Raining Cryptos[*]

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ABSTRACT

I study the effect of hard forks and airdrops on cryptocurrency prices. At the hard fork and airdrop date, holders of the parent coin receive additional coins of a different cryptocurrency. The announcement of a hard fork or airdrop does not affect parent coin prices. In contrast, the distribution of coins immediately decreases the prices of the parent coin by 4.65%. The cumulative average abnormal return over the 5-day post-distribution date equals -12.29%. Importantly, I show that the price drop of the parent coin is significantly lower than the value of the distributed cryptocurrency. This suggests that hard forks and airdrops are partly free money.

Keywords: Cryptocurrency, Hard forks, Airdrops, Free money, Event study

JEL Classifications: C33, G14, G23

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I. Introduction

Eq. 1 splits Bitcoin's total performance from January 1^{st}, 2014 to December 31^{st}, 2020 of 3'709% into a price appreciation and a raining cryptocurrency part. Price appreciation accounts for the largest share of performance. Nevertheless, a substantial performance of close to 50% results from raining cryptos. Raining cryptos are distributed at the hard fork and airdrop date to holders of the parent coin, whereby investors receive additional coins of a different cryptocurrency. Importantly, the value of the distributed coin is frequently unknown. In some cases, the distributed coin acquires a substantial price over time. In other cases, the new coin is never listed on an exchange, making it worthless.

$$\underbrace{R_{Bitcoin,t}}_{\text{3'708.51\%}} = \underbrace{\frac{P_{Bitcoin,t} - P_{Bitcoin,t-1}}{P_{t-1}}}_{\text{Price Appreciation = 3'659.62\%}} + \underbrace{\frac{\sum_{i=1}^{N} P_{\text{Hard Fork,t}} + \sum_{j=1}^{M} P_{\text{Airdrop,t}}}{P_{Bitcoin,t-1}}}_{\text{Raining Cryptos = 48.89\%}} \tag{1}$$

The most famous hard fork is Bitcoin Cash. Bitcoin Cash forked from Bitcoin on August 1^{st}, 2017. At that date, each holder of one Bitcoin received one Bitcoin Cash. Today, Bitcoin Cash is traded on multiple exchanges with a market cap of $11.5 billion. Such forks are frequently regarded as a magic money-making machine: creating free money out of thin air by splitting Bitcoin into multiple chains.[1] This illusive idea attracted pervasive interest within the cryptocurrency community, resulting in numerous hard forks and airdrops.

Unsurprisingly, this distribution of new coins has raised considerable interest by regulators and tax authorities, debating how to tax these profits.[2] In October 2019, the Internal Revenue Service (IRS) released guidance regarding the taxation of hard forks and airdrops. The Revenue Ruling 2019-24 states that taxpayers must report virtual currency received from hard forks or airdrops as gross income.[3] In contrast, the finance literature has paid only limited attention to what extend hard forks and airdrops affect cryptocurrency prices. The limited interest may be due to the difficulty of conceptualising hard forks and airdrops, as there seems to be no equivalent event in traditional asset classes. Analysts sometimes compare the Bitcoin Cash hard fork to a stock split.[4] Shanaev, Shuraeva, Vasenin, and Kuznetsov (2019) interpret hard forks as hostile takeovers. Xu (2019) and Lewis (2018) state that hard forks are most closely related to corporate spin-offs, and tax authorities have argued that it can be compared to a stock dividend.

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[1] Kharif (2018)

[2] See: Webb (2018), Button (2019), Firth (2020), Cotler (2020), and Sabu (2021)

[3] 2019-44 IRB 1004

[4] Bloomberg (2017)

As yet, it remains unclear to what event - if any - hard forks should be compared. More importantly, since empirical studies on the effect of airdrops and hard forks on the parent coin are limited, it remains an open question if hard forks and airdrops are indeed *free money*. This paper closes this gap and has three goals. The first is to explore the announcement effect of a hard fork or airdrop on the parent coin. The second is to examine the reaction of the parent coin at the payout date of the new coin. Third, I compare the price drop of the parent coin at the payout date to the value of the newly distributed coin. I answer these research questions using an event study method. Thereby, I manually collect data of 67 hard forks and airdrops from 19 different cryptocurrencies between 2014 and 2020.

