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ORIGINAL PAPER

Signaling in the Market for Security Tokens

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Abstract
Security token offerings (STOs) are a new means for ventures to raise funding, where digital tokens are issued as regulated investment products on the blockchain. We study market outcomes in the primary and secondary markets for security tokens and examine the associated determinants in the context of signaling theory. We analyze success determinants of 138 STOs and find that a pre-sale and the announcement of token transferability are positively related to the funding success and serve as positive quality signals for investors to overcome information asymmetries. We examine 108 security tokens traded on centralized and decentralized exchanges related to the rapidly evolving area of decentralized finance. There is hardly any underpricing in the market, and it is positively associated with the crypto market sentiment as an external signal. When traded on the secondary market, security tokens generate both extremely positive and negative returns for various short-term time horizons. We disentangle the liquidity situation in the market between centralized and decentralized exchanges and find that decentralized marketplaces are less liquid and offer lower barriers to entry, indicating slow market completion.

Keywords Security token offering · Blockchain · Signaling · STO · Decentralized finance

JEL Classification G24 · K22 · L26 · M13 · O31

1 Introduction

Advances in digitization and information technology have changed and transformed the financial industry fundamentally. Traditional financial institutions and banks are losing their supremacy as new market entrants and emerging technologies supersede or replace their role as financial intermediaries. Distributed ledger technology (DLT)

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and the blockchain, as its most common sub-type (Fisch 2019), enable digitizing any asset class as tokens and are paving the way toward future financial markets. Digital tokens are issued through token offerings on the blockchain, which represent an innovative funding mechanism in entrepreneurial finance. Once the token offering has taken place, the tokens can be traded on the secondary market.

In this study, we examine how signaling affects the behavior of market participants in both the pre-and post-STO phases to provide a holistic picture of the entire market. In particular, we study STO market outcomes such as STO funding success, underpricing, returns, liquidity, and various internal and external signals as determinants. Since the mechanisms and issuance processes are completely different because of blockchain technology, it is worth investigating whether signaling and related theories known from traditional capital markets also apply to the security token market.

The first tokens issued in the year 2013 were utility tokens sold through an initial coin offering (ICO). Utility tokens entail consumption rights for products or services. After a boom period in 2017 and 2018, the initial popularity of ICOs declined because of the lack of investor protection and many fraudulent activities, causing a negative market sentiment (Momtaz et al. 2019). As a result, security tokens issued through security token offerings (STOs) have since emerged as innovative investment products (Lambert et al. 2022). Security tokens represent shares of ownership in corporate equity, fixed income, investment funds, commodities, or less liquid asset classes such as real estate or fine art. Due to the classification as conventional securities and the resulting regulatory requirements, they are considered the regulatory-compliant successors to utility tokens. This new form of venture financing has several advantages: companies can easily reach a large investor base while reducing transaction costs. Moreover, clearing and settlement occur quickly, and at any time, transparency regarding the transactions is achieved through the blockchain, and fractionalization enables investments in less liquid asset classes with high entry barriers (Ante and Fiedler 2020; Lambert et al. 2022). The interoperability of the blockchain could solve the previous problem of lack of compatibility between different systems or databases and theoretically enables self-custody of any tokenized asset on one platform (Momtaz 2023). Another major advantage of STOs is the potential liquidity provided through the possibility to transfer and trade tokens on secondary markets. As a result, security tokens combine the benefits of the underlying technology with the legal protection of conventional securities.

Prior studies on ICOs analyzed success determinants (Adhami et al. 2018; Amsden and Schweizer 2019; Fisch 2019; Howell et al. 2020; Roosenboom et al. 2020), investor characteristics and motives (Boreiko and Risteski 2021; Fahlenbrach and Frattaroli 2021; Fisch et al. 2021; Hackober and Bock 2021) or the informative disclosure and language of white papers (Florysiak and Schandlbauer 2022; Thewissen et al. 2022). Other studies emphasize the post-ICO performance of tokens, such as underpricing (Chanson et al. 2018; Felix and von Eije 2019) and/or short-term returns (Benedetti and Kostovetsky 2021; Fisch and Momtaz 2020; Lyandres et al. 2022; Momtaz 2021a). However, due to the security and regulation characteristics and the associated rights and obligations for companies and investors alike, security tokens need to be considered on their own. The existing literature on STOs studies success determinants during the funding process regarding investors' rights, issuer, and offering characteristics (Lambert et al. 2022) or cheap human capital and social media signals (Ante and Fiedler 2020). Momtaz (2023) describes the economics, law, and technology of STOs and provides a comparison of STOs, ICOs, and IEOs. Other studies embed STOs in a theoretical context, e.g., Gan et al. (2021) study the optimal design of an STO, Gryglewicz et al. (2021) examine when token financing is preferable to equity financing, while Miglo (2021) compares STOs and ICOs under moral hazard and demand uncertainty.

We theoretically embed this article in the context of signaling theory to overcome information asymmetries between the STO-issuing company and potential primary and secondary market investors both during the pre-and post-STO phase. This article extends previous research by investigating whether a pre-sale and the announcement of token transferability or later expected liquidity are positively related to the success of an STO. They can be interpreted as positive quality signals and have not been investigated in the context of an STO yet. During a pre-sale, the transparent investment of publicly known experts and institutions serves as a signal for trustworthiness (Howell et al. 2020) and constitutes a method to gather valuation-relevant information at an early point of the process to make the main funding more effective (Momtaz 2020). We find that a pre-sale and the announcement of transferability serve as quality signals, and both have a positive link to the funding success of an STO. The announcement of future token transferability enables the investors to trade the tokens on secondary marketplaces and translates into liquidity in the post-STO phase. Once trading begins, the market valuation should lead to accurate pricing and show whether the signals previously sent about the quality of the STO correspond to reality (Florysiak and Schandlbauer 2022). In this regard, to the best of our knowledge, we are the first to empirically investigate the post-STO phase by analyzing the secondary market for security tokens. As the first market valuation, we study underpricing and relate it to the literature on IPOs regarding determinants such as market sentiment and large investors. Underpricing hardly seems to exist in the STO market, which is related to the market sentiment as an external signal. As a further market valuation, we examine the short-term post-listing performance by calculating buy-and-hold as well as buy-and-hold abnormal returns over different short-term horizons. In this way, we can verify whether the signals previously sent reflect the reality of the quality of the STO and translate into higher returns. We find that both extremely negative and positive returns can be achieved depending on the time horizon. Furthermore, we analyze the evolution of the liquidity situation in the market since its inception. In particular, we add to the literature the substream of research that disentangles the effect of a token being traded on centralized or decentralized exchanges as a means of the rapidly evolving area of decentralized finance. So far, this has solely been elaborated for cryptocurrencies as a whole by Aspris et al. (2021) but has not been addressed in any other previous study on the aftermarket performance of tokens. Our study is based on two hand-collected, overlapping, but non-identical datasets comprising 138 STOs and 108 security tokens traded on the secondary market.

The remainder of this paper is organized as follows. In Sect. 2, we present the technological background and classification of STOs. In Sect. 3, we present an overview of signaling theory and derive our hypotheses. Section 4 describes data, variables, and results regarding the pre-STO phase and the analysis of STO success determinants. Section 5 focuses on the post-STO phase, including STO underpricing, returns to investors, and liquidity. Section 6 concludes this study.

2 Security token offerings: background

2.1 Technological background

We first describe the technological background and termini relevant to a security token offering on the distributed ledger technology. DLT refers to an approach in which data is recorded and shared via a decentralized, distributed ledger of various different participants. The blockchain is the most relevant form and sub-category of DLT, although both terms technically are not identical (Fisch 2019). However, we use the terms synonymously in this study. The structure in the form of cryptographic chains of data blocks is characteristic of blockchains. Anyone can see and download a copy of a public blockchain. The only relevant version is the one that contains the latest legitimate transactions (Schär and Berentsen 2020). The immutability of the blockchain and its transactions generate trust between the parties involved (Chod et al. 2022). Ethereum is the most commonly used blockchain infrastructure for ICOs (Howell et al. 2020) as well as for STOs. This has prevailed due to the wide range of application possibilities regarding the programming and execution of smart contracts. Smart contracts are digital contracts that allow specific transactions to be executed automatically when certain predefined events occur (Buterin 2013). The addition of assets to the blockchain is referred to as tokenization, while the digital version of the asset on the blockchain is called a token (Schär 2021). The financial use case for smart contracts is these digital tokens, where the smart contract verifies, for example, that the investor has received payment and then automatically sends the token to the investor's wallet (Cong et al. 2022). The distinction between the three following types of tokens has crystallized (Howell et al. 2020), though there are several hybrid forms. Payment tokens are a means of payment for purchasing goods or services (e.g., Bitcoin). Utility tokens entail consumptive rights to use blockchain-based services and security tokens. For security tokens, we apply the definition of Lambert et al. (2022) as "a digital representation of an investment product, recorded on a distributed ledger, subject to regulation under securities laws" (Lambert et al. 2022, p. 302). The application of blockchain to the entire financial sector holds great potential for systemic change (Guo and Liang 2016; Wright and De Filippi 2015).

2.2 Implications for financial markets

The digitization of assets has multiple implications for investors, companies, and financial markets alike. The global nature of the blockchain, and thus the lower barriers between financial markets of different countries, means companies have a wider geographic scope and can reach a broader investor base

(Chang 2020). Fractional ownership through the divisibility of the underlying asset enables retail investors to invest small amounts of money in previously unattainable asset classes, which allows investors to diversify their portfolios more broadly (Kreppmeier et al. 2023). Investors no longer need to demand higher returns resulting from higher divestment risk. Therefore, digitized assets can reduce illiquidity premia and finally make these assets trade closer to their fair value (OECD 2020). The properties of the blockchain promise increased transparency in tamper-proof, instantaneous transactions. Automated transaction processing, as well as the allocation and distribution of payment flows using smart contracts, can reduce the costs of issuance and transactions (Chang 2020; Guo and Liang 2016). Automated settlement and disintermediation lead to a reduction in trading fees and a significant decrease in settlement times, thereby enabling more efficient financial markets (Momtaz 2023). Moreover, by leveraging a blockchain, the counterparty risk can be eliminated since intermediaries become obsolete (Uzsoki 2019). All of these technical innovations are paving the way for a digitized token economy of the future.

