Underpricing in the cryptocurrency world

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Underpricing in the cryptocurrency world: evidence from initial coin offerings

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Abstract

Purpose – The purpose of this paper is to analyze underpricing in initial coin offerings (ICO). It bridges the gap between findings in initial public offering (IPO) literature and empirical results from ICOs.
Design/methodology/approach – The sample set consists of 279 ICOs between April 2013 and January 2018. A regression analysis is performed with data from the ICOs.
Findings – The results show an average level of underpricing of ICOs of 123 percent in the USA and 97 percent in the other countries. The results for the US ICOs are significantly higher than for US IPOs on average and also higher than US IPOs at the beginning of the dot.com bubble. The authors also study the determinants of ICO underpricing. The authors use proxies based on asymmetric information from the IPO literature as well as ICO-related variables. First-day trading volume and a good sentiment on the ICO market go together with more ICO underpricing. Moreover, hot markets make first-day investors to benefit less. Finally, companies that use a large issue size or a pre-ICO (a sale of cryptocurrencies before the ICO) leave less money on the table.
Research limitations/implications – A first restriction is that the authors focus on ICOs and not on crowdfunding, though there are similarities in that both of them are novel ways to finance projects. A second restriction is that the authors had to decide on the definition of a listing day. Cryptocurrencies are traded on many exchanges, and if the exchange is tailored to the cryptocurrency itself, the data on, e.g., close prices are not necessarily to be trusted. The authors, therefore, decided to use close price data from coinmarketcap.com, which requires a listing on two exchanges. This choice implies that there may have been trades before the listing day itself. A third restriction arises from the relative newness of the ICO phenomenon. The authors gathered data on underpricing from coinmarketcap.com and combined that with project information from icobench.com. However, the data were not simply matched and they required manual adjustments based on several other sources. The authors hope that in due time data on ICOs will be as adequate as data on IPOs and that they become more readily available. It might help if regulators or the crypto community would institute publication requirements. Adherence to such requirements would also reduce the extent of fraud and of asymmetric information, so that solid issuers with good projects might benefit from less underpricing.
Practical implications – The research may help in reducing underpricing, as the authors find that issuers can reduce it by holding a pre-ICO and by considering larger issue sizes. If they do so, investors will get fewer opportunities to benefit from underpricing. Investors can, nevertheless, also profit from the knowledge generated in this paper. When market sentiment is positive and first-day trading volume is expected to be high, investing in ICOs is likely to give them higher first-day returns. Finally, the authors hope that this paper will serve as a basis for further research into the exciting and dynamic world of cryptocurrencies.
Originality/value – There is hardly any research on underpricing of ICOs. The paper is interesting for its table with a brief comparison of ICOs and IPOs. It also searches for variables from the asymmetric information theory behind IPOs to be applied in explaining ICOs. It shows high levels of ICO underpricing in comparison to IPOs. It also gives suggestions for issuers of (and investors in) ICOs.

Keywords IPO, Underpricing, Bitcoin, Cryptocurrency, ICO, Initial coin offering
Paper type Research paper

1. Introduction

Instead of selling stocks through initial public offerings (IPOs) companies recently started to distribute digital coins or tokens to raise capital via so-called initial coin offerings (ICOs) (Conley, 2017). The number of ICOs grew dramatically. Token sales that raised at least 100,000

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US dollars increased from 7 per month in September 2016 to 107 per month in August 2018 with a spike of 172 in February 2018[1]. Most notably in US dollars are the ICOs of the blockchain software architecture firm EOS (4.2bn US dollars) and the tech-company Telegram, which raised 1.7bn US dollars for an unfinished blockchain technology project[2].

A major problem for issuing companies is underpricing, which means that the price at which a company issues an asset is below market value. As a consequence, the price of the issued stock adjusts to a higher market price on the listing day. Managers consider underpricing to be relevant for attracting investors (Brau and Fawcett, 2006), but underpricing may not be entirely deliberate. In the latter case, the company would have been able to raise a higher amount of capital (Ibbotson and Jaffe, 1975) and the company would leave less "money on the table" (Loughran and Ritter, 2002).

Underpricing is well-documented for IPOs, but it is not for ICOs. Many studies in the field of IPOs find underpricing (Ritter, 1984, 1987; Miller and Reilly, 1987; Tinic, 1988; Carter and Manaster, 1990). Until now, two studies find underpricing in ICOs too (Adhami *et al.*, 2017; Momtaz, 2018), though the results from these papers diverge strongly.

In this study, we discuss major differences between ICOs and IPOs. Then, we examine the magnitude of underpricing in ICOs. We also compare for the US ICO underpricing with that of IPOs. Finally, we analyze the possible determinants for ICO underpricing. Because asymmetric information between investors and issuers of ICOs is substantial and because much IPO literature addresses asymmetric information as a major cause for underpricing, we search the IPO literature for relevant determinants and then apply them to ICO underpricing. By doing so, we aim to bridge the gap between the scarce ICO literature and the IPO literature.

We find average and median underpricing in ICOs of 108.5 and 32.9 percent, respectively. For US ICOs, we find an average (median) underpricing of 123.1 percent (54.6 percent) and for Non-US ICOs of 97.2 percent (25.8 percent), respectively. Average underpricing percentages for US ICOs are also significantly higher than for averages of US IPOs, and even for average US IPOs at the beginning of the dot.com bubble in 1999. First-day trading volume and market sentiment go together with higher ICO underpricing, while issue size, being in a hot ICO market and the use of a pre-ICO influence underpricing negatively. Finally, ICOs for finance and entertainment products have significantly less underpricing.

The structure of this paper is as follows. Section 2 presents cryptocurrencies and ICOs and goes into the theory of IPO underpricing. Section 3 describes the data and the methodology. Section 4 provides the results, and Section 5 gives the conclusions.

