Tokens and ICOs: A Review of the Economic Literature

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1 Introduction

Initial Coin Offerings (ICOs hereafter) are marketed as an alternative to Initial Public Offerings (IPOs) for ventures who wish to raise funds. Even though their names are similar, the two processes are quite different. IPOs are usually run by established companies with proven track records in terms of profitability. Moreover, IPOs are associated with the sale of specific equities which are submitted to clear regulations. ICOs are instead organized by startups to raise capital through a token sale directed at a crowd of investors. Often, this token is a cryptocurrency, a digital medium of exchange based on some Distributed Ledger Technology.

The first reported ICO was conducted by Mastercoin in 2013, with the fundraising event running for almost one month. Mastercoin proposed the implementation of a payment system, and raised close to 5,000 bitcoins, valued around $500,000 at the time. Between 2015 and 2017, about 1,000 ICOs followed, raising more than $6 billion from the public, thus vastly exceeding venture capital investments in funding innovative projects related to blockchain technology. For comparison, in 2017, blockchain entrepreneurs raised $5 billion through ICO offerings, as opposed to $876 million through venture capital funding. In 2018, according to ICObench, 2,218 ICOs reached their conclusion and investors could choose, on average, among 482 token sales per day.[1] This outburst led to tremendous excitement around cryptocurrencies as a new funding model for innovation in the upcoming digital age. But the euphoria proved to be short-lived: outright fraud, rampant speculation and the resulting

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[1]Financial estimates as reported by coindesk.com.

volatility in the trading of many cryptocurrencies eventually eroded investor confidence. By the closing months of 2018, the ICO market had recorded a radical downturn.

At the time of writing, the jury is still out on whether ICOs can provide a durable alternative to venture capital. Because ICOs are fundamentally different from other financing arrangements, they cannot be designed nor evaluated using off-the-shelf techniques. Instead, ICOs require a new analytical framework, and our contention is that they will not be ranked equally alongside other financing instruments until we have acquired a proper understanding of their specificity. The objective of this survey is to provide readers with an overview of the ongoing efforts towards that goal. Given the burgeoning growth of the field, we make no claim to having been thorough in our coverage of the related literature. In particular, we focus on theoretical insights and refer readers interested in empirical findings to the survey by Li and Mann (2018), and readers interested in the rapid evolution of ICO regulation to Collomb et al. (2018). We hope that those whose work we have overlooked will understand and forgive.

The paper is structured as follows. Section 2 describes how ICOs are conducted and provides an overview of data on their market history. Section 3 discusses the corporate finance issues raised by ICOs and how they should and should not be designed in order to align the interests of sellers and buyers of digital coins. Section 4 presents a few models of ICO pricing, while Section 5 concludes by discussing the numerous challenges that still have to be tackled.

2 Description

Tokens vs. Cryptocurrencies. Before describing the process of conducting an ICO, it is important to dispel the common misconception according to which all tokens are substitutes of Bitcoin. Although early blockchain projects, such as Mastercoin, were indeed inspired by Bitcoin, the current wave of ICOs is financing infrastructures and platforms whose scopes go well beyond the realms of payment systems. Accordingly, although cryptocurrencies are indeed tokens, all tokens are not cryptocurrencies. Whereas cryptocurrencies are digital assets which are used for the sole purpose of making or receiving payments, tokens are virtual representations of an asset or utility within their specific blockchain ecosystem. Take for instance Ether, the token native to the Ethereum platform. Ethers are used to pay the transaction fees required by miners for the execution of the smart contracts recorded on the Ethereum blockchain. Hence Ethers can be consumed to record payments, but they also allow their owners to perform a much broader set of transactions.

The plasticity of tokens has been leveraged by their issuers to raise funds across a vast array of industries and applications. The usual metaphor is that utility tokens are a modern form of vouchers since they entitle their holders to a discount or to the right to exchange them against the services provided by the platform that recognizes them. Finally, native tokens are distinguished from other tokens depending on whether or not they have been issued on the same blockchain as the one that provides the services.[2] Bitcoin and Ether are examples of native tokens. An example of not native tokens are REP, which allow their owners to access Augur's prediction market but they have been issued on the Ethereum platform through the execution of a specific custodial contract.[3] To understand how this can be done, we now have to dive into the inner workings of ICOs.

The ICO Process. Typically, companies wishing to enter the ICO process will lay down their plans in a public document called a white paper. This document is similar to traditional investment documents for IPOs. It describes the service that the company intends to build, how the associated token relates to that service, how token holders stand to gain, and how the funds obtained will be allocated to various aspects of the project. The service itself can be anything from an on-line gambling game to be run as a smart contract on an existing blockchain, to an entirely new concept of blockchain. The white paper also describes the parameters of the token sale such as: the starting and closing dates of the sale, the price of the token (often on an increasing schedule), the total amount of tokens minted, the amount of tokens reserved for the team leading the ICO. Plans for the creation and allocation of tokens during the lifetime of the platform are also laid out. An important additional parameter is how long a token will be locked up before becoming tradable. It is often the case that a substantial amount of tokens are sold privately prior to the public token sale, in which case price and lockup conditions may be different.

The white paper also needs to describe the medium of the sale itself. By and large, ICOs have used specific smart contracts on the Ethereum blockchain to conduct their sales. An investor willing to buy a certain amount of tokens has to obtain a corresponding amount of cryptocurrency and to transfer that amount to the dedicated contract which will lock up that amount until the closing date. The contract may define a soft and a hard cap. The hard

[2] There is some disagreement on the terminology as some users prefer to use the term coins for assets that are native to their own blockchain, and reserve the term token for assets that are created on existing blockchains.

