decreases when p_H increases, p_L decreases, $\frac{t_L^E}{t^I}$ increases and R decreases.*

When p_H increases or p_L decreases, the gain from pretending to be the high-type increases and the high-type needs to retain a greater fraction of tokens to signal quality. Therefore s^* decreases. When $\frac{t_L^E}{t^I}$ decreases, s^* increases. This is because the low-type entrepreneur gains more from selling tokens to the investor as the relative value the investor places on these compared to the low-type entrepreneur increases. As R increases, s^* increases. This is because an increase in R increases the value of selling tokens to investors.

Retention During Bubbles: In the model equilibrium, high-type entrepreneurs who have their type revealed by the public signal sell all their tokens to investors. High-type entrepreneurs who do not have type revealed retain a fraction of tokens to signal their type. We define Ret^* as the total fraction of tokens retained in equilibrium. This is given by,

$$\text{Ret}^* = q(1-\alpha)(1-s^*)$$

$q(1-\alpha)$ is the measure of high-type investors who do not have their type revealed and they each retain a fraction $1-s^*$ of tokens. A decrease in α can be interpreted as an increase in noise in the market. If only a few ICOs are happening in a month, investors have more to study a company's whitepaper, business plan, examine their prototype, read analyst reports, talk to other investors and so on. This can be thought of as a time of high α when a large fraction of firms have their type revealed to investors. On the other hand, at a time when many ICOs are taking place it is harder for investors to undertake such detailed due diligence. We interpret this as a low α. As α decreases, a greater fraction of high-type entrepreneurs retain tokens.

We define β_q as the model-implied correlation between firm quality and investor supply,

$$\beta_q = \frac{Cov(\text{P(high-type)}, s)}{Var(s)}$$

Then we can establish the following proposition,

Proposition 3 *[Retention and Bubbles] In the unique signaling equilibrium, ICO-quality is negatively correlated with the fraction of tokens sold to investors, $\beta_q < 0$. As α decreases and the quality of public information deteriorates, the magnitude of this correlation increases, i.e.,*

$$\frac{\partial \mid \beta_q \mid}{\partial \alpha} < 0$$

In our empirical results we proxy for ex-post firm-quality by whether or not a firm's token starts trading on a reputable exchange after their ICO.

4 Data

We hand collect data from several of ICO tracking websites that provide information to potential ICO investors and the general public. These websites include ICO Data (`https://www.icodata.io/`), Token Data (`https://www.tokendata.io/`), CoinMarketCap (`https://coinmarketcap.com/`), Cryptoslate (`https://cryptoslate.com`), ICO Bench (`https://icobench.com`), ICO Drops (`https://icodrops.com`), ICO Rating Agency (`https://icorating.com`), and ICO Checks (`https://icocheck.io`). To merge ICO characteristics across different websites, we employ three identifiers: ticker symbol, token name, and website URL. The combined database includes 4,524 distinct ICOs between January 1, 2016 through June 30, 2018, including ongoing and completed ICOs.[13] To the best of our knowledge, this is among the most comprehensive ICO database to be used for academic research.[14]

[13]We also collect data for 1,743 planned ICOs. However, they are excluded from our sample because we focus on performance measures of ICOs.

[14]At the largest end, Deng et al. (2018) use a sample of 3,573 completed ICOs between August 2015 and July 2018, and Benedetti and Kostovetsky (2018) use a sample of 2,390 ICOs that were completed on or before April 30, 2018. The remaining empirical papers referenced in our literature discussion use samples that include anywhere from 64 to 659 ICOs.

We collect data on both ex-ante characteristics of ICOs that are known to investors at the time of an ICO (*ICO Start Date*, *ICO End Date*, *ICO Sale Price*, *ICO Hard Cap*, *ICO Soft Cap*, *ICO Investor Supply*, etc) and the performance of the company following the ICO (*ICO Funds Raised*, *Market Cap*, *Price*, *Volume* etc.). The full list of collected variables along with their definitions is provided in Table 1.

Table 2 reports summary statistics for all ICOs that have been competed by June 30, 2018, as well as for ICOs that have started after June 1, 2018 but have been ongoing as of June 30, 2018. When announcing a project, token issuers typically produce a whitepaper that provides project details and key terms of an ICO. Not surprisingly, we find that a median ICO in our sample indeed has such whitepaper. A growing number of ICOs now require their contributors to pass Know Your Customer (KYC) verification before purchasing tokens. This is the procedure of identity verification in which each buyer has to provide his credentials (e.g. passport or driver's license number) in order to participate in an ICO. KYC ensures transparency of transactions which helps to guarantee the safety of investors' assets and prevent scammers from participating in ICOs. On the other hand, its contradicts one of the main principles of the crypto world – anonymity – and as such can be viewed as a barrier to enter an ICO. Given its recent adoption into the ICO market, only 20% of ICOs in our sample implement KYC. An even smaller fraction of token issuers (16%) request investors to pre-register on a "whitelist" before their token sale launch. Only "whitelisted" customers are able to purchase tokens during sale. Similar to KYC, whitelists create barriers to participate in an ICO.

One key measure of ICO success is the amount of capital that token issuers collect for future product development. Table 2 and Figure 2 demonstrate that the amount of funds raised by ICOs is highly skewed. While the mean and median value of funds raised is $17.8 million and $5.7 million, respectively, the largest ICO in the history EOS, developer of infrastructure for decentralized apps, has raised $4,234.3 million after year-long crowdsale. Other large ICOs include Telegram Open Network, Petro, and Dragon. A related measure of ICO success is whether the issuer raises any funds at all. One third of all initial coin offerings in our sample have raised a strictly positive amount of funding as captured by *Successful Dummy*. This is an indicator that equals 1 if ICO *Funds Raised* > 0 and zero otherwise.

In the recent period, the average size as measured by the amount of capital raised has nearly doubled indicating a higher interest of investors in the ICO market (see Panel (b)

of Figure 3). We also observe a steep increase in the aggregate amount of capital that has been attracted by token issuers at the end of 2017. Panel (a) of Figure 3 shows that the ICO market has reached its monthly peak of $5,863 million in June 2018. Most of the funds raised in this month is attributed to EOS that completed its ICO on June 26, 2018 and raised $4,234.3 million. One unique feature of the EOS ICO is that it occurred over multiple rounds, raising $150 million in June 2017, $180 million in July 2017, $100 million in November 2017, $420 million in December 2017, $750 million in January 2018, and $500 million in February 2018, which is not reflected in the time-series of total funds raised[15]. Another peak coincides with the completion date of Telegram Open Network raising $1,700 million. Excluding the 10 largest ICOs as measured with the amount of capital raised demonstrates that the ICO market has stabilized at around $2,000 million throughout 2018. We also plot the amount of capital raised in July 2018, even though the data is collected as of June 30, 2018. We find that a number of ICOs achieve their financing goal before the end date of ICO. As of July 2018, token issuers have already raised $825.5 million dollars.