2.3 Differentiation from existing forms of financing

IPOs are the traditional, regulation-compliant way to list a company publicly for the first time. A common feature of IPOs and STOs is that the offering has to comply with regulations, and investors receive binding rights. A substantial difference between STOs compared to IPOs is the use of a blockchain. This ensures that the settlement of the transactions after an STO is faster and more efficient (Mills et al. 2016). The issuance and marketing processes of IPOs and blockchain-based offerings are completely different: IPOs perform a book-building process and use social media solely to attract investors; token offerings communicate relevant financing information for the offering to prospective investors through social media channels (Ofir and Sadeh 2020).

The basic idea behind crowdfunding (CF) is that funding of a target amount is achieved by collecting small amounts of money from the crowd of investors – this is a common feature with STOs due to fractionalization. For CF, platforms handle the projects holistically, act as intermediaries, and perceive monitoring functions in the selection process of the projects. In ICOs or STOs, platforms play only a subordinate role in displaying aggregated information about projects due to the blockchain, leading to a shift in screening activities exclusively to individual investors (Block et al. 2020). The problem with CF is that the shares purchased may be difficult to resell or liquidate because there is no real secondary market, while tokens can usually be traded on secondary markets.

Both CFs and ICOs are about raising money from potential users to spend later on the platform for services, outside of which the token has no value (Howell et al. 2020). Thus, utility tokens are legally classified only as donations with limited rights, while investors in regulated security tokens receive corresponding rights from the underlying financial instrument (Ante and Fiedler 2020).

3 Theory and hypotheses

3.1 Signaling theory

The conceptual framework of our hypotheses draws upon the literature in the field of information asymmetries and signaling. Signaling theory deals with reducing information asymmetries between the involved parties (Spence 2002). In the case of STOs, these information asymmetries arise because the STO-issuing firm has internal, private information about its quality and future prospects that is not available to the public. The signal itself must be observable for the receiver and associated with monetary, time, reputation, or effort-related costs that prevent imitation (Connelly et al. 2011). Therefore, companies are incentivized to communicate this information to potential investors and reduce information asymmetries. As a result, investors are better able to identify high-quality ventures and invest accordingly (Bergh et al. 2014; Florysiak and Schandlbauer 2022). Information asymmetries are especially prevalent in token offerings, as these companies are often young and lack a solid track record and experience (Howell et al. 2020). This effect is amplified by retail investors, who are mainly present in the market for token offerings (Lee et al. 2022). In comparison to institutional investors, retail investors have less experience and financial resources to evaluate investment opportunities (Ahlers et al. 2015). Additionally, the underlying blockchain requires investors to have a certain level of technical knowledge and familiarity (Momtaz 2021a). Consequently, it is crucial for companies conducting an STO to send quality signals to potential investors in order to reduce information asymmetries. Information asymmetries and the related signaling play an important role both during the STO on the primary market (the pre-STO phase) and when security tokens are traded in the secondary market (the post-STO phase).

3.2 Hypotheses development: Pre-STO phase

An STO consists of several rounds, and a pre-sale can precede the actual main public offer. A pre-sale commonly aims at a limited group of investors and has several advantages. On the one hand, Howell et al. (2020) compare a pre-sale to the book-building process in IPOs to ascertain information about the correct demand and price, which makes the main funding more effective (Momtaz 2020). Usually, a pre-sale has a discount on the token price for early investors. A pre-sale could therefore lead to early participation and a momentum effect (Roosenboom et al. 2020) due to the authentication of the issuer, especially when prominent experts or institutions can be attracted (Howell et al. 2020). In the context of reward-based and equity crowdfunding, it is found that the generation of early investors and an early, strong campaign is a quality signal of project success for potential investors (Colombo et al. 2015; Vulkan et al. 2016). The possibility of costly gathering price-relevant information and attracting early attention before the main offering could signal that the STO is of high quality, which may be perceived as positive by investors.

Hypothesis 1: *The implementation of a pre-sale phase is positively related to the success of an STO.*

There are two ways to trade and transfer a security token: on exchange platforms or directly from peer-to-peer (P2P). Even if a security token is not listed on an exchange platform, an investor can generate liquidity via a P2P transaction. The transferability of the token is constitutive of the possibility of obtaining future liquidity by trading the security token. From a technical standpoint, the feature of transferability of a token cannot be taken for granted. Some companies point out that the issued token may not be transferred and that the transferability will therefore be technically restricted over the course of programming the token.[1] This technical limitation restricts the future liquidity of the token. Florysiak and Schandlbauer (2022) even go so far as to claim that a security token gets its value from the fact that it is tradable. Already in the ICO context, it is stated that technical aspects of the technology used, such as the transferability of the token, play a major role in the investment decision of an investor (Fisch et al. 2021). Transferability is a major advantage of STOs over crowdfunding. For equity crowdfunding, a platform is explicitly required to trade the shares due to the lack of a blockchain (Signori and Vismara 2018). Investors could therefore rate the announcement of transferability of the security token as a quality signal and invest primarily in STOs in which they can resell the security token without restrictions from the issuing company to generate future liquidity. The explicit emphasis on the intent of transferability is a potential indicator of high-quality STOs and shows that they intend to trade their tokens in the secondary market in the future, thus deriving value.

Hypothesis 2: *The announcement of transferability is positively related to the success of an STO.*

Transferability is both a quality signal during the pre-STO phase and a technical prerequisite for tokens to be traded on the secondary market in the post-STO phase. The market valuation in the post-STO phase can be used to verify to what extent the signals sent during the STO correspond to reality and are subsequently reflected in the associated STO market outcomes.

3.3 Hypotheses development: Post-STO phase

In the following, we focus on the post-STO phase by investigating underpricing or, more specifically, 'money left on the table' for the issuer (Loughran and Ritter 2002). We account for underpricing as the return of an STO investor on the primary market who holds the token until the listing on the secondary market. We derive hypotheses for the determinants of STO underpricing that relate to external signals,

[1] Vermögensanlagen-Informationsblatt RAAY Real Estate GmbH, 2020: "Investors do not have the right to transfer and encumber the token to third parties. An obligation of the issuer or the company to take back the token exists through the right of termination.[...] A sale of the token by the investor is generally not possible." [translation by the authors]

in other words, the signals that come from outside the STO-issuing firm as opposed to the pre-STO phase.

In the *increased monitoring hypothesis*, Stoughton and Zechner (1998) state that underpricing is a way to attract large investors under the assumption that only these investors are capable of monitoring. In practice, companies seek to incorporate large investors into the shareholder structure who have mechanisms to monitor and influence management in order to increase the firm value in the interests of all shareholders (Admati et al. 1994). Stoughton and Zechner (1998) state that small investors free-ride on large investors' monitoring, an agency-problem which is also documented in the context of equity crowdfunding (Hornuf and Schwienbacher 2018; Moritz et al. 2015). Therefore to increase the firm value, the company needs to lure large investors with the help of underpricing in their own interest. As a consequence, the fewer large investors invested in the STO, the primary offering, the more pronounced the underpricing will be to incentivize large investors to invest in the secondary market.

Hypothesis 3: *The number of large investors during the STO is negatively related to underpricing.*

The IPO literature suggests that market sentiment is an important predictor of underpricing (Loughran and Ritter 2002; Green and Hwang 2012). The demand of sentiment investors may disappear in times of negative market sentiment, and, therefore, 'normal' investors with IPO stocks in inventory need to be compensated through underpricing for the associated risk of losses (Ljungqvist et al. 2006). We expect that the market for security tokens is salient to this kind of market timing since Baker and Wurgler (2006) have shown that investor sentiment is particularly present for subjective and difficult-to-arbitrage securities, such as security tokens. It is up to the STO-issuing firm when exactly the trading of their tokens on the secondary markets starts. In order to prevent their token from generating negative initial returns, they will time the first trading day and avoid phases of negative market sentiment (Drobetz et al. 2019). Consequently, we assume that issuers await times of positive market sentiment and avoid negative market sentiment as an external signal, which increases underpricing.

Hypothesis 4: *The market sentiment is positively related to underpricing.*

4 Pre-STO phase

4.1 Sample construction and data of STO success determinants analysis

There is no central database of all STOs carried out to date. As such, this sample is obtained by manually collecting and matching data from multiple data sources and websites. First, the starting point was the website *Digital Asset Network*. From there, we moved to various aggregator sites and looked for offers declared as STO.[2] In the second step, we searched the companies' websites for information about each STO. For STOs issued in the USA, we additionally accessed the *EDGAR* database from the SEC. We collected documents such as white papers, legal documents, prospectus, and further investor documents. Third, a plausibility check took place to verify the collected data, including matching with transaction data from the blockchain, as information in different databases may converge. The final step for each observation was to check the accordance with the definition of a security token of Lambert et al. (2022). We had to exclude many STOs due to limited data availability, STOs that were announced but for which there was never an offer and offerings that did not meet the definition. We executed these steps in sequence and obtain 71 STOs with very detailed data. We validated and complemented our self-collected data with 67 STOs from the *Token Offerings Research Database* (TORD) of Momtaz (2021b) after removing duplicates and follow-up research. Finally, we end up with 138 STOs. These STOs were issued between 1st March 2017 and 31st December 2020. The sample size in other STO success determinants studies is similar, especially the reduction due to missing detailed information to perform the multivariate analysis (Ante and Fiedler 2020; Lambert et al. 2022).

4.2 Variables of STO success determinants analysis

The choice of the dependent variable to measure STO success is not completely trivial. In pure equity markets, naturally, a valuation-based measure is preferable, which relates the amount raised to the portion of equity sold by the issuer. For instance, two companies may raise the same amount of money in the STO but give up a different proportion of equity, resulting in different valuations. However, in addition to stocks, our sample also includes fund or debt tokens, whose observations we do not want to lose by opting for a valuation-based variable since the focus of this study is on new entrepreneurial funding mechanisms in general and not on the type of capital. Therefore, the *Funding Amount* serves as our simplified dependent variable reflecting a firm's overall ability to raise funds from investors and is thus the most direct way to gauge a firm's access to external finance (An et al. 2019). The use of the variable to quantify the success of a project is common in the literature on venture capital (Baum and Silverman 2004), crowdfunding (Block et al. 2018; Mollick 2014), ICOs (Fisch 2019; Lyandres et al. 2022), and STOs (Ante and Fiedler 2020; Lambert et al. 2022). Accordingly, our results need to be interpreted from the investors' perspective, as they reflect the collective reaction of investors to the STO rather than the financial corporate valuation or implications thereof. To account for the high skewness of the *Funding amount*, we use a log transformation. As an alternative measure of success, we incorporate the variable *Funding amount to target* as an additional dependent variable. It is the percentage ratio of the *Funding amount* to the *Hardcap*, the pre-defined target amount of the STO. Considering this

[2] The aggregator websites considered in this study are Block Databank, Blockdata, BlockState, CoinMarketPlus, Digital Asset Network, ICO Bench, ICO Drops, ICO Holder, ICO Stamp, ICOs Bull, STO Analytics, STO Docket, STO Filter, STO Market, STO Rating, STO Scope, The Tokenizer.

ratio allows us to address the issue that a few STOs with large *Funding amounts* may bias our results (Lambert et al. 2022).