My first result is easy to summarize. I find no abnormal return of the parent coin at the announcement date of a hard fork or airdrop. Moreover, I document no significant price increase of the parent coin between the announcement and payout date. At first sight, this result may seem surprising - when in fact, it is not. A price increase at the announcement date would suggest a perpetuum mobile. Value could be created out of nothing by forking Bitcoin infinite times, resulting in a continuous price increase. Therefore, no positive abnormal return of the parent coin at the announcement date is consistent with the efficient market hypothesis.

The second aim of the paper centers around the payout date of the hard forked or airdropped coin. I find that the distribution of the newly forked coins immediately decreases the prices of the corresponding parent coin by 4.65%. The cumulative average abnormal return is -12.29% over the 5-day event window after the payout date. When I only consider hard forks and airdrops of coins that are ex-post traded on an exchange, the price of the parent coin decrease by 6.70% at the distribution date. Interestingly, considering a subsample of events that distribute coins that are ex-post never listed on an exchange decreases the price of the parent coin by 2.77%. I conclude that the value of the distributed coin determines the price decrease at the payout date.

Finally, I test for a free money effect in cryptocurrency markets. I compare the price drop of the parent coin at the payout date to the price of the forked coin. I document that the median ratio between ex-snapshot price drop and price of the distributed coin equals 0.187. Thus, price drop of the parent coin is much lower compared to the value of the distributed cryptocurrency.

More broadly, this paper contributes to the scarce event study literature in cryptocurrency markets testing the EMH. Using a unique dataset, I am able to empirically test if hard forks and airdrops are indeed free money. To the best of my knowledge, this is the first paper to investigate this research question systematically. My findings have significant implications. First, hard forks and airdrops are, to some extend, magic money-making machines. The price drop of the parent coin is much lower than the value paid out through hard forks and airdrops. Interestingly, this can also have negative consequences for cryptocurrency investors. At the payout date, the price of the parent coin significantly decreases. Therefore, hard forks and airdrops have eroded the performance of cryptocurrency investors, who have never claimed the newly distributed cryptocurrencies. I conclude that cryptocurrency markets are not weakly efficient.

The paper proceeds as follows. Section II develops the hypothesis on the price development of the parent coin during a hard fork and airdrop. Section III reviews the literature. Section IV provides a technical description of hard forks and airdrops. Section V summarizes the data. Section VI describes the methodology. Section VII presents the results from the event study analysis for the announcement and snapshot date. Section VIII compares the price drop of the parent coin to the value of the newly distributed coin. Section IX concludes.

II. Free Money

Figure 1 describes the price development of the parent coin during hard forks in four hypothetical cryptocurrency markets. The first three scenarios represent free or partly free money. The fourth scenario equals an efficient and frictionless market. In all scenarios, I set the value of the parent coin (i.e. Bitcoin) to \$100 and the value of the distributed coin to \$5. Note that a hard fork and airdrops proceed similarly to a dividend payment. In an announcement post, a yet unmined block of the parent blockchain is specified. When this block is mined, a snapshot of the ledger is taken. This date is referred to as snapshot date and equals the payout date of the new coin to the owners of the parent coin. Panel A of Fig. 1 represents free money. Each day, the price of Bitcoin remains at \$100. Thus, the investor receives the value of the hard fork (\$5) for free. Panel B of Figure 1 depicts a perpetuum mobile. After the announcement date, the Bitcoin price increases by \$5. In such a market, the price of Bitcoin could be infinitely increased by constantly forking Bitcoin. Panel C of Figure 1 represents a partially efficient market. At the snapshot date, the price of Bitcoin drops by \$2. The price drop is not equal to the received value of \$5, which may reflect market frictions. Panel D of Figure 1 equals a frictionless and efficient market. The price falls by the exact amount of the hard forked coin. Note that these scenarios have considerable commonality to the stylized effect of a dividend payment in stock markets. In an efficient and frictionless stock market, the stock price must fall by the exact amount of the dividend on the day shareholders can no longer claim the dividend.[5]

Which market describes cryptocurrency markets most precisely? Take Bitcoin Cash as a stylized example. The Bitcoin Cash hard fork was announced on July 22nd, 2017 and forked from Bitcoin at block 478'558. This block was mined on August 1st, 2017, which equals the snapshot date. In other words, on August 1st, 2017, every Bitcoin holder obtains one Bitcoin Cash. At the snapshot date, the price of a Bitcoin fell by 5.5%. This equals a price drop of \$157.08. On August 1st, 2017 Bitcoin Cash immediately started trading at \$294.60 and closed at \$380.01. Thus, the price drop of Bitcoin was lower compared to the value of Bitcoin Cash ($\frac{157.08}{294.60} = 0.53$). This example provides stylized evidence of free money.
The results presented in this paper suggest that Panel C of Figure 1 provides the most precise description of cryptocurrency markets.