In our analysis, we measure issuers' signal of project quality with the percentage of the tokens that are sold to outside investors during the fund raising campaign, which we denote as *Investor Supply*. As discussed earlier, this measures the fraction of all tokens that are sold to investors at the time of the ICOs. Figure 4 demonstrates that there is a lot of heterogeneity among token issuers when choosing what percentage of tokens to sell. *Investor Supply* ranges from 0% to 100%. An average ICO puts for sale 58% of all issued tokens (see Table 2). The non-sold tokens are held by insiders, which include members of the issuer team and early supporters of the project. The percentage of these non-sold tokens is denoted as *Token Retention* (which equals 1−*Investor Supply*).

5 Empirical Findings

In this section, we test our main hypothesis that token issuers signal the quality of their project to potential investors by retaining a higher fraction of tokens during the ICO. This proposed signaling mechanism is consistent with the model in Section 3. It is also consistent with rational investors that respond to issuers' signal and choose to fund projects they infer

[15]Importantly, since we conduct all empirical tests at the ICO level, not breaking down the funds raised by rounds should not affect our findings.

to be of higher quality.

5.1 Signaling with Token Retention

As a first step, we test whether ICOs that sell a larger fraction of tokens to outside investors tend to raise a smaller amount of funds. The specification is as follows, for ICO j:

$$ln\left(ICO\ Funds\ Raised_j\right) = \alpha + \beta \cdot ICO\ Investor\ Supply_j + \gamma X_j + \epsilon_j, \tag{1}$$

where the dependent variable is the natural logarithm of the total funds raised during the ICO.[16] The coefficient estimate on *ICO Investor Supply* captures the relationship between signal quality and ICO success. Additionally, we control for a number of other observed ICO characteristics X_j that might affect the ICO success. In particular, we control for whether an ICO requires its investors to pass KYC verification and register on its whitelist.

In Table 3, we report the estimates of the above specified regression. In Columns (1) and (3), we include only ICOs that have been completed (i.e., have the end date of ICO) before June 30, 2018. We find that a 1 percentage point increase in the investor supply by the issuer, or equivalently a 1 percentage point increase in the token retention, leads to an approximately $1.3 - 1.9\%$ decline in the total raised funds. This result is consistent with the signaling mechanism described in our model. Importantly, this relationship is both economically and statistically significant.

As mentioned before, a number of ICOs achieve their fundraising goal before the ICO end date. As such, we also run the regressions including the ICOs that are ongoing at least for a month as of June 30, 2018 but haven't been completed yet. The results are reported in Columns (2) and (4) of Table 3. Including these active ICOs allows us to increase our sample size from 860 to 1098, and it doesn't affect, neither qualitatively nor quantitatively, the relationship between the signal quality and the ICO fundraising success.

[16]The total funds raised are denominated in US dollars. Some websites report raised funds in alternative currencies, e.g. Ethereum or Bitcoin. We convert these amounts to USD using the exchange rate prevailing on the last day of the ICO. This may introduce bias in our measure of the funds raised as most successful ICOs manage to achieve their funding goal way before the announced end date of ICO. This bias might be also attenuated due to the fact that cryptocurrency prices are highly volatile. For robustness, we run all the regressions restricting our attention only to ICOs that report the amount of raised funds in USD. All results continue to hold.

We also find that ICOs with *KYC* and *Whitelist* raise $0.4 - 0.8\%$ more funds on average. Both *KYC* and *Whitelist* can be interpreted as additional signals of project quality. When token issuers choose to require their contributors to pass identify verification and/or register for a token sale in advance, they create additional constraints for investors to participate in ICO. In this way, developers of high-quality projects can separate from developers of low-quality projects.

Token issuers very often set their maximum fundraising goal in the details of their initial announcement. This figure is known as a *Hard Cap*. Our initial results could be driven by few large ICOs (as measured by the funds raised) that have a high token retention but, at the same time, fail to achieve their fundraising goal. For token sales that feature a hard cap, a better success metric would be the amount of funds raised in ICO as a fraction of the ICO hard cap, which we denote as *Fundraising Success*. This metric captures how close token issuers are toward achieving their fundraising goal regardless of the ICO size. In Table 4, we report the estimates of the following regression:

$$ICO\ Fundraising\ Success_j = \alpha + \beta \cdot ICO\ Investor\ Supply_j + \gamma X_j + \epsilon_j, \qquad (2)$$

where the dependent variable is the total funds raised as a fraction of the hard cap. We again find a strong negative relationship between the investor supply and ICO fundraising success, implying that indeed investors respond to a signal of token issuers and invest more in projects of higher quality. In line with our hypothesis, when issuers retain a larger fraction of tokens, investors learn that they are of high quality, and consequently these ICOs fund raise more successfully. Specifically, we find that a 1 percentage points increase in the investor supply results in a 0.2-0.4 percentage points decline in the fundraising success. Again, this estimate is both economically and statistically significant.

A set of ICOs choose not to report the amount of funds raised at all, if they failed to achieve their fundraising goal. This creates a concern that our coefficient estimates may be subject to a selection bias. Our regressions might include only ICOs that have been relatively more successful and as such chose to report the amount they raised. Figure 5 shows that around a quarter of ICOs in our sample have achieved their financing goal. At the same time, our sample includes around 30% of ICOs that raised close to 0$. We further address this concern by setting *ICO Fundraising Success* to zero if it is not reported. The results are consistent with our previous findings as shown in Columns (3) and (6) of Table 4. In these

specifications, we only focus on completed ICOs as active ICOs might still report the funds raised upon their completion. There are 376 ICOs that do report the amounts of tokens retained in ICO but have missing funds raised.

5.2 Signal Quality during ICO Bubbles

Popular press has suggested that a rush to participate in the ICO market could be temporary and driven by the irrational sentiment that arose along with the Bitcoin price. In this section, we aim to understand whether investors rationally respond to the project signal during such bubble periods. In times of bubbles, we expect the degree of asymmetric information in the market to increase. Based on our model predictions, we expect the relationship between retention and the quality of ICOs to grow stronger during such times.

First, we investigate whether there is any relationship between the prices of Ethereum/Bitcoin and increased activity in the ICO market. To this end, we propose to use the number of ongoing ICOs in a given month as a measure of the amount of ICO activity. Specifically, for each ICO j, we count the number of ICOs that are active at the launch date of ICO j. Figure 6 shows that indeed the interest of investors in the ICO market closely follows the Ethereum price dynamics. More formally, we run a regression of the natural logarithm of *Number of ICOs* on the natural logarithm of *Bitcoin* or/and *Ethereum* price. As presented in Table 5, there is a strong positive relation between the price levels and investors' sentiments. R^2 varies between 91% and 94%. Further, we find that a 1% increase in the Bitcoin (Ethereum) price results in 0.96% (0.46%) increase in the number of ongoing ICOs.