To test Hypothesis 1, we include the dummy-variable *Pre-sale*, which takes a value of 1 if a firm conducts a *Pre-sale* phase before the main funding, and 0 otherwise. To test Hypothesis 2, we consider the dummy-variable *Transferability*, which accounts for whether a company announces in its published documents for the STO that the token is technically equipped to be transferable for investors.[3]

We include several control variables in our models. We control for different types and rights of tokens representing their economic purpose: *Equity token*, *Fund token*, and the remaining investment tokens. *Equity tokens* usually entail the investor with cashflows in the form of dividend payments. *Fund Tokens* offer diversification opportunities through indirect investments, which makes them potentially attractive to investors. Additionally, the dummy-variable *Voting rights* refers to the possibility of the investor to participate, e.g., in the composition of the board or in structural decisions that provide the investor with opportunities for control. If STO investors are not entitled to a *Voting right*, it would indicate the typical corporate governance issue of separation between control rights and ownership (Lambert et al. 2022). We further control for several variables which are known from CF and ICOs. The dummy-variable *Softcap use* indicates whether a minimum funding threshold must be reached for an STO to be issued. The metric variable *Hardcap* measures the STOs' funding target for which a log transformation is used to account for the skewness. Investors have an incentive to select projects with realistic *Hardcaps*. A target amount set too high could indicate that the project will not reach the amount. A target amount that is too low could suggest that a project will not be carried out (Mollick 2014) or that a campaign will stop early (Fisch 2019). The variable *Telegram* describes whether a company makes use of Telegram as a communication medium. *Telegram* has established itself as a communication channel in the crypto world to communicate information directly with potential investors. The use of *Telegram* signals a company's familiarity with the crypto sphere (Amsden and Schweizer 2019). We additionally include variables related to the characteristics of the issuing company, as investors draw inferences about the quality of the offering from the firm. The variable *Listing* indicates whether an STO-executing firm is listed on a traditional stock exchange, which is a signal for the potential maturity and regulatory compliance of the company. We additionally control for the logarithmized *Age* of the company as the difference between the date of STO and the date of formation of the firm. The probability of a company's survival decreases more significantly in earlier years (Pazos 2019). Investors could anticipate this and invest in older companies. Already in the crowdfunding context, the influence of geography on campaign success was identified (Mollick 2014). Because of this, additional dummy variables for the country of incorporation are included: *USA*, *Cayman Islands*, *UK*, *Europe*, and the remaining countries.

[3] While an investor could also glean this information from the smart contract, it cannot be assumed that the average investor has these technical capabilities. Therefore, we rely on the information provided in the offering documents.

4.3 Descriptive statistics of STO success determinants analysis

We report the descriptive statistics of the variables used in the analysis for STO success determinants in Table 1.

The *Funding amount* has a mean of 9.698 corresponding to $16,285. The minimum and 25th percentile with a value of 0 indicate that there are many unsuccessful offerings. The maximum value of 18.713, which corresponds to $133,953,060, demonstrates the high skewness. The mean and median of the alternative success variable *Funding amount to target* reveal that the majority of companies do not reach the *Hardcap*. *Pre-sales* were conducted on average of 37.7% of the ventures to offer their tokens prior to the main funding phase. The share of companies offering a *Pre-sale* is lower in comparison to ICO studies (Howell et al. 2020; Florysiak and Schandlbauer 2022; Fisch 2019). The *Transferability* feature of the token to ensure future liquidity was mentioned by 83.1% of the ventures in their offering documents.

Our control variables regarding token types and rights show that most STOs with 36.6% issue an *Equity token* entailing dividend payments and 11.3% a *Fund token* as an indirect investment. A share of 18.3% of the tokens provides a *Voting right* to the investor, which is an indication of the separation of control and voting rights. The issuers do not intend to give investors a say in the company matters, which is

Table 1 Descriptive statistics for STO success determinants analysis

Statistic	N	Mean	SD	Min	Pctl(25)	Median	Pctl(75)	Max
Dependent variables								
Funding amount	138	9.698	6.917	0.000	0.000	13.220	14.871	18.713
Funding amount to target	71	0.311	0.401	0.000	0.0001	0.120	0.524	1.070
Explanatory variables								
Pre-sale	138	0.377	0.486	0.000	0.000	0.000	1.000	1.000
Transferability	71	0.831	0.377	0.000	1.000	1.000	1.000	1.000
Equity token	71	0.366	0.485	0.000	0.000	0.000	1.000	1.000
Fund token	71	0.113	0.318	0.000	0.000	0.000	0.000	1.000
Voting rights	71	0.183	0.390	0.000	0.000	0.000	0.000	1.000
Softcap use	71	0.662	0.476	0.000	0.000	1.000	1.000	1.000
Hardcap	71	8.433	8.328	0.000	0.000	13.883	16.660	20.723
Telegram	71	0.563	0.499	0.000	0.000	1.000	1.000	1.000
Listing	71	0.056	0.232	0.000	0.000	0.000	0.000	1.000
Age	71	0.557	0.722	0.000	0.000	0.164	0.895	3.088
Cayman Islands	138	0.051	0.220	0.000	0.000	0.000	0.000	1.000
Europe	138	0.297	0.459	0.000	0.000	0.000	1.000	1.000
UK	138	0.087	0.283	0.000	0.000	0.000	0.000	1.000
USA	138	0.312	0.465	0.000	0.000	0.000	1.000	1.000

This table reports the descriptive statistics (mean, standard deviation, minimum, 25th percentile, median, 75th percentile, and maximum) for the full sample. The different number of observations of N=71 and N=138 is based on the fact that not all of the variables considered in our analysis are included in the *Token Offerings Research Database* of Momtaz (2021b). All variables are defined in Table 8 consistent with the findings of Lambert et al. (2022). The control variables related to modern forms of venture funding reveal that 66.2% of the companies make use of a *Softcap* as a financing threshold. The *Hardcap* with a median of 13.883 corresponding to $1,069,819 and a maximum of 20.723 which corresponds to $999,734,198, both of which are higher than the actual *Funding amount*, indicate that most companies fail to meet their pre-specified *Hardcap*. On average, the mass-market communication channel *Telegram* is used by 56.3% of companies to communicate directly with investors. Table 9 in the Appendix displays the correlation coefficients for all variables related to the analysis of STO success. The variance inflation factors (VIF) are reported below the regression coefficients in Table 2. We have neither high correlations above 0.5 nor VIFs above a conservative threshold of 5. Thus, we assume that multicollinearity is no concern in our analysis.

4.4 Multivariate analysis: STO success determinants

Table 2 presents the results of the tobit models with *Funding amount* as the dependent variable. We estimate a tobit specification as the dependent variable *Funding amount* is left-censored at zero since we account for unsuccessful funding with a value of zero. All specifications are estimated with heteroscedasticity-robust standard errors and year dummies. Model (1) includes the STOs of the *TORD* of Momtaz (2021b) resulting in 138 observations, while models (2) to (5) are reduced to the smaller sample of 71 observations with more detailed data because not all of the variables in our analysis are in the *TORD* database. However, the coefficients continue to have the same signs and similar significances. The hypotheses-related variables are included interchangeably and step-wise in the models (2) to (4). In the full model (5), company-specific variables are also considered. The following explanations refer to the full model (5) with a Pseudo R^2 of 0.129. The relation of the number of observations to the number of variables in our models could be suspicious for overfitting. Therefore, we additionally calculate the Akaike Information Criterion (AIC). We find that our full model (5) has the lowest AIC value compared to the other models, thus, it is the best-fit model for our data.

Model (5) in Table 2 shows that conducting a *Pre-sale* is positively associated with the *Funding amount*. The occurrence of a *Pre-sale*, indicated by the dummy-variable with a value of 1, equals a c.p. increase of 16,204% in the *Funding amount*.[4] This result is important for STO-issuing companies since it emphasizes that the course for a successful STO can be set early on by planning the individual STO phases, including a *Pre-sale*. According to the rationale of signaling theory, conducting a *Pre-sale* involves effort and costs for the STO and is therefore translated into higher signaling costs which only high-quality STOs can afford. Likewise, however, it is an easy-to-observe signal to potential investors that issuers are bearing these costs and are trying to gather valuation-relevant information to make the following main sale more effective. Consequently, we find empirical support for Hypothesis 1.

[4] Since the dependent variable *Funding amount* is logarithmized, we have a log-level model. We, therefore, apply the Halvorsen and Palmquist (1980) correction for an exact interpretation of the economic significance, i.e., for *Pre-sale*: $100(e^{\beta_1} - 1)\% = 100(e^{5.094} - 1)\% = 16,204\%$.