2. Literature review

In this section, we examine the position of cryptocurrencies as assets and discuss the differences between IPOs and ICOs. Furthermore, we go into earlier work on IPO underpricing and provide our hypothesis and regression coefficient expectations.

2.1 Cryptocurrencies as digital assets

The blockchain technology is a major innovation, and it became famous for its use with bitcoins. In a traditional (peer-to-peer) situation, user A could send money to users B and C and a trusted intermediary (quite often a bank) checks whether user A has enough money to transfer the funds to both users B and C. A blockchain transaction, however, does not need a trusted intermediary. It is an entry in a public digital ledger in which all transactions are registered chronologically. It creates trust and consensus on ownership by publishing the transactions. Issuers (and owners) of cryptocurrencies can create a new entry in the ledger by creating (or owning) a key to re-assign the ownership to someone else (Momtaz, 2018). A blockchain combines several new entries into one group (block) (Bonneau *et al.*, 2015) and a typical block contains on average more than 500 transactions. Using blockchains in cryptocurrencies makes the transactions trustworthy, and because issuers of

cryptocurrencies need no other intermediator than the blockchain technology, cryptocurrencies may have a substantial impact on how financial issuers and financial markets will work in the future (Tapscott and Tapscott, 2017)[3].

At an IPO, the issuer provides stocks to the subscribers. Generally, these stocks provide voting power in the issuing company and also sometimes dividends. Issuers of cryptocurrencies may give subscribers a wider range of rights, like a direct medium of exchange (comparable to bitcoin), access to services or products, dividend streams, voting power and other rights. Adhami *et al.* (2017) find, for example, that only 24.9 percent provide voting power. It is usual to make a distinction between a "currency" and a "token." A currency functions solely as a medium of exchange, whereas a token may provide several other benefits to its owner. Within the token category, there are two major groups: a utility token and a security token. A utility token provides the owner future access to the company's products or services. It is a digital coupon. If a cryptocurrency derives its value from an external, tradable asset, it classifies as a security and becomes subject to federal securities regulations[4]. In this paper, we study both types of cryptocurrencies.

2.2 Initial public offering vs initial coin offerings

There are important distinctions between IPOs and ICOs. Table I explains these differences[5]. Shares sold in an IPO refer to residual rights of the shareholders, while tokens sold in an ICO give their holders specific rights that do not accrue to the shareholders. Besides the broader variety of rights available in ICO cryptocurrencies, there are also significant differences in the legal backing, the regulations and the reporting requirements. Only if an ICO falls under the security regulations, the issuer must follow a path comparable to an IPO. Underwriters play a significant role in the IPO literature, but using underwriters for ICOs is not yet common (Sánchez, 2017). An IPO, generally, also requires the use of public accountants, lawyers and banks, whereas an ICO requires programmers.

All requirements for an IPO and the many parties involved make the duration of the IPO process longer than for an ICO. It is thus not amazing that some consider ICOs to be historically the most efficient way to raise capital (Kaal and Dell'Erba, 2018). ICOs do not need to take more than a month, though a pre-ICO may lengthen the ICO process. Because ICOs are generally done for start-up projects, they do not have a track record, while companies that sell shares in an IPO need to have an adequate track record (Pahwa, 2018). Shares issued in an IPO are paid for by regular (fiat) money, while ICO issues are generally paid for by cryptocurrencies like Ethereum or Bitcoin.

The unregulated ICO environment and lower participation by reputed external parties may also result in ICO investors to become victims of fraudulent behavior (Zetzsche *et al.*, 2017). Only a few people may know of the real characteristics of the projects (Chod and Lyandres, 2018). Moreover, ICO investors may be exposed to insider trading, and also pump and dump schemes by large cryptocurrency holders (whales) do occur[6]. Overall, ICOs are thus substantially riskier than IPOs and investors active in the cryptocurrency market also tend to be more risk seeking than regular stock market investors (Lee *et al.*, 2018).

Another difference is that ICO listings by other cryptocurrency exchanges are relatively easy (Hays, 2017) and the issuer need not approve such further listings. For stocks issued in an IPO, however, a dual (or further) listing is initiated by the issuer and takes time. Consequently, large cryptocurrencies are generally traded on more exchanges than regular stocks (bitcoin e.g. on 400)[7]. Of course, the indexes for listed firms and cryptocurrencies differ. Finally, the volume of IPO transactions was still more than 30 times as large as for ICOs in 2017.

2.3 Underpricing theories

Because of the recentness of the ICO phenomenon, there is yet no converging research on the amount of underpricing. Adhami *et al.* (2017) find an average level of underpricing of