Second, we analyze whether signaling in the ICO market plays a bigger role during such periods of bubbles when we expect there to be an increased degree of asymmetric information in the market. We test whether the signaling mechanism is stronger during periods when there is a large number of active ICOs, using the following specification:

$$\begin{aligned} ICO\ Fundraising\ Success_j = &\alpha + \beta_1 \cdot ICO\ Investor\ Supply_j + \beta_2 \cdot Number\ of\ ICOs_j \\ &+ \beta_3 \cdot ICO\ Investor\ Supply_j \times Number\ of\ ICOs_j + \gamma X_j + \epsilon_j, \end{aligned} \tag{3}$$

where all variables, besides dummies, are normalized to capture the average effect of investor supply on the total funds raised as a fraction of hard cap. We are interested in the coefficient

estimate on $ICO\ Investor\ Supply_j \times Number\ of\ ICOs_j$ that captures the differential affect of the investor supply on the ICO success when the number of ICOs is above as compared to below its mean level.

Table 6 demonstrates that even after accounting for potential bubbles in the ICO market there is still a strong negative relationship between token retention and ICO fundraising success. Please note that the interpretation of coefficients has changed as we normalized both the dependent and independent variables. When the number of ICOs is at its mean level, a 1 standard deviation increase in investor supply leads to approximately 0.1 standard deviation decline in the fundraising success. We also find that during ICO bubbles token investors raise less funds towards reaching their hard cap, holding investor supply at its average level. This is consistent with the idea that investors have a limited amount of funds to allocate to projects funding. So, in periods when there are many ICOs happening at the same time each individual ICO receives less financing due to increased competition in the market. In line with our model predictions, we find that signaling project's quality is more important during the bubbly periods as it becomes harder for investors to separate out worthy investments. In particular, for each standard deviation increase in the number of ICOs, a 1 standard deviation decline in investor supply leads to additional 0.05-0.08 standard deviation increase in the fundraising success. We also perform this analysis using the absolute amount of funds raised as the dependent variable and all the findings hold. For brevity, we do not report those results here.

5.3 Ex-Post Measures of ICO Performance

Reaching the fundraising goal during the ICO does not necessary result in successful development of the product. As such the amount of funds raised is only a proxy for the project's quality and it important to explore alternative measures of ICO performance. In this section, we consider whether a token lists on an exchange after an ICO.

Crypto exchanges engage in due diligence prior to accepting a token for listing to protect their reputation both with customers and regulators. Allowing fraud or scam tokens on a trading platform erodes customer trust. Regulatory compliance is important for staying in business. In March 2018, the SEC issued a statement noting that any platform "providing a mechanism for trading assets that meet the definition of a 'security' ... must register with the

SEC as a national securities exchange."[17] Given the regulatory uncertainty about whether tokens are "securities" (see section 2), many exchanges that feature tokens have chosen to register with the SEC (e.g., Coinbase). Part of being a "national securities exchange" is complying with anti-money laundering ("AML") regulations and associated requirements, which means understanding the parties with whom they interact (Token Alliance, 2018).

Recent literature points out that ICOs that result in successful product development are more likely to have their tokens traded on a reputable exchange. In this sense, an indicator of whether ICO's tokens are listed can serve as an alternative measure of the project's quality. Within the industry, it is well known that exchanges screen tokens for quality. For example, the Coinist, an ICO advisor and data provider, writes that "in general, a strong team with a better product that is upfront with information should have a relatively simple time getting listed."[18]

We further test our signaling hypothesis using the following specification

$$ICO\ Listed\ Dummy_j = \alpha + \beta_1 \cdot ICO\ Investor\ Supply_j + \beta_2 \cdot ICO\ Fundraising\ Success_j + \epsilon_j, \quad (4)$$

whether the dependent variable *Listed Dummy* is an indicator that equals to 1 if ICO tokens are traded on an exchange.

In line with our previous findings, we find that ICO investors indeed rely on token retention as a signal of the project's quality. As shown in Table 7, a 1 standard deviation increase leads to a 1.5-4% decline in the probability of tokens being listed on the exchange. This is in addition to the effect of the investor supply on the listing probability through the funds raised. Column (2) demonstrates that an ICO that has achieved its hard cap is much more likely to have its tokens listed. Specifically, a 1 standard deviation increase in the fundraising success results in a 18-20% higher listing probability. This suggests that high-quality ICOs that have been successful in signaling their quality through token retention will more likely reach their funding goal, have their tokens traded and potentially develop their product.

[17] https://www.sec.gov/news/public-statement/enforcement-tm-statement-potentially-unlawful-online-platforms-trading

[18] https://www.coinist.io/how-to-get-your-digital-token-listed-on-an-exchange/

6 Conclusions

In this paper, we provide evidence of signaling in ICO markets. We show that ICOs that perform better ex-post signal their quality to investors by retaining a greater fraction of tokens. These ICOs are more likely to fund raise successfully. When the market for ICOs is noisier, we expect the degree of asymmetric information to be higher. In these times, we find that the correlation between the fraction of tokens that investors retain and ICO quality increases.

In recent years, the ICO market has grown rapidly and is emerging as an important new source of early-stage financing of companies. Our paper contributes to understanding some of the dynamics of this fast growing market. In particular, we show how investors and entrepreneurs are rationally responding to problems that are created by the unregulated and anonymous nature of the ICO market.

Appendix

A Proofs

Proof of Proposition 1. For a fraction s_i of tokens sold by an entrepreneur of type $i \in \{L, H\}$, investors will pay $p_i t^I s_i$. An entrepreneur of type i choose $s_i \in [0, 1]$ to solve,

$$max_{s_i} \in [0,1]\, s_i(p_i t^I s_i) p_i R + (1 - s_i) p_i t_i^E \tag{A.1}$$

Since by assumption $t^I > t_i^E$ and $p_i R > 1$, it follows that

$$p_i t^I p_i R > p_i t_i^E \qquad i \in \{H, L\}$$

Therefore, (A.1) is maximized when $s_i = 1$ for $i \in \{L, H\}$. With no asymmetric information, high and low-type entrepreneurs will choose $s_H = s_l = 1$.

□

Proof of Corollary 1. In the equilibrium with full information, the covariance between the quality of an ICO and investor supply is given by,

$$Cov(P((\text{high-type})), s) = E[P((\text{high-type})) * s] - E[P((\text{high-type}))]E[s]$$

$$Cov(P((\text{high-type})), s) = q * 1 + (1 - q) * 1 - (q + (1 - q)) * 1 = 0$$

□

Proof of Proposition 2. In the equilibrium with asymmetric information, if an entrepreneur's type is revealed, his maximization problem is the same as in the full information case given

by (A.1). In this case, both high- and low-type entrepreneurs whose type is revealed will select $s = 1$. Investors will buy all the tokens at a price of $p_i t^E$ where $i \in \{H, L\}$.