Table 2 Tobit STO success determinants analysis

	Dependent variable:				
	Funding amount				
	(1)	(2)	(3)	(4)	(5)
Pre-sale	3.100**	4.970**		5.538**	5.094**
	(1.563)	(2.320)		(2.155)	(2.216)
Transferability			4.232**	5.018***	5.858***
			(1.770)	(1.761)	(1.676)
Cayman Islands	9.720***	13.128***	11.192***	11.877***	12.839**
	(2.463)	(4.229)	(3.147)	(4.083)	(4.480)
Europe	6.589***	4.683	4.060	3.111	3.064
	(2.269)	(2.990)	(2.733)	(2.806)	(2.764)
UK	3.678	3.775	4.988	4.214	5.150
	(3.545)	(3.733)	(3.130)	(3.395)	(3.189)
USA	3.241	−0.023	0.294	−0.677	−0.893
	(2.335)	(3.016)	(2.684)	(2.726)	(2.839)
Equity token		2.019	1.697	1.784	1.714
		(1.699)	(1.690)	(1.596)	(1.487)
Fund token		3.123	3.316	1.650	1.848
		(3.327)	(3.358)	(3.076)	(3.172)
Voting rights		2.854*	3.787**	3.022*	3.383**
		(1.705)	(1.736)	(1.556)	(1.517)
Softcap use		−4.896***	−5.173***	−5.216***	−5.460***
		(1.357)	(1.326)	(1.279)	(1.223)
Hardcap		−0.288	0.022	−0.228	−0.025
		(0.483)	(0.469)	(0.455)	(0.450)
Telegram		−7.116***	−5.423***	−8.132***	−8.252***
		(2.113)	(1.675)	(1.914)	(1.900)
Listing					4.920
					(3.694)
Age					1.320
					(1.025)
Mean VIF	1.170	1.553	1.466	1.571	1.591
Maximum VIF	1.237	1.963	2.099	2.186	2.078
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	138	71	71	71	71
Pseudo R^2	0.047	0.101	0.095	0.116	0.129
Log pseudolikelihood	−373.305	−189.648	−190.956	−186.322	−183.715
AIC		409.236	411.912	404.645	403.431

This table reports cross-sectional Tobit regressions. The reference category for the countries is *Country other*. All models include a not reported constant. Heteroscedasticity-robust standard errors in parentheses. The symbols *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. All variables are defined in Table 8

Moreover, the coefficient of *Transferability* is positive and significant. The announcement of *Transferability* in the offering documents, indicated by the dummy-variable with a value of 1, equals a c.p. increase of 34,902% in the *Funding amount*. This finding underpins that the announcement of *Transferability* and the expectation of future liquidity enables companies to raise more funding. We find supportive evidence for Hypothesis 2 regarding the positive signaling effect of the announcement of *Transferability* to overcome information asymmetries. Interestingly, when embedding the results in the context of signaling, we observe that a company's intention to offer a transferable security token is crucially related to the success of an STO, even though it does not come at a high cost for the issuer and cannot be easily verified by investors. This may be due to the fact that the expectation to trade the token in the future appears to be the main motive for a token investment (Fisch et al. 2021).

The results pertaining to the token type and rights deliver only for *Voting rights* a positive and significant link to the *Funding amount*. This means that, unlike IPOs (Smart et al. 2008) and equity crowdfunding (Cumming et al. 2019), the separation of ownership and control does not play a major role for STOs. This result is in line with Lambert et al. (2022), who claim that the transparency of the blockchain and the associated lower costs of acquiring information for external investors reduce this agency problem. The coefficient of the variable *Softcap use* is negative and significant. Lambert et al. (2022) argue that if a *Softcap* is used, a company needs to convince more investors to reach the financing threshold in the first place. The utilization of *Telegram* as a communication channel to investors is negatively related to the success of an STO. Lyandres et al. (2022) claim that social media signals depend on the quality and cost of the social media platform, which is in the case of *Telegram* low. The *Cayman Islands* are positively associated with the *Funding amount*. However, we cannot disentangle the real considerations of the companies in this regard. On the one hand, the *Cayman Islands* are considered a tax haven with numerous tax advantages for investors, and on the other hand, they offer a more lax legal framework. For the remaining company-specific variables, we do not find a significant coefficient in any model specification.

As a robustness check displayed in Table 3, we estimate the tobit models with the alternative success measure *Funding amount to target* as the dependent variable.

In the alternative success specification, all signs remain unchanged, but the significance of *Pre-sale* disappears probably because of variation in our small sample (Lambert et al. 2022). The coefficient for *Transferability* is still positive and significant, confirming our prior results. Interestingly, the company-specific variable *Listing* now loads positive and significantly, which is consistent with our expectation that this is an effective signal of a firm's maturity. We can conclude that the robustness check does not show major deviations from the main analysis.

There is a potential endogeneity issue with the explanatory variables *Pre-sale* and *Transferability* and the dependent variable *Funding amount*. An STO-issuing company might choose these features while there are some unobserved characteristics, such as the quality of the STO or the issuing company, that may affect both the choice of a *Pre-Sale* or *Transferability* of the issuer and the funding success. As a matter of fact, investors do not necessarily base their investment decision on *Pre-sale* and *Transferability*, but on other unobserved features. Consequently, we

Table 3 Robustness: alternative success variable

	Dependent variable:		
	Funding amount to target		
	(1)	(2)	(3)
Pre-sale	0.160		0.167
	(0.150)		(0.138)
Transferability		0.303^{***}	0.406^{***}
		(0.109)	(0.109)
Cayman Islands	0.665^{**}	0.555^{*}	0.655^{*}
	(0.327)	(0.288)	(0.339)
Europe	0.235	0.167	0.135
	(0.166)	(0.153)	(0.169)
UK	0.095	0.126	0.176
	(0.191)	(0.169)	(0.178)
USA	−0.002	−0.008	−0.063
	(0.171)	(0.158)	(0.168)
Equity token	0.071	0.060	0.061
	(0.110)	(0.103)	(0.094)
Fund token	0.014	−0.010	−0.054
	(0.160)	(0.140)	(0.159)
Voting rights	0.194^{*}	0.235^{**}	0.244^{**}
	(0.109)	(0.105)	(0.101)
Softcap use	-0.372^{***}	-0.389^{***}	-0.416^{***}
	(0.105)	(0.097)	(0.092)
Hardcap	-0.066^{**}	-0.054^{*}	-0.048^{*}
	(0.031)	(0.032)	(0.029)
Telegram	-0.363^{**}	-0.326^{***}	-0.443^{***}
	(0.139)	(0.110)	(0.125)
Listing			0.398^{**}
			(0.160)
Age			0.083
			(0.066)
Mean VIF	1.77	1.70	1.75
Maximum VIF	3.07	3.05	3.20
Year FE	Yes	Yes	Yes
Observations	71	71	71
Pseudo R^2	0.372	0.406	0.136
Log pseudolikelihood	−32.210	−30.438	−26.275
AIC	94.421	90.876	88.551

This table reports the robustness checks for the STO success determinants analysis. Models (1) to (3) are tobit estimations with a left-censoring at zero with the alternative success variable *Funding amount to target* as a dependent variable. The reference category for the countries is *Country other*. All models include a not reported constant. Heteroscedasticity-robust standard errors in parentheses. The symbols *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. All variables are defined in Table 8 cannot completely rule out the possibility that our results are subject to an omitted variable bias.

5 Post-STO phase

5.1 Overview of ST secondary markets

The secondary marketplaces where security tokens can be traded are either centralized exchanges (CEX) or decentralized exchanges (DEX). Decentralized exchanges are one application case in the decentralized finance ecosystem and are marketplaces where transactions are performed through self-executing smart contracts without an intermediary. The key technical innovation of most DEX is a new model for liquidity provision called automated market making (AMM). While on a CEX, market-making works with conventional limit order books and trades are settled on centralized servers *off-chain*, on a DEX it is automated *on-chain* via trading against a liquidity pool, a pool of tokens locked in a smart contract (Aoyagi 2020).[5] Prices on a DEX are calculated automatically by an algorithm based on the liquidity that can be provided by anyone (Barbon and Ranaldo 2022). Along with this, users of DEX retain control over the private key of their token instead of transferring it to the exchange platform, as in the case of CEX. Therefore, the tokens cannot be stolen during a hacker attack, ultimately lowering the counterparty risk (Lin 2019). DEX can pave the way towards an ‘on-ramping’ of the tokens on a regulated CEX at a later point in time (Aspris et al. 2021). In the US, CEX need to be registered as Alternative Trading Systems (ATS); in Europe, they need an equivalent license as Multilateral Trading Facility (MTF), and they have to screen potential investors with respect to compliance to KYC and AML/CTF regulations.

The choice of the marketplace by the STO issuer can be a signal of the quality of the security token. CEX screen the potential tokens to be listed and typically charge high listing fees as high entry barriers, which only high-quality companies with good future prospects can afford. In addition, CEX function similarly to traditional online marketplaces where investors do not need to be familiar with blockchain technology, making it easier to reach any investor. In contrast, DEX are not regulated, there is no listing fee, but they require familiarity with blockchain technology. Therefore, we assume that trading on a CEX, as opposed to trading on a DEX, is a signal for high-quality tokens and companies.

5.2 Data of STO underpricing

Our first source for secondary market data is *stomarket.com*, and from there, we move to various exchange platforms.[6] The second data source are the blockchain

[5] For a detailed description of the functioning of AMM and liquidity pools see Barbon and Ranaldo (2022), Lehar and Parlour (2022), Mohan (2022), and Schär (2021).

[6] We consider the following CEX and DEX for security tokens in our analysis: tZERO, INX Securities, Tokensoft, Openfinance, CryptoSX, Securitize Markets, Uniswap, Levinswap, StellarX, and MERJ.

explorers *ethplorer.io* and *etherscan.io* for information on the ownership structure. A concern of our dataset from the success determinants analysis is that only a minority of these security tokens are later listed on secondary markets.[7] This has multiple causes since we argued previously that not all projects intend to trade the tokens, and other projects are not successfully funded. The phenomenon of sample reduction is also commonly known in the ICO context (Fisch and Momtaz 2020; Lyandres et al. 2022). Benedetti and Kostovetsky (2021) state that the majority of the money invested in ICOs is in tokens later listed on secondary markets. We complement the secondary market data for a holistic picture of the market by real estate STOs (RE STOs). We acknowledge that there may be some comparability issues between conventional and RE STOs. As in equity markets, though, the underlying business model is not as crucial to returns, liquidity, and related research questions, as REITs in indexes demonstrate. The RE STOs in our sample are not directly tokenized real estate, as this is currently difficult to implement from a legal perspective. As such, a special purpose vehicle is tokenized with the property as the only asset, and investors hold a deed to the cash flows of the company rather than acquiring ownership rights to the property. Additionally, the primary offering of RE STOs cannot be analyzed in the same multivariate setting as ‘conventional STOs’ in Sect. 4. The value of a property, based on the *Funding amount*, is mainly determined by its property characteristics, such as size, location, or type of use. As such, information asymmetries during the primary offering and signals to overcome them differ strongly. In addition, the inclusion of the real estate sector seems reasonable, as Howell et al. (2020) document that the success of token offerings is particularly pronounced when it comes to business models that involve the tokenization of real assets. Nevertheless, when the tokens enter the secondary market, the market dynamics close these information asymmetries, and the market valuation, as well as the trading behavior, are similar. In any type of STO, investors receive regular cash flows from their tokens, whether in the form of a dividend, coupon, or rent payment. As mentioned earlier, this study focuses on the technical aspects of new funding mechanisms on the blockchain, which is why we consider RE STOs as valuable additional observations. Our sample covers the period from January 1st, 2019, to 31st December, 2021. The time difference of one year compared to the success determinants sample is due to the fact that many tokens are not immediately traded on secondary markets or are even legally ineligible because of lock-up periods, as in the US.