Characteristic	IPO	ICO	Explanation
Utility from participation	Well defined rights, like dividends and voting	Exchange medium, access to services or products, dividends and/or other rights	ICO contracts provide a great variety of rights and give exposure to limited specific projects, while IPO rights apply to the overall success of all company projects
Legal backing	Yes	Generally not	ICO-related contracts are not legally enforceable (or only by the platform)
Aimed at	Institutional and private investors	Primarily crypto community	Though cryptocurrencies may form a specific asset base for regular investors, ICOs are still mainly targeted at the crypto community
Regulation	Strong	Weak	The regulatory framework for an IPO is comprehensive and governed by national bodies like the SEC. ICOs are mostly self-regulated
Reporting	Prescribed requirements	Varies strongly	Weak reporting requirements result in varying transparencies in ICOs
Duration to set-up	4–5 months	Around 1-month	Due to heavy regulatory processes, IPOs take more time to set-up than ICOs
Underwriter	Yes	Rare, but pre-ICOs	Underwriting is common for IPOs, but not for ICOs for which the price is originally set by the issuing firm
Strategic aim	Exit and company development	Entry of a specific project	IPOs give exit possibilities for owners and money for developing the company; ICOs often aim at starting a project
Track record	Established company	Early stage company	The track records are generally long for IPOs and short for ICOs
Currency	Fiat currencies	Crypto coins	In an IPO a stock is bought with traditional (fiat) currency. In an ICO cryptocurrencies or tokens are bought and generally paid for by crypto coins
Fraud	Rare	Rather often	For an IPO, a company needs to show a good history. The absence of ICO regulation may result in fraud
Risk	Relatively low	High	Absence of regulation, no track records and reporting requirements, frauds and strong herding behavior make ICO projects risky
Exchange(s)	Listed on one (or some) exchange(s)	Easily listed on (many) trading platforms	Issuing firms decide at (or after) an IPO on dual listings, while trading platforms decide on listing an ICO project. IPOs are traded during stock exchange opening times, ICOs are traded continuously
Trading	During stock exchange opening times	Continuously	IPOs are traded during stock exchange opening times, ICOs do not have weekends and bank holidays and are traded continuously
Index	MSCI world	CCI30	Worldwide stock and cryptocurrency indexes
Size	190	6	Total capital raised in 2017 in 10^9 US dollars

Table I.
Differences between an IPO and an ICO

919.9 percent and a median of 24.7 percent. Momtaz (2018) finds an average level of underpricing in ICOs of 8.2 percent and a median of 2.6 percent. Adhami *et al.* (2017), furthermore, assess determinants for the success of ICOs and use mainly ICO project characteristics. Momtaz (2018) goes into determinants of underpricing and also uses mainly ICO project characteristics. Both papers also use time-varying variables, but they do not link the determinants of underpricing strongly to the IPO literature. In this paper, we, therefore, aim to find the major determinants for underpricing of ICOs from the literature on IPO underpricing.

The most significant concept used to explain underpricing in IPOs is information asymmetry (Baron, 1982; Rock, 1986). IPOs and ICOs are "lemons" (Akerlof, 1970) as the buyer has less knowledge of a product than the seller. In fact, the "lemon" problem may even be worse for ICOs in comparison to IPOs because of the higher risks involved.

One theory of information asymmetry in the IPO literature is the principal-agent theory (Baron, 1982). Baron focuses on information asymmetry between the issuer and the underwriter. The issuing company (the principal) does not know the issue's real value and relies on an underwriter (the agent) to assess it. To induce the agent to work in the best interests of the principal, the principal provides a certain number of shares to the underwriter at low costs via underpricing.

Another explanation for underpricing is proposed by Rock (1986), who introduces information asymmetry between informed and uninformed investors. An underwriter wants to avoid a failure of an IPO. Therefore, the underwriter should lower the issue price below its actual value to attract not only informed but also uninformed investors.

A further application is the signaling theory, which assumes asymmetric information between the issuer and the investors. Various studies argue that issuers address the lack of information for investors by underpricing. A high-quality company incurs opportunity costs in its IPO by underpricing, but – contrary to a low-quality company – it would be able to recoup such costs by reduced underpricing of future (seasoned) issues (Allen and Faulhaber, 1989). A related explanation for underpricing is given by Welch (1992), who argues that if shares are sold sequentially, investors can learn from the purchasing decisions of early investors. Investors at an early stage may transfer beneficial company information to investors later on. An issuer that signals its quality by purposely underpricing the IPO may be able to sell the remainder of the shares in a seasoned equity offering for a higher price.

Companies can also signal quality by retaining stock to signal confidence in the long-term performance of the company (Grinblatt and Hwang, 1989). Moreover, a third party can reduce the information asymmetry that exists between the issuer and the investor (Beatty and Ritter, 1986; Johnson and Miller, 1988; Titman and Trueman, 1986). For example, reputed auditors, reputed underwriters and venture capitalists may reduce information asymmetry and underpricing (Balvers *et al.*, 1988; Carter and Manaster, 1990; Megginson and Weiss, 1991).

Besides information asymmetry, it is also well known that there are cyclical underpricing patterns during "hot" and "cold" markets (Ibbotson and Jaffe, 1975; Ritter, 1984). In a hot market, excessive optimism of investors results in more than average underpricing of IPOs. Hot markets generally occur during periods when a large number of firms institute a public offer (Ibbotson *et al.*, 1988). Lerner (1994) and Loughran and Ritter (1995) argue that a high concentration of IPOs is related to firms trying to exploit great investor optimism. During those "windows of opportunity" IPO firms are timing the market (Loughran *et al.*, 1994; Baker and Wurgler, 2000), but they may not be able or willing to increase the offer price aggressively (Ljungqvist and Wilhelm, 2003; Ljungqvist *et al.*, 2006). In such a case not only issuers benefit from hot markets, but also IPO subscribers may still profit from excess optimism through higher underpricing (Campbell *et al.*, 2008).

As is evident from the discussion above, the IPO literature offers theories that underpricing may be caused by asymmetric information and that its magnitude varies over time. Besides these approaches, some studies also show that underpricing can be explained by firm-, issue- and market-specific factors (Dewenter *et al.*, 2001; Chemmanur and Paeglis, 2005; Butler *et al.*, 2014). In the following, we translate these IPO approaches to proxies that may also be relevant for ICO underpricing.

2.4 Hypothesis and assumptions on signs

2.4.1 The magnitude of underpricing. Managers consider underpricing to be relevant for attracting investors (Brau and Fawcett, 2006) and it indeed exists for various industries, periods and regions (Ibbotson, 1975; Ibbotson and Jaffe, 1975; Ritter, 1984; Van Heerden and Alagidede, 2012). For ICOs, Adhami *et al.* (2017) find an average level of underpricing of 929.9 percent and a median of 24.7 percent for 140 observations, while Momtaz (2018) finds

an average of 8.2 percent and a median of 2.6 percent for 302 observations. These theories and observations result in the assumption that the ICOs in our sample are also underpriced.