We now show that a separating equilibrium in which a high-type entrepreneur who doe not have his type revealed chooses $s_H^* = \frac{p_L - \frac{t_L^E}{t^I R}}{p_H - \frac{t_L^E}{t^I R}}$ exists. The following investor beliefs can support such an equilibrium,

$$\mu(H|s) = \begin{cases} 1 & \text{if} \quad s \leq s_H^* \\ \\ 0 & \text{if} \quad s > s_H^* \end{cases}$$

First, we show that given these beliefs, a low-type entrepreneur whose type has not been revealed will choose $s_L^* = 1$. The low-type entrepreneur chooses $s_L \in [0, 1]$ to solve,

$$max_{s_L} \in [0,1] \mathbb{1}_{s_L \leq s_H^*}(s_L(p_H t^I s_L)p_L R + (1 - s_L)p_L t_L^E) + \mathbb{1}_{s_L > s_H^*}(s_L(p_L t^I s_L)p_L R + (1 - s_L)p_L t_L^E)$$

Since $t^I > t_L^E$ and $p_L R > 1$, it follows that

$$p_H t^I p_L R > p_L t^I p_L R > p_L t_L^E$$

Therefore, if a low-type entrepreneur chooses an $s_L \in (s_H^*, 1]$, it is a dominant strategy to choose $s_L = 1$. Similarly, if a low-type entrepreneur chooses an $s_L \in [0, s_H^*]$, it is a dominant strategy to choose $s_L = s_H^*$. Then a low type-entrepreneur will choose $s_L^* = 1$ iff,

$$p_H t^I s_H^* p_L R + (1 - s_H^*)p_L t_L^E \leq p_L t^I p_L R$$

This just holds for $s_H^* = \frac{p_L - \frac{t_L^E}{t^I R}}{p_H - \frac{t_L^E}{t^I R}}$.

A high-type entrepreneur whose type has not been revealed chooses $s_H \in [0, 1]$ to solve,

$max_{s_H} \in [0,1]\, \mathbb{1}_{s_H \leq s_H^*}(s_H(p_H t^I s_H)p_H R + (1-s_H)p_H t_H^E) + \mathbb{1}_{s_H > s_H^*}(s_H(p_L t^I s_H)p_H R + (1-s_H)p_H t_H^E)$

Since $t^I > t_H^E$ and $p_H R > p_L R > 1$, it follows that

$$p_H t^I p_H R > p_L t^I p_H R > p_H t_H^E$$

Using the same reasoning as for the low-type entrepreneur, if a high-type entrepreneur chooses an $s_H \in (s_H^*, 1]$, it is a dominant strategy to choose $s_H = 1$. Similarly, if a high-type entrepreneur chooses an $s_H L \in [0, s_H^*]$, it is a dominant strategy to choose $s_H = s_H^*$. Then a high type-entrepreneur will choose $s_H = s_H^*$ iff,

$$p_H t^I s_H p_H R + (1 - s_H^*) p_H t_H^E \geq p_L t^I p_H R$$

This simplifies to,

$$t^I s_H p_H R + (1 - s_H^*) t_H^E \geq p_L t^I R \tag{A.2}$$

(A.2) is always satisfied since $t_H^E \geq t_L^E$ and,

$$p_H t^I s_H^* R + (1 - s_H^*) t_L^E = p_L t^I R$$

Therefore a high-type entrepreneur whose type has not been revealed will choose to sell s_H^* fraction of tokens to investors. This is the least-cost separating equilibrium since the low-type's incentive compatibility constraint just binds. Under the Intuitive Criterion, this is the unique equilibrium.

□

Proof of Proposition 3. The correlation between ICO quality and investor supply is given by,

$$\beta_q = \frac{Cov(P(\text{high-type}), s)}{Var(s)} = \frac{-Cov(P(\text{high-type}), 1-s)}{Var(1-s)}$$

$$\beta_q = -\frac{E[P(\text{high-type}) * (1-s)] - E[P(\text{high-type})]E[1-s])}{Var(1-s)}$$

$$\beta_q = -\frac{(1-\alpha)q(1-s_H^*) - q(1-\alpha)q(1-s_H^*)}{(1-\alpha)q(1-s_H^*)^2 - (1-\alpha)^2q^2(1-s_H^*)^2}$$

$$\beta_q = -\frac{1-q}{(1-s_H^*)(1-(1-\alpha)q)}$$

Since $s_H^* < 1$, β_q is always negative. As α decreases, the denominator decreases increasing the absolute value of β_q. Therefore,

$$\frac{\partial \mid \beta_q \mid}{\partial \alpha} < 0$$

□

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Tables and Figures

Table 1: List of Variables

Variable Name	Description
Whitepaper Dummy	an indicator that equals to 1 if an ICO has a whitepaper and 0 otherwise
Whitelist Dummy	an indicator that equals to 1 if an ICO has a whitelist (i.e. requires its buyers to register in advance) and 0 otherwise
KYC Dummy	an indicator that equals to 1 if an ICO requires its investors to pass Know Your Customer (KYC) verification and 0 otherwise
Funds Raised	the amount of capital raised during an ICO
Successful Dummy	an indicator that equals to 1 if token issuers have raised a strictly positive amount of funds during an ICO (*Funds Raised*>0) and 0 otherwise
Hard Cap	the maximum amount of capital that can be raised during an ICO
Soft Cap	the minimum amount of capital that has to be raised during an ICO for a project to proceed as planned
Investor Supply	the fraction of all issued tokens that can be sold to outside investors during an ICO
Fundraising Success	the ratio of ICO *Funds Raised* to *Hard Cap*
Listed Dummy	an indicator that equals to 1 if ICO tokens are traded on an exchange and 0 otherwise

Table 2: Summary Statistics

	N	Mean	SD	1%	10%	50%	90%	99%
Whitepaper Dummy	4524	0.69	0.46	0.00	0.00	1.00	1.00	1.00
Whitelist Dummy	4524	0.16	0.37	0.00	0.00	0.00	1.00	1.00
KYC Dummy	4524	0.20	0.40	0.00	0.00	0.00	1.00	1.00
Funds Raised, $ mil	1501	17.84	121.02	0.00	0.15	5.74	33.34	113.66
Successful Dummy	4524	0.33	0.47	0.00	0.00	0.00	1.00	1.00
Hard Cap, $ mil	2034	515.69	3509.11	0.50	7.00	33.00	1061.50	5335.50
Soft Cap, $ mil	1086	79.58	290.65	0.05	0.75	5.32	171.17	1267.38
Investor Supply, %	2094	0.58	0.21	0.05	0.30	0.60	0.85	1.00
Fundraising Success, %	1087	0.40	0.41	0.00	0.00	0.24	1.00	1.00
Listed Dummy	4524	0.33	0.47	0.00	0.00	0.00	1.00	1.00

The Table reports summary statistics for the sample of 4,524 ICOs between July 2015 and June 2018. It includes both the ICOs that have been completed before June 30, 2018 and ICOs that have started after June 1, 2018 but are still active as of June 30, 2018. We obtain the sample of ICOs by combining the data from the following ICO tracking websites ICO Data, Token Data, CoinMarketCap, Cryptoslate, ICO Bench, ICO Drops, ICO Rating Agency , and ICO Checks. For each variable, the Table shows the number of non-missing observations, along with the cross-sectional mean, standard deviation, 1^{st}, 10^{th}, 50^{th}, 90^{th}, and 99^{th} percentiles. The description of variables is provided in Table 1.