[7] Note that there is a difference between the *Transferability* analyzed in Sect. 4 and the listing on the secondary market. *Transferability* refers to the technical property that the programmer has allowed the tokens to be transferable after the issuance when programming the smart contract, which companies can disclose in the STO prospectus. Whether a company actually lists the tokens on the secondary market is an entirely different matter, for which *Transferability* is merely the technical prerequisite.

5.3 Variables STO underpricing

Our dependent variable in the following analysis is *Underpricing*, which we define as the return in Eq. 1 between the price of the token in the STO $P_{i,0}$ and the first traceable price on the market $P_{i,1}$.[8]

$$Underpricing = \frac{1}{n}\sum_{i=1}^{n}\frac{P_{i,1} - P_{i,0}}{P_{i,0}} \tag{1}$$

In the IPO literature, underpricing is a well-known phenomenon for which a plethora of theories, periods, and results in multiple markets have been investigated over the years.[9] In the following, we transfer explanatory approaches from IPOs that are relevant to the STO context. We also incorporate insights from technology and 'New market' IPOs, as they may have similarities to security tokens due to the technological component. First, we refer to the *market liquidity hypothesis* of Aggarwal et al. (2002), which suggests that companies pursuing a token offering face pressure to underprice to obtain market liquidity to signal their future growth potential. As a result, companies generate information momentum that attracts widespread interest from the media and analysts (Aggarwal et al. 2002), who may also perform certification functions of the issuer (Booth and Smith 1986). This liquidity enables the companies to reduce illiquidity premia, compensates early investors for the undertaken risk, and causes network effects (Momtaz 2020). Consequently, the potential liquidity generated by underpricing is an opportunity for companies to attract investors (Brau and Fawcett 2006), while it also serves to mitigate information asymmetries. Further, another related theory is that higher information asymmetries are associated with higher underpricing (Rock 1986; Welch 1989), based on Ritter (1984) who finds that high-risk IPOs are more underpriced, which provides an explanation for hot issue markets in periods with a large proportion of high-risk IPOs and high underpricing. This phenomenon can also apply to STOs since most companies undertaking an STO cannot present a comprehensive track record, experience, or a market-ready product resulting in high information asymmetries.

To analyze the influence of different investors involved in STOs as outlined in Hypothesis 3, we include the *No. large investors* as a numerical count of the number of investors who hold a share of more than 5% of all issued tokens. We use the 5% threshold related to the Schedule 13D filing, a disclosure requirement to the SEC in the US for investors who acquire more than 5% of the beneficial ownership of a company. We derive the ownership information from the blockchain explorers at the date of the token issuance.[10] To test Hypothesis 4, we consider the variable *Sentiment* as the 30-day return of Ether on the first day of trading. As stated in Sect. 2,

[8] Contrary to our approach, other studies in the ICO context refer to as underpricing the first-day-return between the opening and closing price on the first trading day (Momtaz 2020, 2021a), which we calculate separately in Sect. 5.6.

[9] For a literature review on underpricing, see Ljungqvist (2007).

[10] We only consider unique wallet addresses of investors and their shares. However, due to blockchain technology, we cannot further ascertain what kind of investor it is.

Table 4 Descriptive statistics for STO underpricing

Statistic	N	Mean	SD	Min	Pctl(25)	Median	Pctl(75)	Max
Dependent variable:								
Underpricing	106	0.012	0.144	−0.156	−0.054	−0.021	0.007	0.490
Explanatory variables								
No. large investors	106	3.132	1.574	1.000	2.000	3.000	4.000	10.000
Sentiment	107	−0.001	0.236	−0.583	−0.113	−0.113	0.098	1.289
Public float	106	0.404	0.322	0.000	0.050	0.526	0.705	0.862
Trading volume	107	3.187	2.477	0.000	1.800	2.700	4.200	12.000
DEX	106	0.830	0.377	0.000	1.000	1.000	1.000	1.000
Funding amount	106	12.238	2.590	0.000	11.031	11.110	12.932	18.713
Token price	106	3.481	1.296	0.010	3.891	3.961	4.009	7.311
STO type	107	0.196	0.410	0.000	0.000	0.000	0.000	1.000

This table reports the descriptive statistics (mean, standard deviation, minimum, 25th percentile, median, 75th percentile, and maximum) for the full sample. The variable *Underpricing* is winsorized at the top and bottom 5%. All variables are defined in Table 8

Ethereum is the dominant blockchain platform for STOs, and therefore, the return of the corresponding native token Ether is an appropriate benchmark for the underlying market sentiment. We derive the data from *Coinmarketcap*.

We further control for the *Public float* of the tokens, which represents the percentage of the issued tokens that is attributed to investors who hold a share of less than 5%. A higher share of *Public float* was found to increase liquidity on stock markets (Ding et al. 2016). We include the logarithm of the *Trading volume* during the first 24 h of trading. This measure reflects the actual interest of investors in an STO, resulting in a movement to the true market price (Felix and von Eije 2019). For IPOs, Schultz and Zaman (1994) provide empirical evidence that underpriced stocks are traded more often on the first trading day than fully-priced stocks. We consider the dummy-variable *DEX*, which equals 1 if the token is traded on a decentralized exchange and 0 if it is traded on a centralized exchange. To take into account the prior success in the STO as analyzed in Sect. 4, we consider the logarithms of the variables *Funding amount* and *Token price*. Furthermore, we include the dummy-variable *STO type*, which equals 1 for 'conventional STOs' and 0 for real estate STOs to control for potential differences regarding *Underpricing*.

5.4 Descriptive statistics STO underpricing

We present the descriptive statistics for the variables used in the STO underpricing analysis in Table 4.[11]

[11] Additional detailed descriptive statistics for the conventional STO and RE STO sub-samples are presented separately in Table 10 in the Appendix. It can be observed that there is a disparity between the *Funding amount* and the *Token price* of conventional and RE STOs. However, since the dependent variable *Underpricing* is a fraction of prices, the absolute differences regarding higher *Funding amounts* or *Token prices* are thus scale-free.

We winsorize *Underpricing* at the top and bottom 5% to account for extreme outliers. The average *Underpricing* amounts to 1.2% with a median value of −2.1%. This means that the average STO leaves money on the table, whereas the median indicates overpricing at the cost of the investors. Both the mean and the median values are not far from zero, implying that the majority of the tokens are correctly priced. The minimum of −15.6% and maximum of 49.0% show that there are also companies with extreme over-and underpricing. In general, there does not appear to be underpricing in the ST market, as young companies lack experience, and the market is still in its infancy. The various results for *Underpricing* in 'New Market' or tech IPOs and for ICOs are substantially higher (Adhami et al. 2018; Drobetz et al. 2019; Felix and von Eije 2019; Giudici and Roosenboom 2004; Kiss and Stehle 2002). This may suggest that the 'New Market' is not technologically comparable to blockchain and STOs, or the period under study is the cause of the discrepancies in the results. For ICOs, this is not surprising, as information asymmetries are much more pronounced in completely unregulated ICOs than in STOs. For STOs, the ventures have to issue regulation-compliant prospectus, while unaudited white papers in ICOs mainly present basic information (Florysiak and Schandlbauer 2022).

In an average ST traded on secondary markets, 3.132 large investors are involved at the date of the issuance. The *Sentiment* shows that security tokens become listed on the secondary market on average during days of slightly negative or neutral sentiment represented with −0.1% of the 30-day Ether return, while the minimum of −58.4% and maximum of 128.9% demonstrate the great variation of crypto returns.[12] On average, a share of 40.4% of all security tokens is attributed to the *Public float*. The logarithm of the *Trading volume* during the first 24 h of trading has a mean of 3.187 which represents $24.22. In our sample, 83.0% of the security tokens are traded on a *DEX* and the remaining on a regulated CEX. We use logarithms for the variables *Funding amount* for which the average is 12.238, corresponding to $206,489, and the *Token price* with 3.481, which corresponds to $32.49. The *STO type* reveals that 19.6% of the STOs are 'conventional STOs' and the remaining real estate STOs. Table 11 in the Appendix shows the correlation coefficients for all variables. Although there are occasional higher correlations between *DEX* and the *Funding amount* of −0.784 or the *Token Price* with −0.716, all other correlations are below 0.5. Therefore, we do not include these variables in the same model since they could bias the regression coefficients. We report the VIFs in Table 5, all of which are far below a conservative critical value of 5. Hence, multicollinearity is unlikely to be an issue in the subsequent analysis.

5.5 Multivariate analysis: STO underpricing

The regression estimations of the determinants of STO underpricing are reported in Table 5.

[12] Note that since the beginning of the observation period, the Ether price has increased from $141 in January 2019 to $3,683 in December 2021.