IPO theories also suggest that information asymmetry leads to underpricing. It is likely that asymmetric information is larger with ICOs than with IPOs because the issuing of cryptocurrencies is unregulated, applied to start-up projects and sensitive to fraudulent actions. Moreover, the relative new phenomenon of ICOs may make ICOs also being strongly hyped and herding behavior and fear-of-missing-out thoughts of market participants may further aggravate underpricing. For these reasons, we use the following hypothesis:

H1. Underpricing is higher in US ICOs than in US IPOs.

Because IPO data on non-US countries are not systematically available, we only test this hypothesis for the USA. The hypothesis is not trivial. First, Momtaz (2018) finds an average underpricing of ICOs of 8.2 percent, while the average underpricing in the USA is 17.8 percent[8]. Because the ICOs may be hyped it is, second, also interesting to see if the ICO underpricing in the USA is larger than the highest annual average value of underpricing of US IPOs (71.2 percent) at the beginning of the dot.com bubble in 1999.

2.4.2 Explanations of underpricing. We use variables related to the asymmetric information theories and to the time variation of IPOs and test for their relevance for ICO underpricing. These variables are "Trading volume," "Issue size," "Issuer retained ratio," "Rating" and the "Coins sold ratio" as asymmetric information variables and "Market sentiment" and a "Hot market" dummy to capture time variation. Then we add issue specific dummies, namely, the existence of a "Pre-ICO," the use of a "Bonus scheme," the ICO type (Currency or token), four other category dummies and ultimately also a country dummy.

2.5 Trading volume

The listing day reveals the real interest of investors in an ICO when the price moves to the market value. This is not only ultimately reflected in the level of underpricing but could also be reflected in the trading volume. Miller and Reilly (1987) separate IPOs into groups with either positive or negative levels of underpricing. They find that the positive underpricing group shows a higher trading volume. Schultz and Zaman (1994) find a similar relation between trading volume and the level of underpricing. The trading volume may thus be an important (control) variable for ICO underpricing, and it is likely that its sign is positive.

2.6 Issue size

Beatty and Ritter (1986) argue that issue size is a proxy for *ex ante* uncertainty. In general, it is more beneficial to generate information about the real value for investors if the issue size is large. Essentially, there is more information available about a large issue than about a small one and investors consider a small issue to be more uncertain and more speculative. As a result, less information asymmetry is present in a larger issue. We, therefore, expect that a higher issue size reduces ICO underpricing.

2.7 Issuer retained ratio

The signaling theory assumes that the issuer knows more than the investor and signals company value (Allen and Faulhaber, 1989; Grinblatt and Hwang, 1989; Welch, 1992). Retained stock is a crucial factor for signaling the real value. A large ratio of issuer retained cryptocurrencies would suggest that the issuer is confident about the long-term performance and assumes that the value of the cryptocurrency will rise. Consequently, we expect that retaining relatively many cryptocurrencies is a signal of quality which will attract more investors at the issue date. This will have a positive effect on ICO underpricing.

2.8 Rating

As earlier described, Megginson and Weiss (1991) argue that an expert can lower the information asymmetry by reviewing an issue. For ICOs, it is common to receive a rating about the vision, project, team and profile. Investors use websites, like icobench.com, where experts give ratings and use this to evaluate an ICO. Also issuers can use these ratings to adjust their offer price. Because information asymmetry is reduced for both issuer and potential investor, we assume that a rating reduces ICO underpricing.

2.9 Coins sold ratio

Oversubscription and underpricing often go together, in particular if there is information leakage (Chowdhry and Sherman, 1996). With ICOs a listing can occur while the hard cap (the fundraising target) is not reached. Reaching the hard cap suggests that there is enough interest in the project and uninformed investors may infer from this that early investors consider the project to be viable in the long run. All investors may then be more interested in buying the coins in the market on the first issue day and the underpricing may increase. Here, we use the ratio of the coins sold in the project as an indicator of the long-term performance of the ICO and we assume that a higher ratio of coins sold increases ICO underpricing.

2.10 Market sentiment

Market sentiment is important for underpricing (Loughran and Ritter, 2002). Investors evaluate the available information on IPOs differently during times of high optimism and this may result in a more positive view of long-term performance. As issuers do not fully capitalize on such optimism (Ljungqvist and Wilhelm, 2003; Ljungqvist *et al.*, 2006), underpricing may increase. This can also occur with cryptocurrencies and we assume that positive market sentiment increases ICO underpricing.

2.11 Hot market

A hot market period is defined by a high intensity of IPOs. During that period the level of IPO underpricing is also significantly larger than during a cold market period. The reason may be found that issues during a hot market are riskier and must therefore be compensated by more underpricing. This may also apply to ICO underpricing. However, hot periods can also be used by issuers, because the high interest of investors allows issuers to raise offer prices. In hot IPO markets, they do not raise their offer prices so much that underpricing will vanish (Campbell *et al.*, 2008). Though this may be different for ICOs, we assume in first instance that a hot market for ICOs will not be different from a hot market for IPOs. Therefore, we assume that a hot market period will increase underpricing.

2.12 ICO-specific characteristics

The literature review Section 2.2 indicated the main differences between an IPO and an ICO. The expected influence of firm- and issue-specific characteristics based on the IPO literature is presented above. For ICOs, several aspects of the ICO can be assessed. In this paper, we analyze three ICO-related variables. These are the existence of a "pre-ICO," the existence of a "bonus scheme" and the type of ICO (being a currency or a token)[9]. We assume that a pre-ICO and a bonus scheme may attract early informed knowledgeable investors who may help in setting an adequate offer price and in reducing underpricing. For the dummy "Currency or token," we assume that currencies may be more attractive to investors, because of the successes of earlier currencies like bitcoin. Moreover, we add dummies for issues in the four most important token categories and, finally, we also add a country dummy (for the USA). For the latter five dummies we have no prespecified assumptions on the signs. All variables are explained in Table II.