[3] This contract belongs to the often used ERC-20 class and can be examined at Etherscan (Etherscan).

cap fixes a maximum amount of token to be sold. The soft one fixes a minimum one. If at the closing date the total amount of token sold is under the soft cap, the operation is cancelled and buyers are refunded. The initial token price is usually written in the cryptocurrency native to the chain which hosts the sale contract.

The fact that investors buy their tokens with a cryptocurrency and that the entire operation can be conducted on the associated chain as a smart contract has interesting consequences. For one thing the traditional IPO ecosystem of financial advisers and various intermediates is completely bypassed. Second, there is an exchange risk as the cryptocurrency is volatile relative to fiat. Because the investment process locks the buyers' payment, if the sale is unsuccessful, it may be that the amount refunded has a much lower fiat value than it had at the start. Third, the target audience of the sale is international and the sale therefore addresses a large and diverse community of buyers. Buyers typically go through some KYC process (know your customer) to establish a modicum of identification both for regulatory purposes and for marketing ones. In the case where the service to be built is not hosted on the chain(s) used to collect the investments, there is also a question of whether to trust the proponents of the ICOs. Scams exist but most of the investment risk lies simply in assessing the value proposition of a project and whether its proponents will execute it as planned. Often promises are either unrealistic and/or not pursued. These concerns have been mitigated by the recent emergence of so-called IEOs (initial exchange offerings). These are bona fide ICOs but the sale process differs. Sales are mediated by a crypto-exchange. Investors are offered a selected set of projects, presumably of higher investment quality, and a promise from the exchange to list the token. The latter may be a critical incentive for short-term traders and indeed the first IEOs have been susbcribed in no time—triggering a rebirth in the world of ICOs.

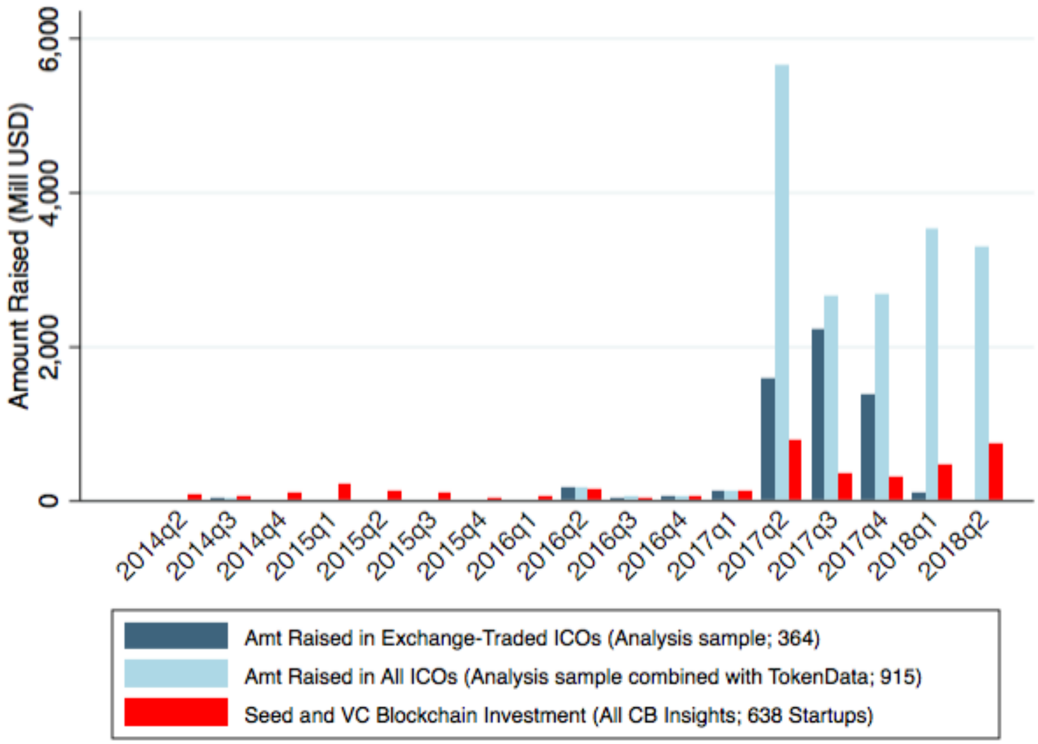
Market History. Aggregate all-time ICO proceeds reached \$22.5 billion by the end of October 2018, with an average ICO size increasing from \$4.35 million in 2014 to \$25.72 million in 2018. Moreover, ICOs have displaced equity issuance and venture capital as sources of capital for blockchain-based startups.

To give an overview of the evolution of capital raised and geographical distribution of ICOs, we draw on the following two papers: Benedetti and Kostovetsky (2018) and Howell et al. (2018). Both articles combine data from CoinMarketCap and other websites, as there is currently no industry-standard data source. More precisely, Howell et al. (2018) combines ICOs from TokenData.io and CoinMarketCap.com. Benedetti and Kostovetsky

(2018) collect data from five aggregator websites which, when combined, give the largest number of ICOs, the most available characteristics, and the highest accuracy: icodata.io, ICObench.com, icorating.com, icodrops.com, and ico-check.com, and CoinMarketCap. For the most recent periods, we rely on data from ICObench.com.[4]

Howell et al. (2018) show that between January 2014 and June 2018, ICOs raised over $18 billion, as in Figure 2.1, with a pick in 2017q2, when at least 15 individual ICOs have raised more than $100 million.