Table 5 Determinants of STO Underpricing

	Dependent variable: Underpricing					
	OLS			*Heckman*		
	(1)	(2)	(3)	(4)	(5)	(6)
No. large investors	0.015	0.015*	0.011	0.014	0.012	0.010
	(0.010)	(0.008)	(0.008)	(0.010)	(0.008)	(0.009)
Sentiment	0.222***	0.227***	0.216***	0.241***	0.236***	0.218***
	(0.064)	(0.062)	(0.064)	(0.057)	(0.058)	(0.064)
Public float	0.002	0.010	0.019	−0.059	−0.034	−0.039
	(0.030)	(0.029)	(0.028)	(0.072)	(0.082)	(0.093)
Trading volume	0.015*	0.015*	0.016**	0.015*	0.014*	0.016**
	(0.009)	(0.009)	(0.008)	(0.008)	(0.008)	(0.007)
DEX	−0.082			−0.077		
	(0.060)			(0.054)		
STO type		0.087			0.087*	
		(0.054)			(0.051)	
Token price			−0.037**			−0.033**
			(0.015)			(0.016)
Mean VIF	1.142	1.136	1.095			
Maximum VIF	1.230	1.194	1.110			
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	105	105	105	254	254	254
Adjusted R^2	0.343	0.351	0.405			
Log Likelihood				−48.053	−47.319	−45.062
ρ				−0.426	−0.343	−0.385

This table reports cross-sectional OLS regressions for the determinants of STO Underpricing in models (1) to (3). Models (4) to (6) present the results from the Heckman (1979) procedure using maximum likelihood estimation with the selection variable *Funding amount*. Heteroscedasticity-robust standard errors in parentheses. All models include a not reported constant. The symbols *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. All variables are defined in Table 8

The signs of the coefficients are consistent across the model specifications, and the adjusted R^2 amounts to about 35% in all models. The coefficient of *No. large investors* is only in model (2) significant at the 10% level on *Underpricing*. It appears that the *increased monitoring hypothesis* does not apply to the STO context. A possible explanation for this could be that Stoughton and Zechner (1998) refer to IPOs and thus pure equity, although our sample also includes debt or funds with different pricing dynamics. Notably, this finding aligns with the counter-intuitive results of Franzke (2004), which suggest that VC-backed IPOs, to which increased monitoring activities are attributed, experience higher levels of underpricing in the German 'New Market' compared to those without VC-backing. To summarize, we cannot provide statistical support in favor of Hypothesis 3. We find a positive significant link between *Sentiment* and *Underpricing*. A one-standard-deviation increase in *Sentiment* is in the model (1) associated with a 36.38% increase in *Underpricing* relative to the average. The results indicate that the *Sentiment* increases *Underpricing*, and issuers seem to time the first trading of their tokens to periods of positive market sentiment, which serves as a positive external signal. Our findings are in line with the IPO (Ljungqvist et al. 2006) as well as the ICO (Felix and von Eije 2019) literature. Thus the conjecture in Hypothesis 4 that the crypto market *Sentiment* has a positive influence on *Underpricing* is supported by our empirical evidence. As for our control variables, the coefficient of *Trading volume* is across all model specifications positive on *Underpricing*. The results align with IPO (Zheng and Li 2008) and ICO literature (Felix and von Eije 2019). None of our model specifications yield a significant effect of *DEX* and *STO type*, which is why we cannot observe any significant difference between tokens traded on centralized and decentralized exchanges or 'conventional' and RE STOs regarding *Underpricing*.[13]

A major criticism could be that this sample potentially suffers from a selection bias resulting from issuers that offer the tokens with a larger discount during the initial offering in order to increase the chance of a subsequent listing. We address this issue similarly to Benedetti and Kostovetsky (2021) and Florysiak and Schandlbauer (2022) by applying the Heckman selection model (Heckman 1976, 1979). We perform a full information maximum likelihood estimation with the selection variable *Funding amount* since this is the major variable of STO success (as outlined in Sect. 4) and crucial for a token to become listed. We can therefore address this sample selection problem in a methodologically appropriate way and consider all listed and unlisted STOs simultaneously, which increases the number of observations. The descriptive statistics for this sample are displayed in Table 10 in Panel C in the Appendix. Models (4) to (6) in Table 5 display the results from the Heckman procedure and have consistent signs as the previous models. We observe that *No. large investors* is no longer significant, whereas the positive and significant influence of *Sentiment* on *Underpricing* remains. Interestingly, in the model (5), the *STO type* is significant on the 10% level on *Underpricing*, meaning that 'conventional STOs' have a higher *Underpricing* in comparison to real estate STOs. This could be due to the fact that the price of real estate can be more accurately determined and is more transparent to the public, making these STOs more likely to be priced correctly. We conclude that a potential selection bias is rather unlikely to be driving our results.

5.6 Returns to investors after the token listing

As a further market valuation, we validate the previously sent signals about the quality of the STO by examining secondary market returns. We analyze buy-and-hold returns (BHR) as well as buy-and-hold-abnormal returns (BHAR) of investors who buy the security tokens on the first day the token is traded on an exchange and hold the token for different short-term time horizons ranging from one day to one year. We concentrate on this approach since, e.g. the common risk

[13] We would like to point out that the signs and significances are consistent across all model specifications, regardless of whether the *Funding amount* and *Token price* are included, or not.

factor models of Fama and French (1993) and Carhart (1997) rely on a longer data history to calculate expected returns, which is not yet available for security tokens. We calculate the raw buy-and-hold return (*BHR*) in the same way as *Underpricing*, but from the first day of trading $t = 1$ to the last day of the holding period T.

$$BHR = \frac{1}{n} \sum_{i=1}^{n} \frac{P_{i,T} - P_{i,t=1}}{P_{i,t=1}} \tag{2}$$

Alternatively, to calculate the buy-and-hold abnormal return (*BHAR*), we adjust the raw return by a value-weighted market capitalization-based benchmark, similar to Fisch and Momtaz (2020) and Momtaz (2021a) as follows:

$$BHAR = \frac{1}{n} \sum_{i=1}^{m} \left[\frac{P_{i,t=T} - P_{i,t=1}}{P_{i,t=1}} - \sum_{j=1,j\neq i}^{n} \frac{MC_{j,t=T}}{\sum_{j=1}^{n} MC_{j,t=T}} \cdot \frac{P_{j,t=T} - P_{j,t=1}}{P_{j,t=1}} \right], \tag{3}$$

where $P_{i,t=1}$ is the price of the security token i at the end of the holding period T and $MC_{j,t}$ refers to the market capitalization of the security token j on day T ($i \neq j$). The market consists of all security tokens with available price data. The value-weighted market benchmark is the product of the raw return of every other security token j over the holding period T and the market capitalization of a security token j over the sum of the whole market capitalization at the end of the holding period T. The adjustment for the market capitalization is suitable for several reasons. Firstly, some small-cap firms experience extreme returns, which could cause severe distortions of the results when using, e.g., volume-weighted or equally-weighted benchmarks (Momtaz 2020). Secondly, market capitalization is subject to boom-and-bust cycles in the entire token market (Chen et al. 2021), which we can take into account in this way. The results of the *BHR* and *BHAR* analysis are displayed in Table 6.

Both the *BHRs* and *BHARs* vary depending on the investment horizon. The number of tokens diminishes over time, as many tokens have been listed in the last year of the observation period, and others have no continuous trading history as they, e.g., changed the exchange platform to increase liquidity. Similar to the results in the ICO literature, we document partly extreme high ratios of mean to the median that exemplify the highly skewed distribution of returns in the market for tokens (Momtaz 2021a). Particularly the high negative mean *BHARs* for holding periods between one week of −10.5% to six months of −34.2% trace back to the current situation on ST secondary markets where a few tokens which suffered substantial decreases in value make up the majority of the market capitalization. On the one hand, this shows the high probability of losses and, on the other, provides further evidence for the rationale that investors need to be compensated for the high risk they take by investing in a company with a weak track record (Benedetti and Kostovetsky 2021). These findings are consistent with Kiss and Stehle (2002), who observe a post-IPO underperformance in the 'New Market' between 1997 and 2001. A naïve investor who invests the same amount of money in every security token experienced, e.g., for a holding period of six months, a positive *BHR* of 9.2%, indicating potential wealth gains. Nevertheless, the corresponding medians fluctuate around the zero point over any holding period. In contrast, considering market capitalization, a security token investor realizes partially extreme negative and positive mean values of the *BHAR*. The medians draw a similar picture. To conclude this section of the post-STO performance, we observe both extremely negative and positive *BHR* and *BHAR* over different short-term investment horizons.

5.7 (Il-)liquidity on secondary ST markets

A key benefit and promise of digital tokens is liquidity due to reduced costs and faster settlement times on the blockchain (Yermack 2017), particularly because of the new method of liquidity provision on DEX. We investigate the liquidity situation on the ST secondary market since its inception, as liquidity is central for future industry development. In Fig. 1, we display the development over time of several key characteristics of ST secondary markets.

The *Market capitalization* shows a strong positive trend, with stagnation in 2019 and during the beginning of the Covid-19 pandemic, followed by a strong growth trend. A similarly positive growth trend is evident for the daily *Trading volume*. The high variability of the daily *Trading volume* relies on the fact that CEXs

Table 6 Analysis of BHR and BHAR

		BHR Mean (Median)	*BHAR* Mean (Median)	Volatility
1 Day	106	0.231 (0.010*)	0.229 (0.002)	0.258
1 Week	106	0.015 (−0.030**)	−0.105** (−0.088**)	0.364
1 Month	105	0.037 (−0.019*)	−0.152** (−0.026*)	0.318
2 Months	102	0.062* (0.006*)	−0.300 (0.020)	0.330
3 Months	98	0.050 (0.006**)	−0.364 (−0.077**)	0.324
6 Months	87	0.092* (−0.005)	−0.342** (−0.351**)	0.420
1 Year	24	0.549 (−0.011)	0.136 (0.047)	2.256

This table reports the raw buy-and-hold returns (BHR) and buy-and-hold abnormal returns (BHAR) adjusted by a value-weighted market capitalization-based benchmark over different short-time horizons ranging from one day to one year. The mean, in parentheses, the median, and the volatility are displayed. The symbols * and ** denote significance at the 5% and 1% levels, respectively. All variables are defined in Table 8 partly have trading hours just like conventional trading platforms and DEX operate continuously.