Variable	Description	Expected sign
Trading volume	The natural logarithm of the trading volume in US$ at the listing day	+
Issue size	The natural logarithm of the number of coins offered multiplied by the offer price (in US dollars)	−
Issuer retained ratio	The number of cryptocurrencies of the project not offered in the ICO divided by the total number of project cryptocurrencies	+
Rating	The rating received at icobench.com between 1 and 5, where 5 is the best rating possible	−
Coins sold ratio	The ratio of coins sold relative to the number for sale	+
Sentiment	Sentiment is equal to the 30-day return of the CCI30 index measured at the listing day	+
Hot market	Dummy with a value of 1 if the ICO happened between July and December 2017, otherwise 0	+
Pre-ICO	Dummy with a value of 1 if coins were available for sale before the official ICO, otherwise 0	−
Bonus scheme	Dummy with a value of 1 if early investors get discounts within the ICO period, otherwise 0	−
Currency or token	Dummy with a value of 1 if the type of a coin was a currency, otherwise (if a token) the value is 0	+
Category dummies	Dummies that get a value of 1 if the token is issued for the respective category of product, otherwise 0. The categories are selected when they applied to more than 10% of the total number of cryptocurrencies listed, namely if used for platform products, for financial products, for software products and for entertainment products, respectively	+/−
USA	Dummy with a value of 1 if the issuer is located in the USA, and 0 otherwise	+/−

Table II.
Description and expected signs of the explanatory variables

3. Data and methodology

3.1 Measuring underpricing

To measure underpricing of ICOs, we use the standard method common for IPOs. The following equation shows the definition:

$$\mathrm{UP}_i = \frac{P_i - E_i}{E_i}, \tag{1}$$

where UP_i is the level of underpricing, P_i is the listing day's close price and E_i the offer price of the relevant ICO(i). Contrary to IPO stocks that end trading on the issue date when their local stock exchanges close, cryptocurrencies are traded continuously. Therefore, there is no local closing time for the trading in cryptocurrencies. Moreover, ICOs are traded on several stock exchanges, but the first trading day may not be similar. Using the first trading day of the first exchange that lists a cryptocurrency is hazardous, because it may be the platform that is focused only on the specific cryptocurrency and it may occur that prices on that platform are (upwardly) managed by the issuer. For that reason, we use the close price at the first listing day at coinmarketcap.com as a more trustful close price[10].

As a robustness test, we also correct for the underpricing by subtracting the return in the ICO market in line with event studies (Brown and Warner, 1980). For the market return, we use the largest cryptocurrency index (CCI30). The following equation shows the definition for the market corrected underpricing (MUP_i) for ICO_i:

$$\mathrm{MUP}_i = \frac{P_i - E_i}{E_i} - \frac{M_{i1} - M_{i0}}{M_{i0}}, \tag{2}$$

where P_i and E_i are defined as in Equation (1) and M_{i0} the price of the cryptocurrency market portfolio (based on the CCI30) at the start of the listing day of ICO_i and M_{i1} the price of the cryptocurrency market portfolio at the end of that day[11].

3.2 Data

The sample consists of cryptocurrency projects that started their ICO between September 2015 and January 2018. icobench.com[12] provides information about the projects and gives social, business, technical, geographical and financial information on the project. coinmarketcap.com provides historical pricing data and contains daily high, low, open, close and volume data in US dollars. We retrieved data from both databases by building a scraper in the programming language Python and connecting this to the websites' application programming interface. However, the data acquired from coinmarketcap.com and icobench.com were often not consistent. Therefore, we supplemented the data by manually adding information from icodrops.com[13], cryptocompare.com[14] and several company websites. Due to the different data sources and incomplete information, the final data set consists of 247 ICOs.

3.3 Descriptive statistics

Table III presents the summary statistics for the variables used in the regression analysis. Mean underpricing proves to be 1.085 (108.5 percent). The lowest level of underpricing was −99.5 percent (implying an end of the issue day price of close to 0), while the highest underpricing was 1,635.3 percent. Correction for the cryptocurrency market index (CCI30) is not trivial, because the minimum return of that index was −17.5 percent on one issue date and the maximum 18.9 percent on the issue date of another cryptocurrency. On average, however, the correction is small as the average for the CCI30 return corrected underpricing is still large (107.0 percent). For the variables trading volume and issue size, we use natural

Variable	Mean	Median	Minimum	Maximum	SD
Underpricing	1.085	0.329	−0.995	16.353	2.164
CCI30 return on issue dates	0.015	0.012	−0.175	0.189	0.050
Market corrected underpricing	1.070	0.335	−1.059	16.356	2.169
Asymmetric information and time-varying variables from the IPO literature					
Trading volume	11.076	10.843	0	17.849	2.980
Issue size	16.459	16.786	9.726	19.414	1.443
Issuer retained ratio	0.578	0.600	0	1	0.253
Rating	3.293	3.500	1.100	4.800	0.848
Coins sold ratio	0.376	0.232	0	1	0.382
Sentiment	0.419	0.191	−0.395	2.001	0.597
Hot market	0.757	1	0	1	0.430
ICO variables					
Pre-ICO	0.360	0	0	1	0.481
Bonus scheme	0.275	0	0	1	0.448
Currency	0.158	0	0	1	0.365
Dummy variables					
Platform products	0.279	0	0	1	0.450
Finance products	0.117	0	0	1	0.323
Software products	0.126	0	0	1	0.332
Entertainment products	0.109	0	0	1	0.313
USA[a]	0.248	0	0	1	0.433

Note: [a]Because of ICOs with an unknown country location, the number of observations is 226

Table III. Descriptive statistics for the 247 ICO projects

logarithms, for which the averages (11.076 and 16.459) represent 64,602 and $14.062m, respectively. Issuers retained on average 57.8 percent of the total cryptocurrencies of the project, but of that percentage only 37.6 percent was the percentage of coins sold, and this is a major difference between IPOs (that are generally entirely sold) and ICOs. We also see that the average rating (3.293) lies somewhat below the median rating (3.500).