Figure 2.1: Amount Raised Through ICOs, 2014q2 - 2018q2.



Note: This figure compares the amount raised through ICOs with the amount raised by blockchain-related startups. Data is quarterly from 2013 through the second quarter of 2018. The dark blue bars show total funding in our estimation sample of 453 exchange-traded ICOs (of which amount raised is non missing for 364). The light blue bars combine our estimation sample with all remaining tokens that had completed ICOs and available amount raised from the TokenData database. Source: Howell et al. (2018).

After the summer 2018, the trend changed. ICObench reports a decline in the ICO market as the number of completed projects in 2019q1 was twice less comparing with 2018q4. The

[4]Note, however, that the patterns described here are broadly similar across all the empirical literature and specialised websites that we are aware of.

overall amount of funds raised in 2019q1 is of about $1bn. However, the average funds raised in the same period ($8.4 million) is higher than in 2018q4 ($6.8 million), and the percentage of ICOs that raised a positive amount of funds is nearly the same (35-33%), even though their number decreased (from 207 to 107).

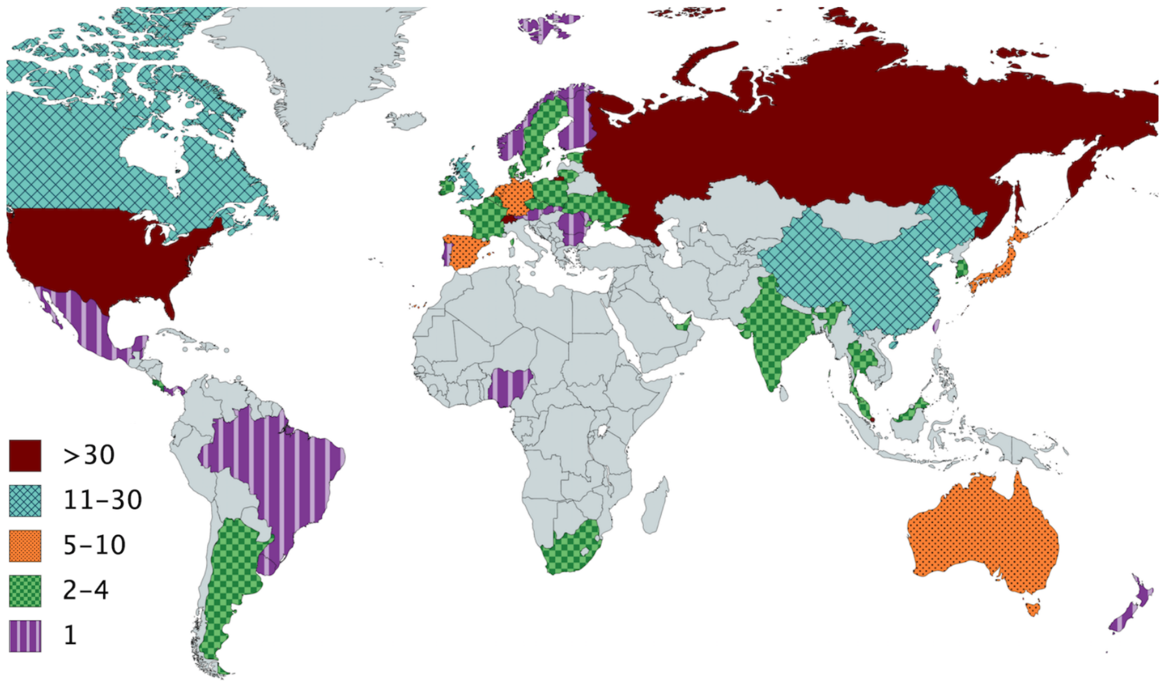
The change in trend at the end of 2018 concerned ICOs' duration as well. The mean ICO duration was between 37 and 40 days in Benedetti and Kostovetsky (2018) and Howell et al. (2018), and it increased to 97 days in January 2019, according to ICObench. Finally, in Benedetti and Kostovetsky (2018), listing ICOs exhibit a median return of 21%, but a mean return of 246%, from the ICO closing price to the first opening price. Over a longer horizon, Howell et al. (2018) find that, conditional on listing on CoinMarketCap, the mean five-month cumulative excess return over Bitcoin is +150%, while the median is -50%.

Even though these numbers cannot be directly compared across sources, as they are sensitive to the details of sample construction, they all reflect a heavily-skewed distribution of ICO proceeds, with a small number of highly-successful transactions driving much of the aggregate activity. This is not abnormal in the world of startup financing. Venture capital firms make most of their profits from only a few investments. The dotcom bubble, for instance, generated many failed companies, but it also gave rise to giants like eBay and Amazon.

Figure 2.2 (Howell et al., 2018) shows the distribution of ICOs by country as of April 2018. Since these are token sales for decentralized digital platforms, they do not really have a single home country. In fact, the team of entrepreneurs and employees are often from many different countries, and the country of registration or incorporation is usually chosen for legal and tax reasons, which is why noted havens like British Overseas Territories, Singapore, Switzerland, Cyprus, and the Baltic States, especially Estonia, are overrepresented in Figure 2.2. The largest English-speaking countries and Russia are also popular locations for ICOs.