The liquidity situation on the market can be explained by the 'chicken-and-egg' problem, at least in the beginning when mainly CEX operated. On the one hand, investors expect to trade many different qualitative tokens while issuers will only pay the listing fees of the exchanges if the latter provides liquidity (Lambert et al. 2022). The analysis of the liquidity in cryptocurrency markets faces the problem of lacking high-frequency intraday data to determine high-frequency bid-ask spreads (Brauneis et al. 2021). As such, other metrics addressing the issue of low-frequency liquidity markets have to be considered. Firstly, we calculate the *CS estimator* of Corwin and Schultz (2012) as a simple bid-ask spread from daily high and low prices; see the detailed formula in the Appendix. Secondly, we compute *Liquidity* based on a modified version of the illiquidity measure of Amihud (2002) and Amihud et al. (2006), which originally determines the trading volume required to move the price by 1%, as follows:

$$Liquidity_t = -log\frac{1}{5}\left[\sum_{t=t-5}^{t}\frac{\left|log\left(\frac{p_t}{p_{t-1}}\right)\right|}{p_t\cdot volume_t}\right], \tag{4}$$

where it is multiplied by the negative of the logarithm to facilitate the numerical interpretation (Howell et al. 2018; Lyandres et al. 2019).[14] We consider both measures over an observation period of one week and one month after the first trading day and average them over five days. Figure 1 reveals that a large number of tokens were newly listed in 2021, which are mainly tokens on DEXs, as DeFi experienced tremendous growth in 2021.[15] The decrease of the *CS estimator* in Fig. 1 over time indicates that the spread diminished, which is indicative of a more liquid market. Contrary, our *Liquidity* measure decreased over time, suggesting that especially newly issued tokens are less liquid. Brauneis et al. (2021) point out that, when studying liquidity levels, the Amihud et al. (2006) measure taking into account the *Trading volume* outperforms and is more meaningful than the *CS estimator*. Therefore, we conclude a general decreasing trend in liquidity on security token secondary markets over time. The graphical findings are empirically extended in the following. The calculation of our metrics with a sample split in CEX and DEX with a corresponding Welch *t*-Test for differences in mean (Welch 1947) and the Mood Median-Test for differences in the median (Mood 1950) are reported in Table 7.

The mean (median) *CS estimator* after a trading period of one week amounts for a CEX to 0.64 (0.59) and for a DEX 0.56 (0.54), whereas after one month, it is 0.58 (0.54) and 0.53 (0.52). A direct comparison of centralized and decentralized exchanges is not possible as the differences in mean and median are not significant. The mean (median) values of the *Liquidity* measure for a trading period of one week is on a CEX with 9.27 (9.66) and substantially lower for a DEX with

[14] The liquidity analysis is only included in the working paper version in Howell et al. (2018).

[15] We account for the increase of observations in 2021 in the empirical analysis with year-fixed effects in the underpricing regression models in Table 5, and we additionally verified the results in unreported analysis with a sample split and found no changes in our results.

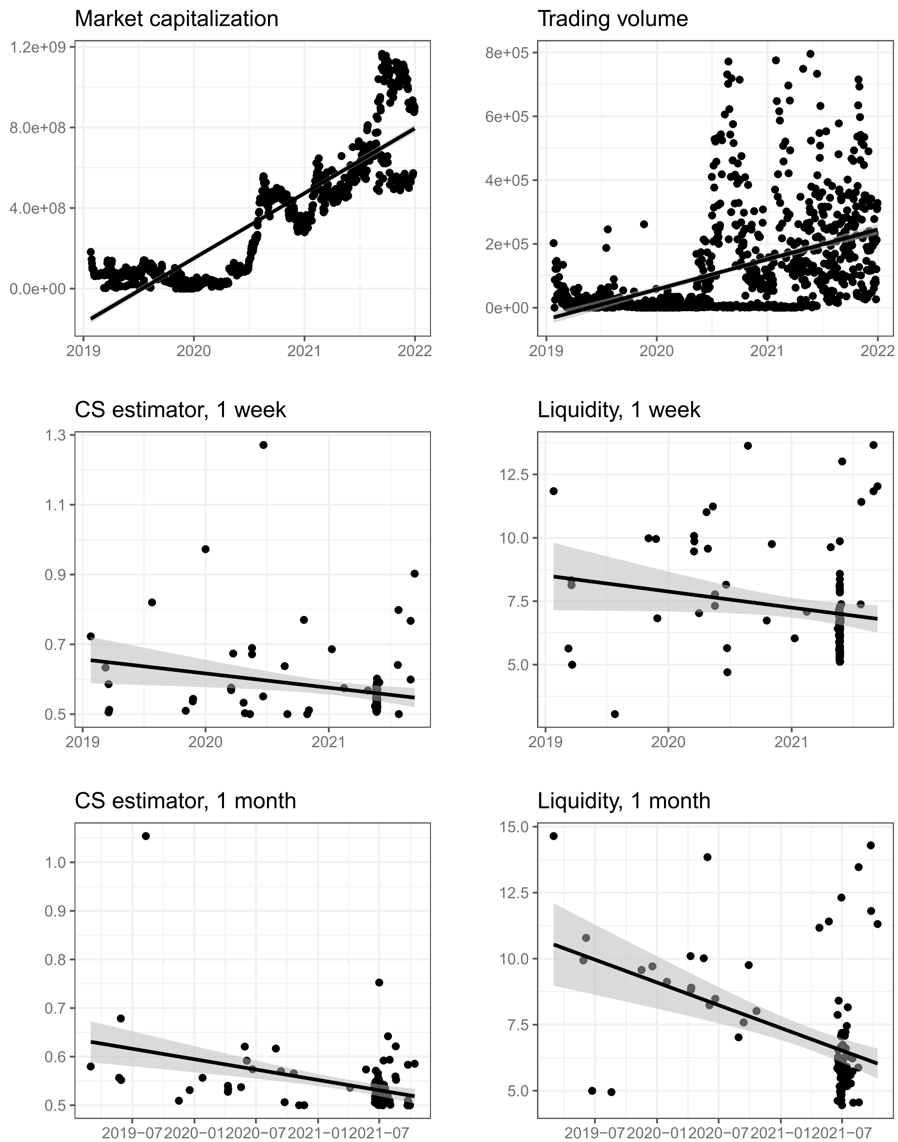

Fig. 1 This Figure presents the evolution of the security token secondary market from 1st January 2019 until 31st December 2021. The black line is the best-fit line. The *Trading volume* is censored at \$800,000 because of the scaling. The variables are defined in Table 8. N = 108

6.76 (6.45). The differences in mean and median are statistically significant, which underpins that decentralized exchanges are less liquid than centralized ones. For a trading period of one month, this finding is confirmed in the same way with an average (median) *Liquidity* on a CEX with 10.82 (9.66) and on a DEX with 6.67 (6.45) and highly significant differences in mean and median. These results are in

Table 7 Security Token market characteristics

		Exchange type		Tests	
		CEX	DEX	Mean Diff.	Median Diff.
CS estimator, 1 week	Mean	0.64	0.56	$t = 2.14$**	
	Median	0.59	0.54		$X^2 = 0.67$
	SD	0.15	0.09		
CS estimator, 1 month	Mean	0.58	0.53	$t = 1.47$	
	Median	0.54	0.52		$X^2 = 1.12$
	SD	0.13	0.04		
Liquidity, 1 week	Mean	9.27	6.76	$t = 2.93$***	
	Median	9.66	6.45		$X^2 = 3.62$*
	SD	3.39	1.33		
Liquidity, 1 month	Mean	10.82	6.31	$t = 5.36$***	
	Median	11.24	5.92		$X^2 = 6.73$***
	SD	3.09	1.45		
	N	18	89		

This table reports the mean, median, and SD (standard deviation) for the *CS estimator* and *Liquidity* after a trading period of one week and one month averaged over the last five days. The sample is split into centralized exchanges (CEX) and decentralized exchanges (DEX), for which the corresponding differences in mean are tested with a Welch *t*-Test and differences in the median with a Mood Median Test. The symbols *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. The variables are defined in Table 8

line with Aspris et al. (2021), who find that CEXs are more liquid and that these tokens have a higher market capitalization which implies market segmentation and a reduction of governance risk. Hasbrouck et al. (2022) propose an increase in trading fees in an economic model as a solution to the low trading volumes on DEX. Both the *CS estimator* and the *Liquidity* measure reflect an increase in liquidity for prolonging the trading period from one week to one month. This fact is not surprising as trading activity can be limited in the first trading days because the exact start of trading is not communicated beforehand, and investors on a CEX have to transfer their tokens to the platforms first before they start trading (Chanson et al. 2018). As comparative values to our results in terms of *Liquidity*, we consider utility tokens from ICOs with a mean value of 12.59 and NASDAQ shares as an industry benchmark with a much higher value of 18.16 (Howell et al. 2018). This comparison reveals that the security tokens in our sample are less liquid than other investment possibilities.

Overall, it may seem as if liquidity has deteriorated over time, and the situation on security token secondary markets has worsened. However, more tokens have been listed primarily on less liquid DEXs over time. This is an indication of the slow completion of the range and the maturation of the market, which is driven by the increasing adoption of DEXs. For the tokens with low liquidity, it would have otherwise been unlikely to become listed on the secondary market at all. In this case, DEXs offer a simple way for a listing with low entry barriers and perspectives for a (cross-)listing on a CEX in the future, which so far is mainly used by high-quality security tokens. Meanwhile, the main problem is no longer the infrastructure but the lack of liquidity, which manifests itself in technology and global regulatory uncertainty as well as security concerns – in sum: trust and confidence in the system.

6 Conclusion

Security token offerings are a means for companies to raise capital where they issue digital tokens as regulated investment products on the blockchain. In this paper, we examine how signaling affects the market participants in the primary and secondary markets for security tokens, such as the STO-issuing company or investors in the primary and secondary markets. In order to obtain a holistic picture of the signaling effect on the entire market, we analyze market outcomes in the pre-STO phase and in the post-STO phase. We study success determinants of STOs which are a way for issuers to signal their quality to investors to overcome information asymmetries during the primary offering in the pre-STO phase. We find that both the execution of a pre-sale phase as a method to gather price-relevant information prior to the main funding and the announcement of token transferability as the expectation of future liquidity are positively linked to the funding success. In the post-STO phase, we find evidence that security tokens are almost correctly priced with a mean (median) of 1.2% (−2.1%), indicating that issuers do not use underpricing as a way to attract investors. Drawing on the literature on IPOs, we show that underpricing is positively related to the sentiment on the crypto market, which serves as a positive external signal, and companies time the first notation of their tokens to avoid phases of negative market sentiment. Finally, the market valuation should reveal the true quality of security tokens. We find that over various short time horizons, both extremely positive and negative buy-and-hold (abnormal) returns can be achieved by an investor. Moreover, we conclude that the security token market lacks professionalism in investment evaluation and selection, as a naïve diversification strategy is a more promising approach to achieving higher returns. We find that liquidity after the start of trading has decreased since the inception of the secondary market. However, this finding relies on the increasing number of tokens on less liquid decentralized exchanges. These exchanges offer lower entry barriers and complete the supply on the secondary market.