Table III further shows that ICOs took place on average during a period of good market sentiment (when the monthly CCI index rose by 41.9 percent) and that the majority of coins (75.7 percent) were sold during a hot market period. Table III also shows that issuers of cryptocurrencies on average are reluctant (or not accustomed) to using instruments that may assist in reducing underpricing as a pre-ICO and a bonus scheme are only applied in 36.0 and 27.5 percent of the cases. Furthermore, 15.8 percent of the cryptocurrencies are coins. 27.9 percent of the ICOs are used for financing a platform and 11.7, 12.6 and 10.9 percent for finance, software and entertainment products, respectively. Finally, 24.8 percent of the ICOs for which the country was known came from the USA.

3.4 Mean and median tests

We test for a normal distribution on the level of underpricing with the Jarque–Bera test. That test rejects the null hypothesis of a normal distribution. We therefore also add to the *t*-test the non-parametric Wilcoxon signed-rank test. We also test whether the average level of underpricing is higher for US ICOs than for the point estimate of equally weighted US IPOs (17.8 percent) and whether it is different from the point estimate of the highest annual underpricing (of 71.2 percent found at the beginning of the dot.com bubble in 1999). For the non-parametric Wilcoxon signed-rank test, we compare the median of ICO underpricing to the median percentage of underpricing in US IPOs (6.6 percent; provided to us by Jay R. Ritter).

3.5 Determinants of ICO underpricing

To find possible relationships between ICO underpricing and the independent variables, we apply regression analysis. The following equation shows the formula for the regression analysis (while omitting the four token category dummies and the country dummy):

$$\begin{aligned} \mathrm{UP}_i = {} & \alpha + \beta_1 \times \mathrm{Tradingvolume}_i + \beta_2 \times \mathrm{Issuesize}_i + \beta_3 \times \mathrm{Issuerretainedratio} \\ & + \beta_4 \times \mathrm{Rating}_i + \beta_5 \times \mathrm{Coinssoldratio}_i + \beta_6 \times \mathrm{Sentiment}_i + \beta_7 \times \mathrm{Hotmarket}_i \\ & + \beta_8 \times \mathrm{Pre-ICO}_i + \beta_9 \times \mathrm{Bonusscheme}_i + \beta_{10} \times \mathrm{Currency}_i + \varepsilon_i, \end{aligned} \tag{3}$$

where UP_i is the for negative numbers adapted natural logarithm of the level of underpricing of project *i*. As a robustness test, we also use the adapted natural logarithm of the level of market corrected underpricing (MUP_i) as a dependent variable. The adaptations are made by adding a value of 2 to the (market corrected) underpricing ratio, so that the log transformations of UP_i and MUP_i do not generate missing values for first-day losses. The β's are equal to an unknown parameter and measure the effects of the independent variable belonging to project *i* on that project's underpricing. The error term is ε_i.

Then we perform a White heteroskedasticity test and a Breusch–Pagan test to check for heteroskedasticity. The tests do not reject the null hypothesis for homoscedasticity, but we still prefer to use robust standard errors, which has become standard practice in empirical finance research. We also identify outliers by using the Cooks D approach. We do this by deleting data points which have a Cooks D value higher than $4/n$, where n is the number of observations. As a result, we drop 19 observations. This makes that the R^2 increase while it also results in a sharp decrease in skewness. Then we correct for missing values (five observations) and for issues for which matching on codes gave ambivalent results

(seven observations) and one coin that was clearly meant as a joke. The total remaining sample size for the regression analysis ultimately became 247.

We test for multicollinearity, also because issue size, issuer retained ratio and coins sold ratio may be related (due to issue size). The highest correlation between the independent variables was 0.350, so that there is no concern for multicollinearity. In addition, the variance inflation factors were far below 10, so that that they did not indicate multicollinearity either. Of course, for a new field of research also other non-incorporated variables may be of relevance. Unfortunately, there is no way to test for omitted unavailable variables. However, we applied the Ramsey test, which showed that omitting quadratic forms of the used variables was not a relevant concern.

4. Results

4.1 Percentage of underpricing

Table IV shows the distribution results of the performance of ICOs on the listing day. The results show an average level of underpricing of 108.5 percent and a median of 32.9 percent. Both are significantly different from 0, so that there is underpricing in ICOs. The same results apply if we distinguish between US and non-US ICOs. For US ICOs, the mean (median) underpricing is 123.1 percent (54.6 percent) and both measures are significantly different from 0. For non-US ICOs, these percentages are 97.2 and 25.8, which are also significantly different from 0. We thus find that our assumption of the existence of underpricing is correct. When we compare US ICOs with non-US ICOs, we see that the means (and medians) are larger for US ICOs, but with a t-value of 0.650 (not tabulated) and a χ^2 of 0.587 for the Kruskal–Wallis test (not tabulated) they do not differ significantly.

We also find with a t-test of 3.967 (not tabulated) that the average underpricing in US ICOs (123.1 percent) is significantly higher than that of a point estimate of the average underpricing of IPOs in the USA (17.8 percent). According to the Wilcoxon signed-rank test (with a not tabulated z-value of 3.524), this is also the case for the median underpricing in US ICOs in comparison to that of US IPOs (54.6 vs 6.6 percent). Hence, we cannot reject our hypothesis that in the USA, the underpricing of ICOs is larger than that of IPOs.