In 2019q1, ICObench reports that the United States, Singapore and the United Kingdom were the countries hosting the largest number of ICOs since 2015, and these three were also the countries with more new ICOs ending during 2018. In the last year, the U.K. overcame Russia in the general ranking, while Germany reached the eighth position, overtaking Canada and the Netherlands - the latter of which exited the top 10. Considering the whole sample of ICOs indicating a precise localization in their white papers, the spatial concentration decreased from 2017 to 2019, but remains very high: ICOs hosted by the top 10 countries account for about 76 percent of the capital gathered, and the projects establishing their headquarters in the United States alone amassed almost 30 percent of the funds. In 2017, these values were even higher: 90 percent and 61 percent, respectively. Moreover, in response to risks and potential abuses, China banned cryptocurrencies at the end of 2017 and South Korea has pursued stern regulatory policies.

Figure 2.2: The Geography of ICOs.



Note: This figure shows the location of ICO issuers in our sample. Not shown are the Cayman Islands (3 ICOs), Curacao (1), Cyprus (1), Gibraltar (1), Marshall Islands (1), Saint Kitts (1), and ICOs whose teams are dispersed across >4 countries (28). There are additionally 87 ICOs whose issuer locations are unknown. Source: Howell et al. (2018).

In this regard, Benedetti and Kostovetsky (2018) show that ICOs are mostly located in countries with above-average World Bank Rule of Law rankings and high standards of living, two metrics which are highly correlated with each other. They also show that these two measures are positively associated with ICO success, with listed ICOs originating from countries that are 0.2 points higher in their Rule of Law rating and have about \$4,000 more in GDP per capita, relative to their entire sample.

3 Corporate Finance of Tokens

So far we discussed the use of tokens as a means to raise funds. But tokens can also be used to generate incentives. For example, as already discussed in previous chapters, blockchain protocols combine cryptographic tools and economic incentives. The main purpose of a protocol's token is precisely to provide those incentives, because it can be used to remunerate the network participants according to rules specified within the protocol itself.[5] Of course, for these tokens to generate incentives two additional conditions must be satisfied. First, they must have positive value, which is typically achieved by establishing that the token is necessary in order to operate the protocol.[6] Second, the token must be tradeable so that it can be exchanged for goods and services, either directly or by first exchanging them for fiat money.

By virtue of having positive value and being tradeable, a token that is successful in generating incentives within the protocol can also generate incentives *off-protocol*. For example, the team behind a specific blockchain-based protocol may hold a large number of tokens initially. To the extent that the quality of the protocol (scale, reliability, usability, security, expressivity, privacy-related guarantees, governance structures . . .) determines the value of the protocol's token, then holding a large stock of tokens provides incentives to work hard and produce a high-quality protocol.

In this section we review the theoretical literature studying the role of tokens in generating off-protocol incentives. We call this body of literature "corporate finance of tokens" because it studies the impact of tokens on traditional corporate finance decisions such as whether and how to raise financing, what investments to undertake. It is however important to keep in mind that, in the context of blockchains and tokens, those decisions may be relevant also

[5] Note that this problem is specific to public blockchains. In private blockchains, an organization (either a consortium or a single firm) determines who can participate to the network. This organization also provides incentives to the network participants. This is why private blockchains do not need to use tokens.

[6] The simplest way to make a token necessary is to establish it as the internal currency of the protocol (see decentralized marketplaces such as Golem, Sia, Filecoin, iExec). But the function of a token within a protocol can be extremely complex. For example, MakerDAO is a blockchain based protocol that allow users to create Collateralized Debt Obligation (CDO) by locking a given amount of Ethers in a smart contract. The system is designed so that the USD-value of these obligations is roughly constant. Its associated token is MKR and has several uses. For example, a user who wants to retrieve his collateral will need to pay a fee established in MKR. Also, if the value of the collateral falls below the nominal value of the CDO, the protocol will automatically liquidate the collateral, and simultaneously sell newly created MKR so to cover the shortfall. MKR holders are therefore bearing the risk associated with issuing the CDO. Finally, MKR holder can vote to change some parameters of the protocol (such as the fee required to retrieve a collateral or the threshold below which a collateral is liquidated).

to organizations that are not corporations but consist of a loose group of developers working on the same open-source project.

We divide the analysis in two parts, each corresponding to a specific type of token. In the first part, we consider tokens that are associated to blockchain-based protocols. The specificity of this case is that a developer (or a group of developers) releases the protocol as an open-source, free to use piece of software, that can be used by third parties to transact with each other. These transactions are fully disintermediated, in the sense that the developer does not impose fees or prices for using the technology. The developer's source of revenue is the sale of the token which is required to use the protocol. This case covers the largest ICOs to date, as well as tokens representing at least 90% of the total crypto-market.[7]

In the second part, we consider tokens that represent contracts between issuers and the token holders.[8] For example, a token may represent a voucher and therefore give the right to acquire a good or a service from the issuer. Or it may represent a full-fledged security, such as a claim to the issuer's profits or revenues. Importantly, in this case the issuer is typically a company operating a business that may be completely unrelated to blockchain (except for the issuance of tokens). Although quantitatively less important than the first case, tokens belonging to this second category seem poised to play a central role in the future due to their relevance to firms in general, not only to those developing blockchain-based protocols.

Although useful, this classification also has limitations. The main one is that it can be ambiguous whether a specific token falls into one or the other category. The reason is that the developer of a blockchain-based protocol could sell the protocol's tokens before the protocol is mature enough to be used, under the expectation (explicit or implicit) that he will complete the work in the future. Establishing whether, in this case, buyer and seller of the token enter into a contractual agreement (and the type of contract) is the core of the debate regarding the regulation of ICOs. It will not, however, be discussed here.[9]

A second limitation is that some of the papers discussed below, although most closely related to one case may be relevant for the other case as well. For example, several authors argued that the way the token is sold can help overcome coordination failures whenever there

[7]At the time of writing, among the top-30 tokens the only ones that are not associated to blockchain-based protocols are Binance Coin (a voucher to access Binance, an exchange) and Tether (a token backed by USD deposits). The value of the remaining 28 tokens is 90% of the total crypto-market (data from `http://www.coinmarketcap.com`).