Table 3: Signaling in ICO Market with Token Retention

	(1)	(2)	(3)	(4)
Investor Supply	-1.933***	-1.739***	-1.299***	-1.303***
	(-5.48)	(-5.70)	(-3.79)	(-4.34)
KYC Dummy			0.784***	0.776***
			(4.11)	(4.93)
Whitelist Dummy			0.786***	0.426***
			(3.97)	(2.59)
Constant	16.325***	16.400***	15.408***	15.698***
	(75.20)	(87.43)	(67.48)	(78.78)
R2	0.034	0.029	0.126	0.091
N	860	1098	860	1098

The Table reports the estimated coefficients from cross-sectional regressions using OLS:

$$ln\left(ICO\ Funds\ Raised_j\right) = \alpha + \beta \cdot ICO\ Investor\ Supply_j + \gamma X_j + \epsilon_j,$$

The dependent variable in each regression is the natural logarithm of total funds raised in ICO. The total funds raised are denominated in U.S. $. The investor supply is expressed in percentage points. In Columns (1) and (3), only ICOs that have been completed before June 30, 2018 are included. In Columns (2) and (4), also ICOs that have started after June 1, 2018 but are still active as of June 30, 2018 are included. T-statistics are shown in brackets. ***, **, and * indicate significance at the 1%, 5%, and 10% level.

Table 4: Signaling in ICO Market with Token Retention

	(1)	(2)	(3)	(4)	(5)	(6)
Investor Supply	-0.420***	-0.412***	-0.291***	-0.294***	-0.324***	-0.207***
	(-5.47)	(-6.10)	(-5.07)	(-3.86)	(-4.78)	(-3.69)
KYC Dummy				0.073*	0.070**	0.078**
				(1.82)	(2.05)	(2.58)
Whitelist Dummy				0.171***	0.120***	0.175***
				(4.11)	(3.39)	(5.54)
Constant	0.668***	0.659***	0.445***	0.501***	0.534***	0.312***
	(14.14)	(15.81)	(12.46)	(9.74)	(11.73)	(8.36)
R2	0.042	0.040	0.024	0.107	0.080	0.099
N	691	898	1067	691	898	1067

The Table reports the estimated coefficients from cross-sectional regressions using OLS:

$$ICO\ Fundraising\ Success_j = \alpha + \beta \cdot ICO\ Investor\ Supply_j + \gamma X_j + \epsilon_j, \tag{A.3}$$

The dependent variable in each regression is the ratio of ICO total funds raised to hard cap. Both the fundraising success and investor supply are expressed in percentage points. In Columns (1), (3), (4) and (6), only ICOs that have been completed before June 30, 2018 are included. In Columns (2) and (5), also ICOs that have started after June 1, 2018 but are still active as of June 30, 2018 are included $. In Columns (3) and (6), the fundraising success is set to zero if the company does not report the amount of funds raised. T-statistics are shown in brackets. ***, **, and * indicate significance at the 1%, 5%, and 10% level.

Table 5: ICO Activity and Cryptocurrency Sentiment

	(1)	(2)	(3)
Ln(Bitcoin Price)	1.694***		0.957***
	(17.69)		(3.44)
Ln(Ethereum Price)		1.008***	0.458**
		(16.58)	(2.72)
Constant	-9.308***	-0.646**	-5.594***
	(-13.03)	(-2.35)	(-3.83)
R2	0.913	0.911	0.938
N	32	29	29

The Table reports the estimated coefficients from cross-sectional regressions using OLS:

$$ln\left(Number\ of\ ICOs_t\right) = \alpha + \beta_1 ln\left(Bitcoin\ Price_t\right) + \beta_2 ln\left(Ethereum\ Price_t\right) + \epsilon_t$$

The dependent variable in each regression is the natural logarithm of number of ICOs. For each ICO j, we count the number of ICOs that are active at the beginning date of ICO j. The independent variables - Bitcoin and Ethereum prices - are expressed in U.S. $. T-statistics are shown in brackets. ***, **, and * indicate significance at the 1%, 5%, and 10% level.

Table 6: Signaling and Cryptocurrency Sentiment

	(1)	(2)	(3)	(4)	(5)	(6)
Investor Supply	-0.170***	-0.173***	-0.131***	-0.089**	-0.114***	-0.071**
	(-4.45)	(-5.21)	(-4.29)	(-2.41)	(-3.46)	(-2.46)
Number of ICOs	-0.052	-0.068**	-0.127***	-0.208***	-0.191***	-0.264***
	(-1.36)	(-2.04)	(-4.16)	(-5.19)	(-5.40)	(-8.59)
Investor Supply × Number of ICOs	-0.077**	-0.063*	-0.068**	-0.065*	-0.052*	-0.060**
	(-2.06)	(-1.94)	(-2.20)	(-1.84)	(-1.65)	(-2.10)
KYC Dummy				0.303***	0.278***	0.337***
				(3.03)	(3.25)	(4.33)
Whitelist Dummy				0.527***	0.395***	0.552***
				(5.16)	(4.47)	(6.90)
Constant	-0.004	-0.002	-0.002	-0.322***	-0.263***	-0.301***
	(-0.10)	(-0.06)	(-0.07)	(-6.31)	(-5.76)	(-7.91)
R2	0.038	0.038	0.037	0.143	0.107	0.159
N	672	879	1039	672	879	1039

The Table reports the estimated coefficients from cross-sectional regressions using OLS:

$$\begin{aligned} ICO\ Fundraising\ Success_j =& \alpha + \beta_1 \cdot ICO\ Investor\ Supply_j + \beta_2 \cdot Number\ of\ ICOs_j \\ &+ \beta_3 \cdot ICO\ Investor\ Supply_j \times Number\ of\ ICOs_j + \gamma X_j + \epsilon_j, \end{aligned}$$

The dependent variable in each regression is the ratio of ICO total funds raised to hard cap. Both the fundraising success and investor supply are expressed in percentage points. The number of ICOs is defined as in Table 5. All the variables besides dummies are normalized. In Columns (1), (3), (4) and (6), only ICOs that have been completed before June 30, 2018 are included. In Columns (2) and (5), also ICOs that have started after June 1, 2018 but are still active as of June 30, 2018 are included $. In Columns (3) and (6), the fundraising success is set to zero if the company does not report the amount of funds raised. T-statistics are shown in brackets. ***, **, and * indicate significance at the 1%, 5%, and 10% level.