Ultimately, we also test whether ICO underpricing in the USA is larger than the point estimate of the highest annual underpricing of 71.2 percent in the USA at the beginning of the dot.com bubble in 1999. It proved that the t-value was 1.955 (implying a one-sided p-value of 0.028), so that the difference is significant in a one-sided test.

4.2 Regression results

Table V presents the regression results. In this section, we first evaluate the variables related to information asymmetry from the IPO literature and then we evaluate the additional included ICO variables and the category and country dummies.

Table V shows that the IPO-based coefficients have a similar sign in all five regressions. Overall, the adjusted R^2 are around 0.3. For the signs of the coefficients, we find, first, that the

	Whole sample (247 ICOs)[a]	US sample (56 ICOs)	Non-US sample (170 ICOs)
Mean	1.085	1.231	0.972
Median	0.329	0.546	0.258
Minimum	−0.995	−0.916	−0.995
Maximum	16.353	8.278	12.320
SD	2.164	1.986	1.942
t-statistic	7.876***	4.638***	6.525***
z-value Wilcoxon signed-rank test	7.102***	3.793***	5.663***

Notes: [a]Includes 21 ICO with unknown country of origin. ***Significant at 1 percent level

Table IV. Underpricing for all ICOs and for US and non-US ICOs

	(1)	(2)	(3)	(4)	(5)
Trading volume	0.081*** (0.012)	0.079*** (0.012)	0.080*** (0.012)	0.081*** (0.013)	0.082*** (0.013)
Issue size	−0.103*** (0.025)	−0.104*** (0.024)	−0.104*** (0.025)	−0.119*** (0.025)	−0.121*** (0.025)
Issuer retained ratio	0.104 (0.120)	0.111 (0.122)	0.121 (0.121)	0.137 (0.119)	0.137 (0.120)
Rating	−0.066* (0.038)	−0.049 (0.037)	−0.050 (0.037)	−0.036 (0.039)	−0.034 (0.040)
Coins sold ratio	−0.035 (0.094)	−0.049 (0.099)	−0.043 (0.101)	−0.066 (0.099)	−0.073 (0.100)
Sentiment	0.127** (0.052)	0.149*** (0.052)	0.149*** (0.052)	0.124** (0.052)	0.116** (0.052)
Hot market	−0.221*** (0.076)	−0.182** (0.077)	−0.158* (0.081)	−0.139* (0.078)	−0.138* (0.079)
Pre-ICO		−0.102* (0.059)	−0.115* (0.060)	−0.106* (0.063)	−0.113* (0.064)
Bonus scheme		−0.019 (0.061)	0.001 (0.062)	0.038 (0.064)	0.041 (0.065)
Currency or token		0.155* (0.088)	0.132 (0.107)	0.129 (0.109)	0.129 (0.110)
Platform products			0.019 (0.093)	0.000 (0.095)	−0.000 (0.096)
Finance products			−0.146 (0.096)	−0.204** (0.103)	−0.221** (0.105)
Software products			0.065 (0.103)	0.080 (0.105)	0.081 (0.106)
Entertainment products			−0.151 (0.105)	−0.236** (0.096)	−0.250** (0.096)
USA				−0.020 (0.070)	−0.023 (0.071)
Constant	2.036*** (0.377)	2.010*** (0.363)	2.002*** (0.383)	2.187*** (0.357)	2.211*** (0.360)
Observations	247	247	247	226	226
Adjusted R^2	0.294	0.304	0.309	0.329	0.330

Table V.
Regression results on underpricing for the ICO projects

Notes: The dependent variable is the level of underpricing (Columns 1–4) or underpricing corrected for the same day development of the CCI30 (Column 5). Robust standard errors are shown in parentheses. *,**,***Significant at 10, 5 and 1 percent, respectively

trading volume on the listing day has a 1 percent significant positive coefficient. This is in line with our assumption and it corresponds with findings in the IPO literature (Miller and Reilly, 1987; Carter and Manaster, 1990; Schultz and Zaman, 1994; Megginson and Weiss, 1991).

Second, the issue size variable shows a 1 percent significant negative coefficient. When an ICO is large, investors are likely to have more information, which leads to a lower level of underpricing. This is in line with our expectation and with the findings of Beatty and Ritter (1986) and Miller and Reilly (1987).

Third, of the time-varying variables the market sentiment variable shows a 1 percent significant positive sign, and this is in line with our assumption. In the new environment of cryptocurrencies, investors are positively influenced by the expectations of the market value of such projects. This result is in line with the findings of Ljungqvist *et al.* (2006) and Campbell *et al.* (2008). However, the hot market variable (Ritter, 1984) has an unexpected negative sign. This may be caused by ICO issuers raising their offer prices strongly in hot markets. If so, it would mean that hot ICO markets differ from hot IPO markets.

Fourth, the signs of the issuer retained ratio (positive), the use of a rating (negative) and the ratio of coins sold (negative) are as expected, but the coefficients are generally not significant. Also all ICO-related variables (pre-ICO, bonus scheme and currency) have the expected sign. However, only the pre-ICO coefficient is marginally significant over all four regressions in which it is included. Using a pre-ICO might thus be beneficial for an issuer.

Fifth, ICOs for finance and entertainment products have significant negative coefficients (in the last two regressions shown in Columns 4 and 5). This means that for these categories of products underpricing is less in comparison to that of other products. Finally, while underpricing on average was larger in the USA than in other countries (see Table III), we find a negative (but not significant) coefficient for the US dummy in the last two columns (4 and 5).