[8]Here contract is synonymous with agreement. A different matter is whether this agreement can be legally enforced. This is, indeed, an area open for additional research. See the conclusions for further discussions.

[9]See Collomb et al. (2018) for an analysis of the regulatory issues raised by ICOs.

are network externalities. Indeed, a successful ICO may create the expectation that many people will want to use the protocol, and this expectation may induce even more people to use the protocol (see Li and Mann, 2018, discussed below). Network externalities are extremely important for blockchain-based protocols, and hence this insight primarily applies to the first case. But it may also be relevant to the second case if the token issuer is building a platform or any other business with strong network externalities. With these two caveats in mind, we now proceed to discussing the relevant literature.

3.1 Protocol Associated Tokens

Papers studying the role of tokens associated to blockchain-based protocols in generating off-protocol incentives can be roughly divided in three groups: those studying the incentives to develop a blockchain protocol (Canidio, 2018); those studying the incentives to adopt a blockchain protocol (Bakos and Halaburda, 2018, Cong, Li, and Wang, 2018, Sockin and Xiong, 2018, Li and Mann, 2018); and those studying the incentives to maintain a decentralized platform[10] (Cong, Li, and Wang, 2019).

To the best of our knowledge, the only paper studying the incentives to create a blockchain-based protocol is Canidio (2018). In the model, a developer can exert effort and invest funds in the development of a blockchain-based protocol. The developer holds the initial stock of tokens and can choose when to hold an ICO. Following the ICO, in every period there is a frictionless market for tokens where users, investors and the developer himself can trade tokens. The protocol can be used indefinitely, but the developer has a finite life-span and hence, at some point, will sell all his tokens and exit the game.

Tokens therefore can be sold to raise funds to invest in the development of the protocol, or they can be sold to earn a profit. The main result is that there is a trade off between these two uses of tokens. The reason is that in every period in which the market for tokens is open, in equilibrium there is a positive probability that the developer will sell all his tokens and, as a consequence, no development will occur. Holding an ICO, therefore, allows the developer to raise funds but also introduces the possibility that the developer will dump all his tokens on the market in the future. Interestingly, the equilibrium is inefficient even if the developer has enough own funds to invest in the development of the protocol (and hence the only role of tokens is to generate a profit). From the social welfare viewpoint, effort and investment

[10] A decentralized platform is the peer-to-peer network generated by the different users of a blockchain-based protocol.

should maximize the present discounted value of the surplus generated by the protocol. The developer instead maximizes the price at which he can sell his tokens, that depends exclusively on usage of the protocol during the period in which he expects to sell his tokens. He therefore ignores completely that the protocol will generate value intertemporally.[11]

Sockin and Xiong (2018), Cong, Li, and Wang (2018), Bakos and Halaburda (2018), and Li and Mann (2018) study the role of tokens in achieving high-adoption equilibria in decentralized platforms. Because the value of the platform for potential users will depend on the overall level of adoption (network externalities), each person will want to join a decentralized platform only if he/she expects other people to join as well. This scenario may give rise to multiple equilibrium levels of adoption. A specificity of a decentralized platform (relative to all other contexts in which there are network externalities) is that all exchanges occuring on the platform must use the protocol (and platform) specific token. The papers above study how the presence of such token affects a platform's equilibrium levels of adoption. In Sockin and Xiong (2018), agents first purchase tokens and then trade on a decentralized platform. They compare the set of equilibria under full information, to the set of equilibria emerging when users do not know other users' demand functions. Their main result is that the token price and volume are noisy signals for the demand for the platform, and determine what type of adoption equilibrium will emerge. Cong, Li, and Wang (2018) consider an infinite-horizon, continuous-time model in which agents purchase tokens to trade on a platform. In this environment, holding a token is valuable because it allows to transact on the platform and because it may appreciate in value. This second dimension introduces a new, *intertemporal* source of network externalities: holding tokens is more valuable if more users are expected to hold tokens in the future. Relative to a benchmark without tokens, the presence of tokens therefore "accelerate the adoption of productive platforms or precipitate the abandonment of unproductive platforms."[12]

Bakos and Halaburda (2018) and Li and Mann (2018) study how the creator of the platform can sell tokens in a way that induces the high adoption equilibrium. Bakos and Halaburda (2018) consider a 2-period model, in which, in every period, the token issuer will sell tokens and then users will trade on the platform. Period-1 users can purchase tokens only from the issuers, while period-2 users can purchase tokens also from period-1 users.

[11] Interestingly, depending on the parameter of the model, the developer may be over-investing or under-investing in the development of the protocol (relative to the first best).

[12] Cong, Li, and Wang (2018), page 6. In their model, productivity measures the overall technological quality of the protocol which evolve stochastically over time.

The main result is that the platform owner is always better off *not* introducing tokens, and instead inducing the high adoption equilibrium via negative initial prices (i.e., a subsidy). Tokens will therefore be used only when the platform owner is cash constrained and cannot pay those subsidies. The intuition is that tokens have "equity-like" properties because early adopter benefit from the token appreciation (which depends on the platform future success) therefore reducing the platform owner's profits. In Li and Mann (2018), the platform owner sells tokens initially in an ICO, and then users use tokens to transact in a infinitely-repeated game. They show that the sale of tokens at ICO can be used to induce the high-adoption equilibrium. Because tokens are worthless elsewhere, purchasing them signals the intention to use the platform. A successful ICO sale generates the expectation that those who purchased at ICO will use the platform and therefore induces participation also of users who did not purchase the token at ICO. Note, however, that this logic may simply shift the coordination problem from the platform adoption phase to the ICO phase, because users will want to purchase tokens only if other users will purchase. Li and Mann (2018) show that holding the ICO over multiple periods and having an increasing price schedule for tokens (as it is commonly observed in ICOs) can overcome this second coordination problem.