Table 7: Signaling and Ex-Post Measures of ICO Success

	(1)	(2)	(3)	(4)	(5)
Investor Supply	-0.040*			-0.030***	-0.015
	(-4.01)			(-1.82)	(-1.34)
Fundraising Success		0.182*	0.197*	0.176*	0.198*
		(12.50)	(22.09)	(10.59)	(17.93)
Constant	0.184*	0.319*	0.195*	0.317*	0.211*
	(18.61)	(21.90)	(21.79)	(19.47)	(19.36)
R2	0.010	0.153	0.248	0.158	0.241
N	1521	867	1480	691	1067

The Table reports the estimated coefficients from cross-sectional regressions using OLS:

$$ICO\ Listed\ Dummy_j = \alpha + \beta_1 \cdot ICO\ Investor\ Supply_j + \beta_2 \cdot ICO\ Fundraising\ Success_j + \epsilon_j$$

The dependent variable in each regression is the dummy variable that equals to 1 if an ICO j is listed on the exchange. Both the investor supply and fundraising success are expressed in percentage points and normalized. In Columns (3) and (6), the fundraising success is set to zero if the company does not report the amount of funds raised. T-statistics are shown in brackets. ***, **, and * indicate significance at the 1%, 5%, and 10% level.

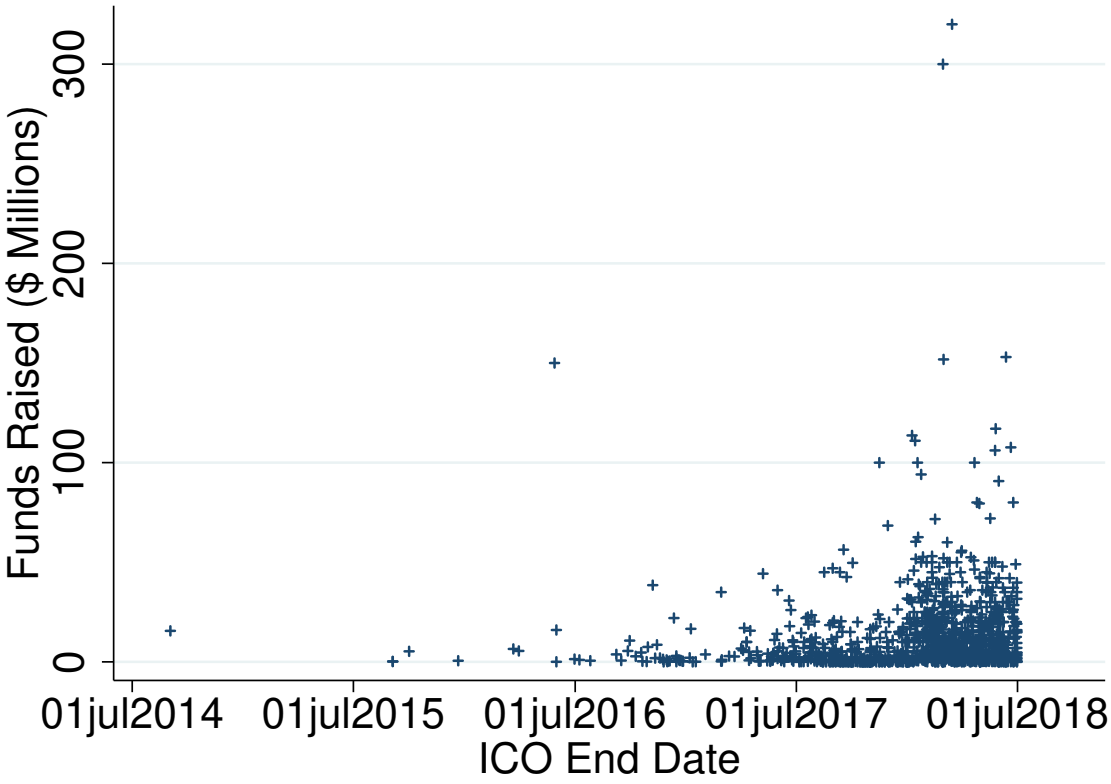
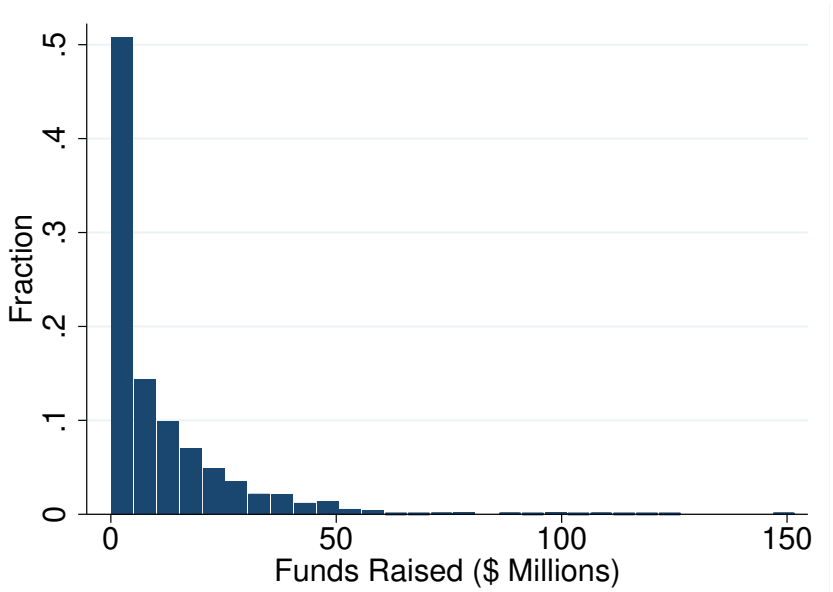
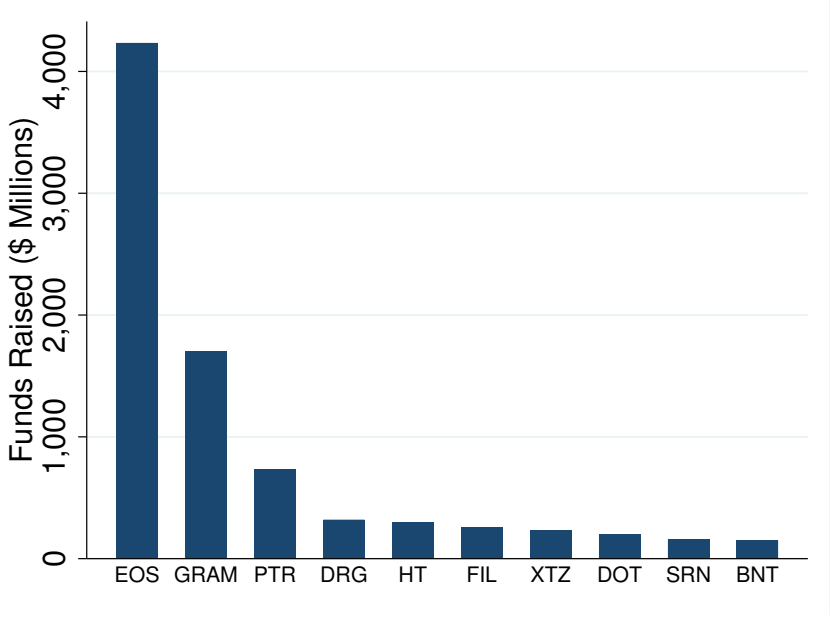


Figure 1: ICOs by Funds Raised and Date

The Figure is a scatter plot where each points represents an ICO. The $x-$value is the end date of the ICO and the $y-$ value is the amount of funds raised in the ICO denominated in the U.S. $. We only include the ICOs that have completed as of June 30, 2018. The ICOs with the amount of funds raised above $500 million are excluded.