Our results highlight that companies that intend to raise funding via STOs would be well advised to offer a pre-sale phase in their STO and assure their intentions to trade the tokens on the secondary market while already devising a plan for successful future trading. From an investor's perspective, these signals can be interpreted as positive quality signals on the basis of which appropriate investment decisions are conducted. Nonetheless, since extremely negative returns can also be achieved in the short term and there seems to be a lack of liquidity in the secondary market, investors should be well versed in the technical fundamentals and risks of blockchain investments. At this point, the legislator could also exert influence without at the same time over-regulating and hindering the further growth of the industry.

Our study has limitations. Because of the exclusion of several STOs due to limited data availability and the hand-collection of the data, we cannot completely rule out the possibility that a potential selection bias is present in our data. Therefore, the generalization and external validity of our results is reduced. Nevertheless, we collected and cross-checked data from various sources, such as the companies' websites, LinkedIn-Pages, aggregator websites, white papers, regulated prospectus, blockchain explorers, as well as Telegram channels. Consequently, one avenue for future research is to generalize our findings in a larger sample within a more mature market with a greater variety of determinants, particularly more balanced between conventional and RE STOs for the analysis of underpricing. Besides, we can only consider the returns to investors resulting from the changes in the token's value and cannot observe and include interest and dividend payments.

Most STOs use the Ethereum blockchain, which merged to the proof-of-stake consensus mechanism in September 2022, silencing criticism of high energy consumption and setting the stage for greater scalability. Hence, this progression will contribute to the future development of the security token industry on a technological and cost level. In many jurisdictions, the record must still be paper-based or stored in a central governmental database (Lambert et al. 2022). It is necessary for regulators to enact legislation simplifying these processes. Since blockchain technology does not stop at national borders, legislation should ideally be implemented on a large scale, thus ensuring legal certainty for investors.

Appendix

See Tables 8, 9, 10.

Table 8 Definition of all variables

Variable	Description	Source
Pre-STO phase		
Funding amount	Logarithm of the amount of the achieved financing volume in USD	STO research
Funding amount to target	Percentage ratio of the amount of the achieved financing volume to the funding target (Hardcap)	STO research
Transferability	The variable indicates whether a company announces prior the STO that the issued security token will be transferable by the investor (=1), 0 otherwise	STO research
Equity token	The variable indicates whether the token represents a share in equity (=1), 0 otherwise	STO research
Fund token	The variable indicates whether the token represents a share in an investment fund (=1), 0 otherwise	STO research
Voting rights	The variable indicates whether a voting right for the investor is securitized in the token (=1), 0 otherwise	STO research
Softcap use	The variable indicates whether a funding threshold must be achieved to be completed (=1), 0 otherwise	STO research
Hardcap	Logarithm of the pre-defined funding target in USD	STO research
Telegram	The variable indicates whether a company uses Telegram as a communication medium with potential investors as part of its STO (=1), 0 otherwise	Telegram
Listing	The variable indicates whether the company is listed on a traditional stock exchange (=1), 0 otherwise	STO research
Age	Logarithm of the difference from the start date of the STO and the date of foundation of the company	Own calculations
Cayman Islands	The variable indicates whether the company has been incorporated in the Cayman Islands (= 1), 0 otherwise	STO research
Europe	The variable indicates whether the company has been incorporated in Europe (= 1), 0 otherwise	STO research
UK	The variable indicates whether the company has been incorporated in the UK (= 1), 0 otherwise	STO research
USA	The variable indicates whether the company has been incorporated in the USA (= 1), 0 otherwise	STO research
Post-STO Phase		
Underpricing	Raw return between token price in the STO and first price on the secondary market	Own calculations
No. large investors	Absolute numbers of investors with a share of more than 5% of all tokens at token issuance	Ethplorer, Etherscan
Sentiment	30-day return of Ether (ETH) on the first trading day	Coinmarketcap
Public float	Percentage share of public float at token issuance	Ethplorer, Etherscan
Trading volume	Logarithm of the trading volume during the first 24 h on an exchange platform in USD	Exchange Platforms
DEX	Dummy-variable which equals 1 for a decentralized exchange, 0 for a centralized exchange	STO research
Funding amount	Logarithm of the funding amount in USD	STO research
Token price	Logarithm of the token price during the STO in USD	STO research
STO type	Dummy-variable which equals 1 for a ‘conventional’ STO, 0 for a real estate STO (RE STO)	STO research

Table 8 (continued)

Variable	Description	Source
Sec notation	Dummy-variable which equals 1 for an STO listed on a CEX or DEX, 0 otherwise	STO research
BHR	Raw buy-and-hold return	Own calculations
BHAR	Buy-and-hold abnormal return adjusted by a value-weighted market capitalization based benchmark	Own calculations
CS estimator, 1 week	Corwin and Schultz (2012) estimator one week after the start of trading averaged over the last five days	Own calculations
CS estimator, 1 month	Corwin and Schultz (2012) estimator one month after the start of trading averaged over the last five days	Own calculations
Liquidity, 1 week	Liquidity measure based on Amihud (2002) and Amihud et al. (2006) illiquidity, one week after the start of trading and averaged over the last five days	Own calculations
Liquidity, 1 month	Liquidity measure based on Amihud (2002) and Amihud et al. (2006) illiquidity, one month after the start of trading and averaged over the last five days	Own calculations

List and definitions of all variables with the corresponding source. The source 'STO research' comprises the comprehensive data collection process for the pre-STO phase on Digital Asset Network and various aggregator websites, company websites, EDGAR database, LinkedIn profiles, (legal) prospectus and white papers, blockchain explorers with the corresponding cross-check and for the post-STO phase the exchange platforms

Table 9 Correlation matrix for STO success determinants

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Funding amount	1											
(2) Funding amount to target	0.548	1										
(3) Pre-sale	0.087	−0.171	1									
(4) Transferability	0.196	0.143	0.031	1								
(5) Equity token	−0.001	0.048	−0.092	−0.047	1							
(6) Fund token	0.122	−0.118	0.099	0.161	−0.178	1						
(7) Voting rights	0.136	0.135	0.094	−0.078	0.169	−0.169	1					
(8) Softcap use	−0.394	−0.410	0.111	0.075	−0.013	−0.028	0.030	1				
(9) Hardcap	−0.029	−0.317	0.362	0.064	−0.165	0.287	−0.048	0.109	1			
(10) Telegram	−0.149	−0.268	0.492	0.285	−0.038	0.224	−0.024	0.151	0.356	1		
(11) Listing	−0.018	0.070	0.068	−0.216	0.068	−0.087	−0.116	0.045	−0.123	−0.031	1	
(12) Age	0.100	0.181	−0.064	−0.053	0.069	−0.063	0.108	0.005	−0.221	−0.136	0.194	1

This table reports the Bravais-Pearson correlation coefficients for the STO success determinants analysis for the full sample. All variables are defined in Table 8

Table 10 Detailed Descriptives for STO Underpricing

	N	Mean	St. Dev.	Min	Pctl(25)	Median	Pctl(75)	Max
Panel A: Conventional STOs								
Underpricing	20	0.025	0.207	−0.156	−0.135	0.000	0.020	0.490
No. large investors	20	2.200	1.436	1.000	1.000	2.000	3.000	6.000
Sentiment	21	0.047	0.275	−0.583	−0.095	0.105	0.218	0.473
Funding amount	20	14.843	4.481	0.000	13.773	16.321	17.561	18.713
Token price	20	1.862	1.877	0.010	0.693	0.693	2.635	7.311
Trading volume	21	4.334	4.026	0.000	0.000	4.997	7.315	12.219
Public float	20	0.248	0.266	0.000	0.001	0.150	0.455	0.744
DEX	21	0.238	0.436	0.000	0.000	0.000	0.000	1.000
Panel B: Real Estate STOs								
Underpricing	86	0.009	0.126	−0.156	−0.046	−0.022	0.005	0.490
No. large investors	86	3.349	1.532	1.000	2.000	3.000	4.000	10.000
Sentiment	86	−0.012	0.225	−0.583	−0.113	−0.113	0.033	1.289
Funding amount	86	11.632	1.352	10.856	11.021	11.090	11.293	18.421
Token price	86	3.858	0.726	0.693	3.941	3.972	4.010	5.093
Trading volume	86	2.907	1.853	0.000	1.792	2.596	3.886	10.853
Public float	86	0.441	0.325	0.012	0.058	0.629	0.721	0.862
DEX	86	0.965	0.185	0.000	1.000	1.000	1.000	1.000
Panel C: Sample Heckman selection model								
Sec notation	254	0.416	0.494	0.000	0.000	0.000	1.000	1.000
Funding amount	254	11.596	3.600	0.000	10.995	11.220	13.221	18.713

This table reports the descriptive statistics (number of observations, mean, standard deviation, minimum, 25th percentile, median, 75th percentile, and maximum) for conventional STOs (Panel A), Real Estate STOs (Panel B), and the selection equation of the sample for the Heckman selection model for listed and unlisted STOs (Panel C). All variables are defined in Table 8 in the Appendix

Table 11 Correlation matrix for STO Underpricing

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Underpricing	1							
(2) No. large investors	0.280	1						
(3) Sentiment	0.419	0.216	1					
(4) Public float	−0.079	0.150	0.002	1				
(5) Trading volume	0.375	−0.046	0.195	−0.140	1			
(6) DEX	−0.187	0.168	−0.204	0.250	−0.303	1		
(7) Funding amount	0.368	−0.157	0.234	−0.279	0.325	−0.784	1	
(8) Token price	−0.372	−0.036	−0.184	0.243	−0.157	0.716	−0.676	1

This table reports the Bravais-Pearson correlation coefficients for STO Underpricing for the full sample. All variables are defined in Table 8

Calculation of the CS estimator

Calculation of the Corwin and Schultz (2012) estimator based on daily high (H_t) and low (L_t) prices of two consecutive time intervals t and $t+1$

$$
\begin{aligned}
CS_{t,t+1} &= \frac{2(exp(\alpha)-1)}{1+exp(\alpha)} \\
\alpha &= \frac{\sqrt{2\beta}-\sqrt{\beta}}{3-2\sqrt{2}} \\
\beta &= \left[ln\left(\frac{H_t}{L_t}\right)\right]^2 + \left[ln\left(\frac{H_{t+1}}{L_{t+1}}\right)\right]^2 \\
\gamma &= \left[ln\left(\frac{H_{t,t+1}}{L_{t,t+1}}\right)\right]^2
\end{aligned}
$$

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Declarations

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