Cong, Li, and Wang (2019) build on Cong, Li, and Wang (2018) to study the incentives to maintain a decentralized platform by a platform owner. The owner chooses how many tokens to create in each period, and then uses these tokens to pay workers who will increase the value of the platform (by, for example, fixing small bugs or participating to the platform as miners). The choice of how many tokens to create affects the platform owner's payoff in several ways. Creating new tokens increases the monetary supply and therefore decreases the price of tokens. But to the extent that these new tokens are used to pay workers (instead of being consumed by the platform owner), they will increase the value of using the platform and the demand for tokens. The main result is that the platform owner will choose the monetary policy that maximizes the value of the platform. That is, he does not want to issue too many tokens today because this would decrease the price of tokens, the extent to which workers are willing to be paid in tokens, and hence the value of the platform. One can compare with Canidio (2018) where the developer (also the platform owner) chooses both how many tokens to sell on the market and how much effort to exert in the development of the protocol. That latter model will better fit a situation in which the technology underlying the decentralized platform (that is, the protocol) still needs to be fully developed. In Cong, Li, and Wang (2019) instead there is no such effort, and hence the model better fits a situation in which the technology underlying the decentralized platform already exists.

3.2 Tokens as Contracts

Any company or startup, whether related to blockchain or not, can enter into agreements and issue securities. In some cases these agreements and securities can be traded and exchanged, often in electronic form (think about bonds, shares, vouchers and coupons). On a superficial level, therefore, blockchain-based tokens are just one of the possible electronic forms that these agreements and securities can take.

In reality, however, tokens have distinct advantages. The first one is that issuing (and then exchanging) agreements and securities in the form of tokens can be done at virtually no cost. This is the reason why ICOs have been so successful and is the subject of much of this chapter. The second advantage is that the space of feasible contracts is enlarged, that is, tokens allow the contracting parties to specify provisions that cannot be specified in a traditional contract. This is achieved thanks to smart contracts, which can be used, for example, to pay token holders automatically if certain conditions are met, or to automatically provide a service to token holders.

There is an emerging literature studying the problem of a firm that can finance its cost of production by selling tokens in an ICO, and compare ICO financing with traditional equity financing from a venture capitalist (VC) or debt financing. Within this literature, Catalini and Gans (2018), Chod and Lyandres (2018) and Garratt and van Oordt (2019) assume that tokens represent a pre-sale of output, that is, a firm issues tokens and simultaneously commit to accepting those tokens as sole mean of payment in the future. From the technical viewpoint, these models borrow from the literature on crowdfunding with the difference that, whereas with crowdfunding only users pre-purchase products, in an ICO also investors can purchase tokens with the goal of reselling them (to users) at a profit. Catalini and Gans (2018) consider an entrepreneur who, by paying an initial cost, can start a project of unknown quality. To finance the initial cost the entrepreneur can sell tokens at an ICO. In this case, he needs to decide the price for tokens, the token-denominated price for its service, as well as the growth in the supply of tokens over time. They show that, even assuming that the entrepreneur can commit initially to a monetary policy, traditional equity financing is preferred to ICO financing. The drawback from using tokens (relative to equity financing) are even more severe when the entrepreneur cannot commit to a monetary policy. Chod and Lyandres (2018) introduces a risk averse entrepreneur who can ex-post choose how much to produce. Their central assumption is that VCs are less diversified than ICO investors, because tokens can be bought in (almost) infinitely small amounts. This implies that ICO financing is preferred to equity financing whenever the project is particularly risky (in the sense, for example, of having a very skewed return distribution). Finally, Garratt and van Oordt (2019) assume that the entrepreneur, in addition to choosing how much to produce, can also invest in a cost-saving technology. Their main result is that the ICO can achieve the first-best level of investment in cost saving, which can be achieved neither under equity financing nor under debt financing. This is because the entrepreneur maintains the incentive to reduce the cost of production even if part of the output was pre-sold at ICO (which is not the case if profits were pledged to third parties).

Malinova and Park (2018) is, to the best of our knowledge, the only paper tackling the problem of token design. They consider a model very close to Chod and Lyandres (2018), but assume that tokens can represent either a pre-sale of output, or a revenue-share agreement. Each of these design choices leads to a different form of inefficiency: revenue sharing leads to underproduction because only a fraction of the revenue (the fraction not pledged to ICO investors) benefits the entrepreneur; pre-sale of output leads to overproduction because the entrepreneur fails to internalize that each unit produced will reduce the equilibrium price of the token (and hence the return to the token holders). Interestingly, when combined together (either in the same token or by issuing two different types of tokens), they can achieve the same outcome as traditional equity financing. In a version of the model with moral hazard, the appropriate design of a token can "beat" equity in the sense of better aligning the incentives of entrepreneurs and investors, and hence leading to higher profits.

4 Token Pricing

Having discussed the implications of tokens for corporate governance, we now turn our attention to the other main area of corporate finance, namely the valuation of financial instruments. For reasons that will become clear below, it is important to separate tokens which are only used for transaction purposes from tokens which provide access to a service.