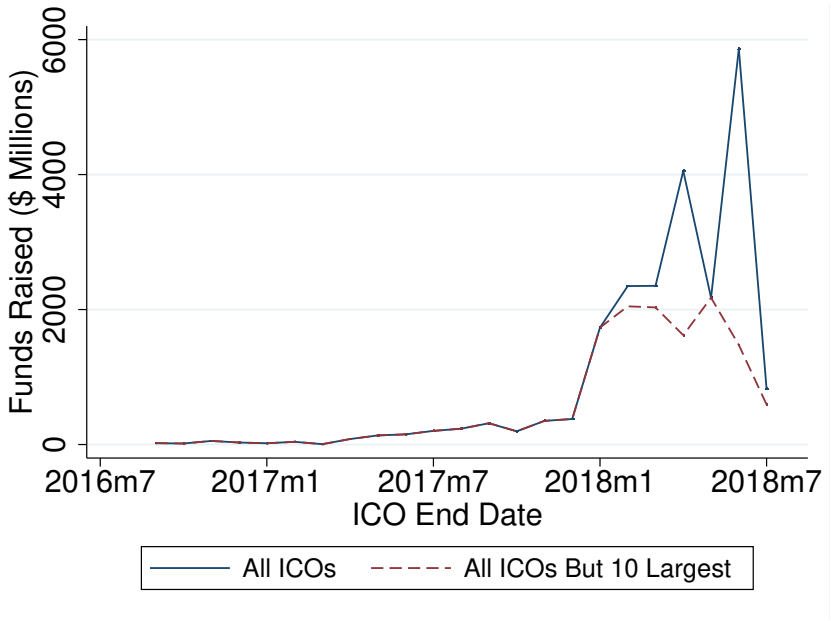
(a) Distribution of ICO Funds Raised



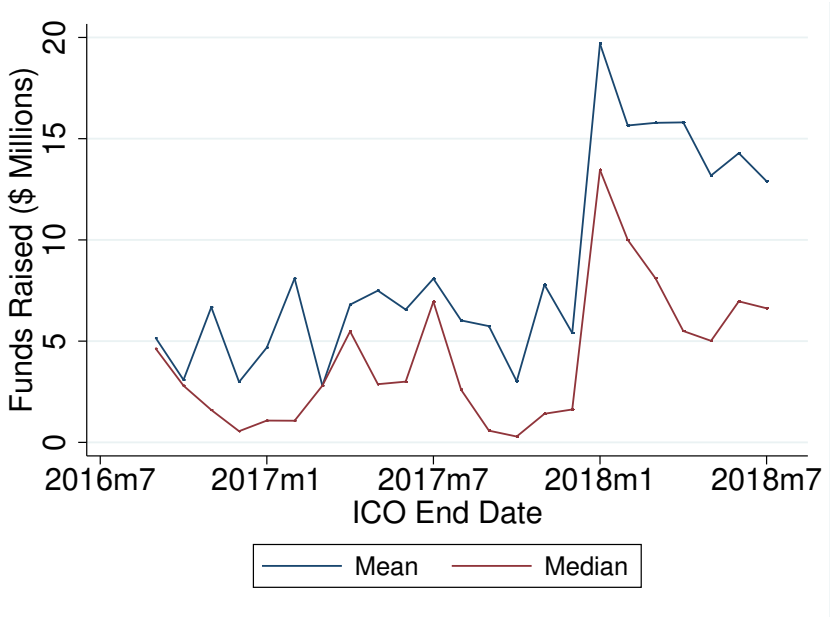
(b) Top 10 Largest ICOs

Figure 2: ICOs by Funds Raised

Panel (a) of the Figure depicts the distribution of ICOs by the amount of funds raised. Top 10 largest ICOs are excluded. Panel (b) of the Figure features the top 10 largest ICOs. The horizontal axis represents the project ticker and the vertical axis represents the amount of raised funds. *EOS* corresponds to the project EOS, *GRAM* – Telegram Open Network, *PTR* – Petro, *DRG* – Dragon, *HT* – Huobi Token, *FIL* – Filecoin, *XTZ* – Tezon, *DOT* – Polkadot, *SRN* – Sirin Labs, and *BNT* – Bancor.



(a) Aggregate Funds Raised



(b) Average Size of ICOs

Figure 3: Total Raised Funds

Panel (a) of the Figure depicts the aggregate capital raised in the ICO market starting from July 2016 until July 2018. Panel (b) of the Figure plots the cross-sectional mean and median of the amount of funds raised starting from July 2016 until July 2018. The raised funds are denominated in the U.S. $.

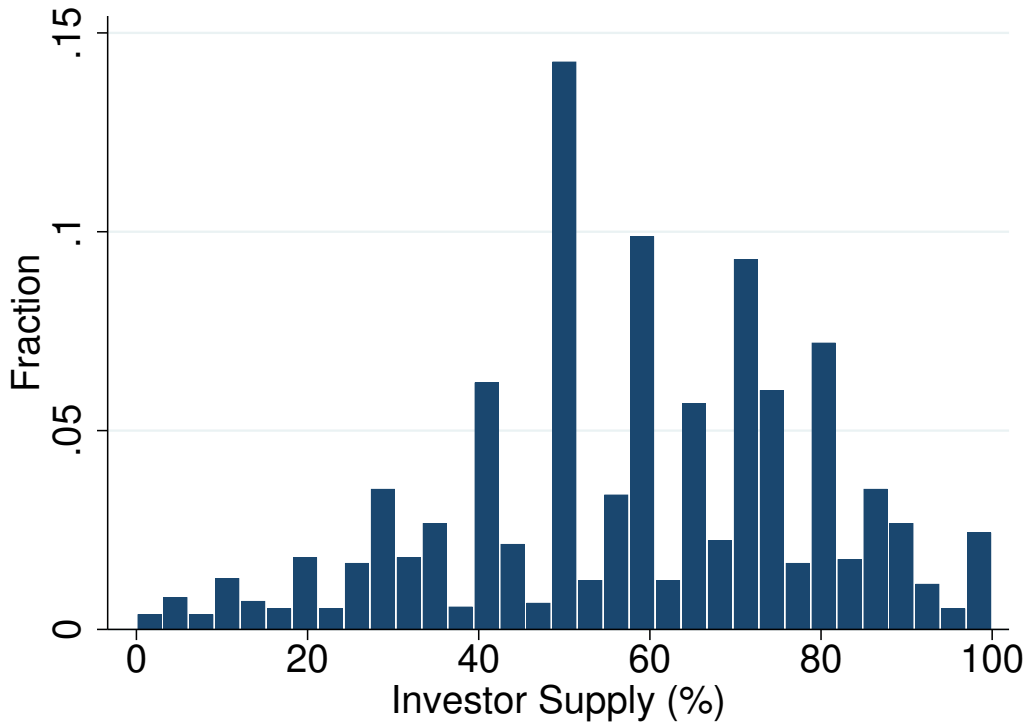


Figure 4: Distribution of ICO Investor Supply

The Figure depicts the distribution of ICO investor supply. Only ICOs that have been completed before and on June 30, 2018 are included.