5. Conclusions

We analyze the existence of ICO underpricing and whether ICO underpricing in the USA is stronger than that of IPOs in the USA. Then we apply underpricing literature based on theories of information asymmetry of IPOs to ICOs. Moreover, we test whether additional ICO-specific characteristics and country and category dummies explain underpricing.

The observations on 247 ICOs provide evidence of high average and median underpricing of 108.5 and 32.9 percent, respectively. These values are in between the values of other recent studies (Adhami *et al.*, 2017; Momtaz, 2018). Because ICOs have *inter alia* less legal backing, less regulation and lower track records than IPOs and because ICOs are more likely to be fraudulent, there will be more information asymmetry between issuers and investors in ICOs than between issuers and investors in IPOs. We, therefore, assumed that ICOs would be more underpriced than IPOs. We were able to confirm this for the 56 ICOs from the USA. US ICO underpricing was on average also significantly larger than the average underpricing of US IPOs at the beginning of the dot.com bubble in 1999.

Regression analysis shows that the variables trading volume, issue size, market sentiment, a hot issue market and the use of a pre-ICO significantly influence ICO underpricing. Higher (first-day) trading volume and a better market sentiment go together with a higher level of ICO underpricing and the issue size, a hot market and the existence of a pre-ICO have negative effects.

There are also some restrictions. A first restriction is that we focused on ICOs and not on crowdfunding, though there are similarities in that both of them are novel ways to finance projects. A second restriction is that we had to decide on the definition of a listing day. Cryptocurrencies are traded on many exchanges and if the exchange is tailored to the cryptocurrency itself, the data on, e.g., close prices are not necessarily to be trusted. We, therefore, decided to use close price data from coinmarketcap.com, which requires a listing on two exchanges. This choice implies that there may have been trades before the listing day itself. A third restriction arises from the relative newness of the ICO phenomenon. We gathered data on underpricing from coinmarketcap.com and combined that with project information from icobench.com. However, the data were not simply matched and they required manual adjustments based on several other sources. We hope that in due time data on ICOs will be as adequate as data on IPOs and that they become more readily available. It might help if regulators or the crypto community would institute publication requirements. Adherence to such requirements would also reduce the extent of fraud and of asymmetric information, so that solid issuers with good projects might benefit from less underpricing.

Our research may help in reducing underpricing, as we find that issuers can reduce it by holding a pre-ICO and by considering larger issue sizes. If they do so, investors will get fewer opportunities to benefit from underpricing. Investors can, nevertheless, also profit from the knowledge generated in this paper. When market sentiment is positive and first-day trading volume is expected to be high, investing in ICOs is likely to give them higher first-day returns. Finally, we hope that this paper will serve as a basis for further research into the exciting and dynamic world of cryptocurrencies.

Notes

1. https://elementus.io/blog/ico-market-august-2018/ (all websites that are referred to in the footnotes of this paper were accessed at November 9, 2018)
2. https://bloomberg.com/news/articles/2018-03-30/telegram-raises-1-7-billion-in-coin-offeringmay-seek-more
3. Financial institutions may also consider cryptocurrencies as an alternative form of investment (Lee *et al.*, 2018).
4. The statement on cryptocurrencies and initial coin offerings (ICOs) by the US Securities and Emissions Committee indicates when a cryptocurrency is considered to be a security. Tokens and offerings that incorporate features and marketing efforts that emphasize the potential for profits based on the entrepreneurial or managerial efforts of others have characteristics of a security under US law. A crucial step in testing if the project falls under security regulation is the Howey test, which is created by the US Supreme Court (Momtaz, 2018).

5. See for an overview of ICO practices and differences with an IPO also: pwccn.com/en/financial-services/publications/introduction-to-token-sales-ico-best-practices.pdf
6. For the exposure to insider trading and pump and dump schemes, we refer to: https://forbes.com/how-is-trading-cryptocurrency-different-from-stocks-and-forex-trading
7. See the markets section at https://coinmarketcap.com/currencies/bitcoin
8. See Table I of the US IPO database of Jay R. Ritter for a sample size of 8,360 IPOs between 1980 and 2017 in the USA. site.warrington.ufl.edu/ritter/ipo-data/αα. We also found the average annual value of US IPO underpricing at the beginning of the dot.com bubble of 1999.
9. We also considered including the ICO failure rate as a negative measure of ICO market success (ratio of announced ICOs that ultimately did not get a listing to the total number of ICOs announced during the 30 days preceding the ICO). However, due to its relatively high and unexpected positive correlation with the hot market dummy and because it reduced our number of observations and the adjusted R^2 we discarded this variable.
10. coinmarketcap.com normally lists a cryptocurrency if it is publicly and actively traded on at least two cryptocurrency markets. It also checks whether the market volume weighted close prices of the last trades are not driven by suspect outliers. The choice of the coinmarketcap.com listing day thus implies that there may have been trades before that day. We, however, like to add that IPOs may also have "when issued" trades before the official listing date.
11. The CCI30 index is a major benchmark for the cryptocurrencies market. Its components are the 30 cryptocurrencies with the largest market capitalization (see https://cci30.com). The CCI30 index close price is based on a value weighted average of cryptocurrencies trading before the end of the day (at 0.00 hours GMT). The matching of the CCI30 index returns and the listing day returns of the individual cryptocurrencies will not be 100 percent because there may have been trades in the individual cryptocurrency before the listing on coinmarketcap.com
12. ICObench is the number one ICO rating platform and community supported by investors and experts (icobench.com).
13. ICO Drops contains a complete list of all ICOs in three columns "Active ICO," "Upcoming ICO" and "Ended ICO" with rating and analysis (icodrops.com).
14. Cryptocompare is one of the major cryptocurrency data hub and interactive platform (cryptocompare.com).

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