4.1 Valuation of Cryptocurrencies

Not surprisingly, given the spectacular growth of Bitcoin price,the bulk of the research on token pricing has strived to determine the value of cryptocurrencies. Pinning down the fundamental value of money is a notoriously hard problem with a long tradition. It is well known that multiple equilibria supported by self-sustaining beliefs may arise.[13] Since most people would agree that cryptocurrencies are not likely to replace but simply compete with fiat money, the question can be narrowed down to determining the rate at which agents will be willing to exchange their fiat money against some cryptocurrency. Once the issue has been reframed in such terms, it becomes clear that the indeterminacy of exchange rates originally established by Kareken and Wallace (1981) should apply. Accordingly, the first insight of pricing theory is to provide a theoretical explanation for the extreme volatility of cryptocurrencies. Going beyond this qualitative finding, ongoing research tries to identify the conditions which allowed cryptocurrencies to bootstrap themselves out of the no-trade equilibrium.

Early contributions by Athey et al. (2016), and Bolt and Van Oordt (2016) demonstrate that anticipations of future transactional usage may incentivize investors to hoard currencies that are not yet widely accepted. Focusing on the tradeoff between central bank money and privately issued digital currencies, Garratt and Wallace (2018) argue that agents trade storage costs against disaster risks. This threat is explicitly modeled in Pagnotta (2018) where the crash risk is determined by miners' investment, giving rise to price-security feedback loops which may amplify or dampen the effect of demand shocks on Bitcoin price. Besides such fundamental factors, price fluctuations are also driven by speculative behavior. Uhlig and Schilling (2018) show that indeterminacy can support a speculative equilibrium where the cryptocurrency is held by agents who anticipate that its value will appreciate in future periods. Biais et al. (2018) devise and estimate an econometric model which separates changes in Bitcoin price that are driven by fundamental news from those that are driven by self-fulfilling expectations. Their estimation indicates that although fundamentals are significant factors, the bulk of return variations on bitcoin are driven by multiplicative noise.

The papers listed above build on models of dual-currency regimes because they focus on Bitcoin. Hence they leave aside the evergrowing proliferation of cryptocurrencies described in Section 2. One exception is Garratt and Wallace (2018) who also study the cloning process of Bitcoin, casting some doubt on its social value and long-run sustainability. Fernández-Villaverde and Sanches (2019) identify the conditions under which currency competition works. They extend the canonical framework of Lagos-Wright and find that, for money com-

[13] See the book by Rocheteau and Nosal (2017) for a comprehensive study of the theory of money, including recent advances in the field of *new monetarist economics*.

petition to be consistent with price stability, the cost function associated with the production of private money must satisfy some restrictive requirements. But they also show that these requirements can be relaxed, and privately-issued money made consistent with price stability, when an upper-bound on the overall supply of each cryptocurrency is enforced by some immutable protocol. Fernández-Villaverde and Sanches (2019) therefore suggest that the commitment power of blockchains was the critical feature that led to the emergence of multiple cryptocurrencies.

4.2 Valuation of Utility Tokens

Pricing utility tokens is, in principle, more straightforward than pricing cryptocurrencies because utility tokens should trade at a price that reflects the value of the service they give access to. From the standpoint of valuation theory, such rewards are treated as exogenous and utility tokens can be priced in the same way as other assets. That being said, there is no off-the-shelf formula that can be lifted from the asset pricing literature because utility tokens fundamentally differ from standard securities such as debt and equity.

To see why, we now describe a simplified version of the model proposed by Danos et al. (2018). Consider a platform that issues tokens and commits to exchanging *one unit of service against one token*. There are two markets: (i) a trading market where tokens are bought using fiat money, and (ii) a commodity market where tokens are sold in exchange of the platform's service. The platform has monopoly power on the commodity market, while the price or exchange rate of the token in fiat money, p, is determined on the perfectly competitive and frictionless trading market.

Each period is divided into two subperiods. The trading market opens at the beginning of the period. It allows users to sell and buy tokens at the market price p_t. Then the trading market closes and preference shocks are revealed. The maximum quantity of services desired, or willingness to pay, of each user is randomly drawn from the continuously differentiable distribution function $F(\cdot)$. Using c and d to denote the quantity of services consumed and desired, we assume that the per-period utility function u of users is linear, i.e., $u(c; d) = \min(c, d)$.

The timing is crucial and cannot be reversed. Suppose instead that users first observe their willingness to consume and then adjust their token holdings. Since tokens do not bear any interest, users would find it optimal to hold zero tokens at the beginning of the period and the market price would collapse to zero.

Following the same steps as in Danos et al. (2018), one can show that the token price obeys the following law of motion

$$rp_t = \underbrace{[1 - F(M)]\,(1 - p_{t+1})}_{Convenience\ Yield} + \underbrace{p_{t+1} - p_t}_{Capital\ Gain}\,, \tag{1}$$

where M is the mass of available tokens per user, and r is the user's discount rate. Condition (1) decomposes the rate of returns of tokens into two components: a capital gain and a convenience yield. First, token holders benefit from any appreciation in the price of the token as captured by the capital gain. Token holders may also enjoy a convenience yield; with probability $1 - F(M)$ the marginal token is consumed and provides a utility of 1. Since the service is delivered *in exchange* for the token, we also have to take into account the loss of the token and deduct its price from the marginal utility, as captured by the term $-p_{t+1}$ in the convenience yield. This substraction of the asset price is the fundamental difference between token and share pricing. Whereas shares give their owner the right to a stream of dividends, utility tokens do not yield any benefits until they have been exchanged. Hence their fundamental value is equal to the discounted surplus of the *next trade*.