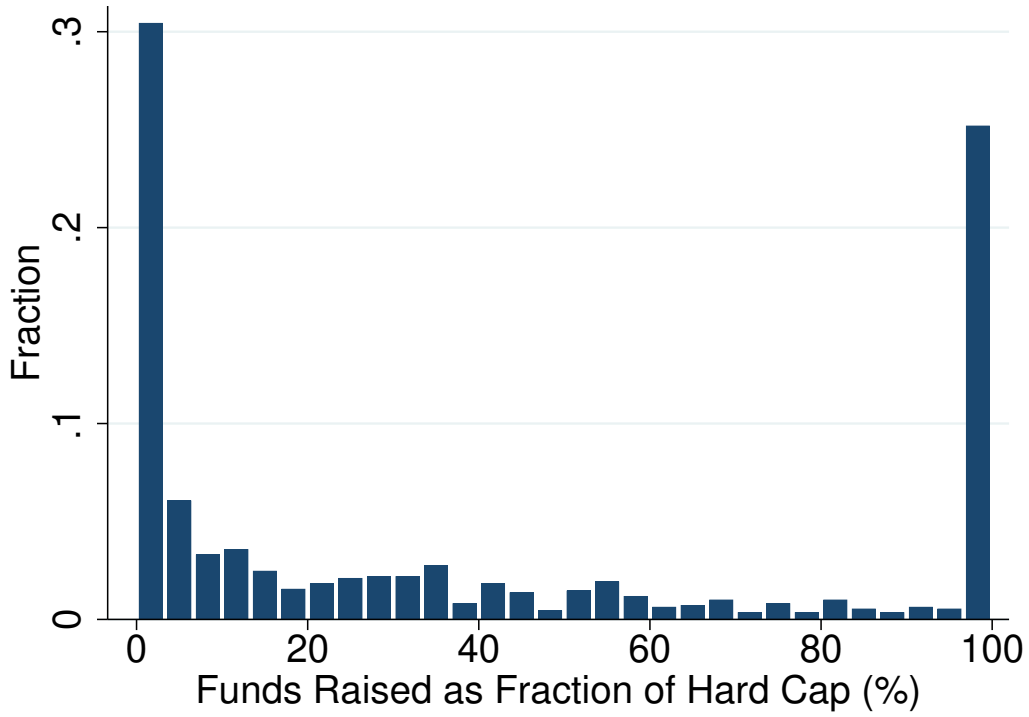
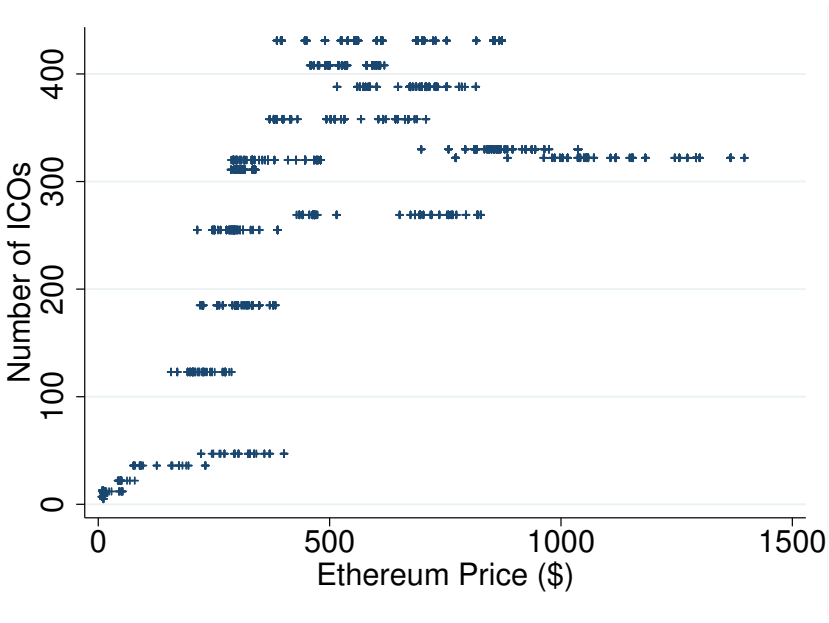
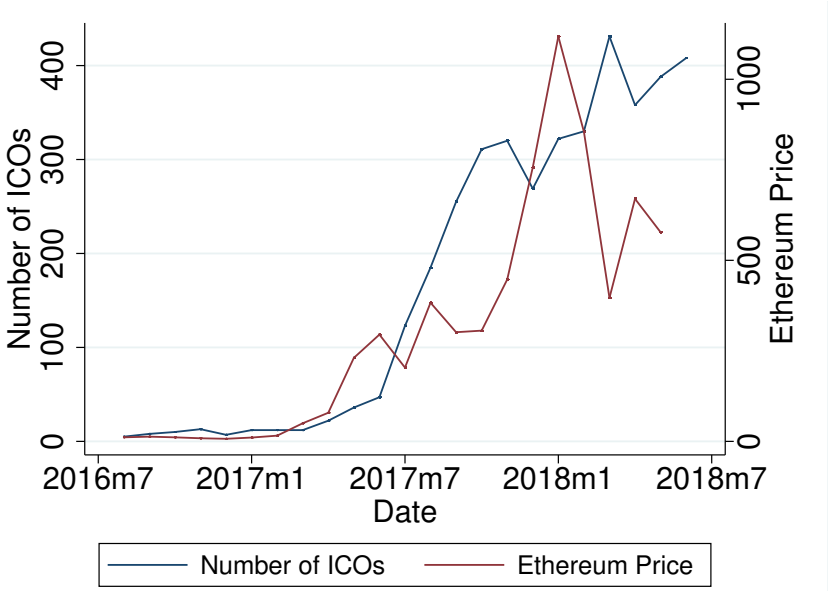


Figure 5: Distribution of ICO Fundraising Success

The Figure depicts the distribution of ICO raised funds as a fraction of hard cap. Only ICOs that have been completed before and on June 30, 2018 are included. The ICOs with non reported funds raised are omitted.



(a) Scatterplot of Number of ICOs and Ethereum Price



(b) Time-Series of Number of ICOs and Ethereum Price

Figure 6: ICO Activity and Cryptocurrency Sentiment

Panel (a) of the Figure is a scatter plot where each points represents an ICO j. The $x-$value is the Ethereum price denominates in the U.S. $ and the $y-$ value is the number of ICOs happening at the same time as the ICO j. Panel (b) of the Figure depict time-series of the Ethereum price (right vertical axis) and the number of ICOs (left vertical axis) starting from July 2016 until June 2018.