Condition (1) also highlights that, for the price of the token to remain bounded, the convenience yield should eventually be positive. Setting $p_t = p_{t+1}$ in (1) yields the token price in steady-state, wich we denote by $\hat{p}$,

$$\hat{p} = \frac{1 - F(M)}{r + 1 - F(M)} < 1. \tag{2}$$

As expected, the equilibrium price is decreasing in the overall supply of tokens M. More interestingly, the platform services are paid at a price that is *lower* than the marginal utility since $\hat{p} < 1$. This is the main cost of requiring users to pay in tokens instead of fiat money.[14]

To take stock, this basic model has three main insights. First, it identifies the conditions under which tokens are valuable, namely when users need to acquire the services so quickly that they do not have the time to refill their token holdings. Second, it clarifies the cost for the platform of relying on an ICO to raise funds. By issuing tokens, the platform actually commits to selling its product at a discount that compensates users for the opportunity cost of holding tokens instead of interest bearing securities. Third, it shows how the pricing

[14] The other loss for the platform is demand rationing since a share $1-F(M)$ of users would like to consume more than allowed by their token holdings.

formula for tokens fundamentally differs from that for other financial instruments because tokens do not generate any dividends until they are exchanged.

In order to capture how token prices evolve over time, Danos et al. (2018) embed their model into a dynamic framework with time-evolving parameters. Their approach endogenizes the velocity of circulation, making it feasible to compute the price at the ICO stage that is consistent with convergence to the long-run equilibria. This model is therefore related to Cong, Li, and Wang (2018) and Cong, Li, and Wang (2019), both already discussed in the context of corporate finance of tokens. Cong, Li, and Wang (2018) provide a fully microfounded model for the pricing of utility tokens. They assume that users need to stake tokens in order to access the platform and they let the platform's productivity fluctuate randomly over time. Cong, Li, and Wang (2018) derive a general pricing formula which depends on the deterministic trend and volatility coefficient of the demand shifters. Their analysis shows that token appreciation may accelerate platform adoption as users internalize network externalities. In their follow-up paper, Cong, Li, and Wang (2019) describe how the management of tokens through burning and minting can be fine tuned so as to fulfill the incentive constraints of the different stakeholders.

5 Conclusion

Despite growing interest toward the study of tokens and the incentives that they generate, several promising areas of study have so far received little or no attention.

With respect to protocol-associated tokens, the majority of papers have focused on how tokens can help overcome coordination failures on the adoption phase of the protocols. But beside this, all other areas of inquiry seem, as of now, fairly open. For example, competition between different protocols is widespread. See, the proliferation of cryptocurrencies (Bitcoin, Bitcoin Cash, Bitcoin Gold, Litecoin, Monero, Dash, ZCash, ...); the proliferation of decentralized computing platforms, each with their own associated token (Ethereum, EOS, Tezos, Cardano, Tron, Ethereum Classic, NEM, ...); the multiplicity of decentralized payments platforms (Ripple, Stellar, ...). The intensity of this competition is partly explained by the fact that most of these protocols are open source, which implies that anybody can modify the source code of a given protocol and then create a "fork": a new protocol, with its own development, incompatible with the initial protocol.[15] It is however unclear, at this

[15]See Canidio (2018) for a discussion regarding why almost all blockchain-based protocols are open source.

point, how competition between blockchain-based protocols affects the incentives to develop these protocols, and whether it undermines their long-run sustainability.[16]

A related issue is the likely emergence of multiple token usage and how they could be addressed by the emergence of an intermediary sector. Intermediation could also help foster market liquidity and accompany the growth of functional cross-chain solutions which allow tokens to hop from one chain to the next. Evidently the widespread availability of chain connectors has the potential to transform the dynamics of competition and may favour more collaborative developments, going some way towards the formation of an abstract blockchain as an homogeneous computational medium.

With respect to tokens issued by firms, an important area of inquiry are firms' incentive to honor their initial commitments. In all the papers mentioned above, it is assumed that the firm can indeed commit, possibly because of an existing legal and regulatory framework.[17] But this seems unlikely. The reason is that tokens can be sold to investors worldwide, each investing small amounts. In this environment, no individual investor has the incentive to monitor and then bring to court a firm that, for example, starts accepting means of payments other than the token or declares bankruptcy after paying his management above-market salaries. The cost of coordinating several investors to organize something akin to a class action may be prohibitively high. It is therefore worthwhile exploring to what extent a firm initial commitment is credible even in the absence of legal enforcement.

Yet another issue that is important to study is token design. As already discussed, a security exchanged as a token can look very different from a traditional security. For example, the issuer of a revenue-share agreement could pay its holders weekly or even daily at virtually no cost. Moreover, smart contracts can be used to automate certain parts of the execution of a security contract. Because of this, different security tokens can be pooled together creating new types of CDOs (collateralized debt obligations), with a smart contract handling the flow of cash to the CDO holders. Developing the theoretical approaches we have reviewed to address new token designs and the resulting incentives, as well as the pricing of structured tokens, is likely to be one of the most fruitful area for further research.

[16]It is worth mentioning that Abadi and Brunnermeier (2018) model competition among blockchains. They argue that the possibility of creating a fork determines how the blockchain record keepers (i.e., the miners) can be rewarded. Therefore, they connect blockchain competition to the design of blockchain-based protocols and on-chain incentives.

[17]Catalini and Gans (2018) also discuss the role of commitment in ICO financing.

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