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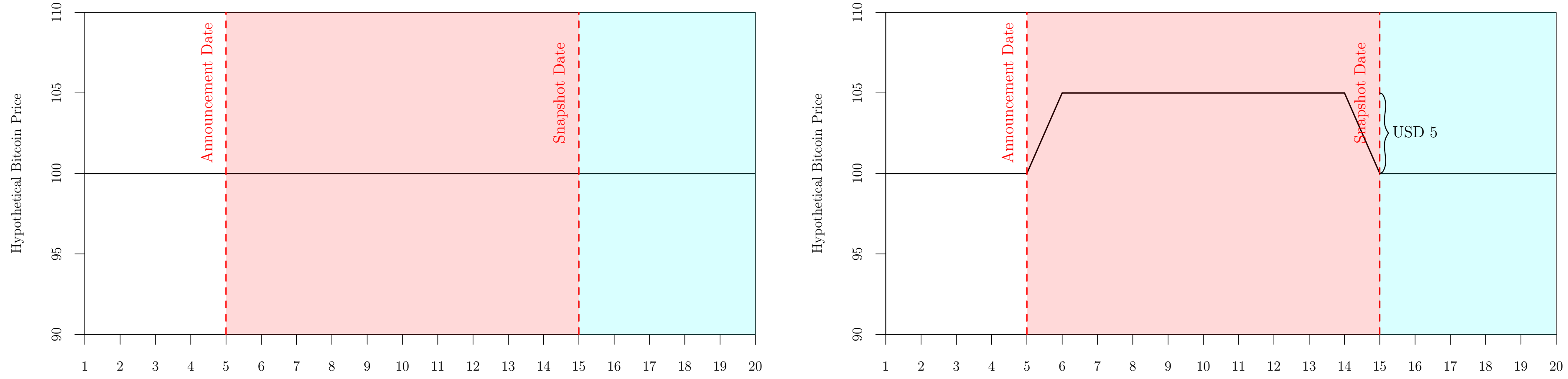
[5] In reality, this is not the case. See: Elton and Gruber (1970), Booth and Johnston (1984), Frank and Jagannathan (1998), Michaely, Vila, and Wang (1996).

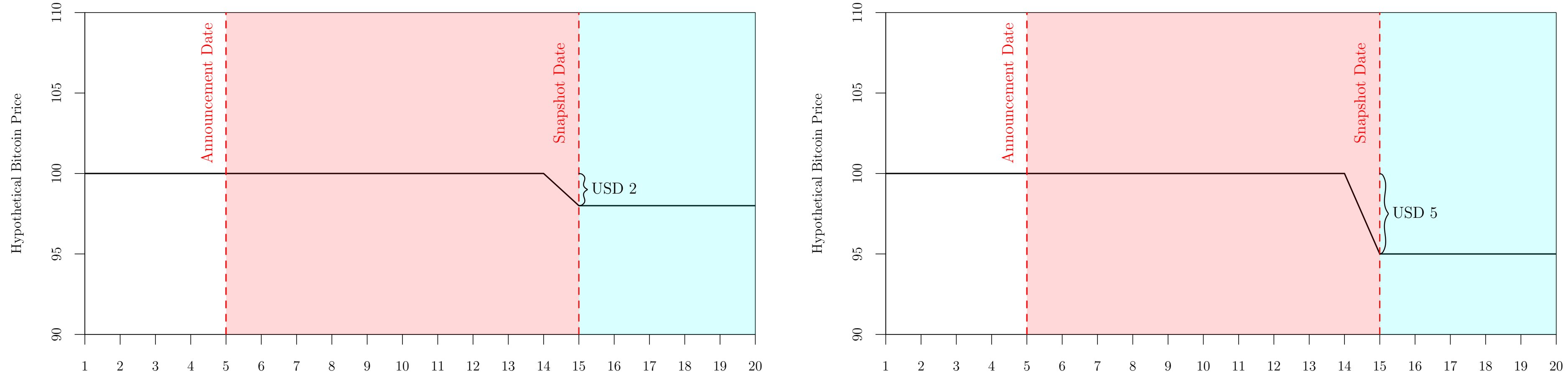
Figure 1. Hypothetical Price Developement of the Parent Coin

This figure depicts four hypothetical price development of the parent coin during hard forks. I assume that the parent coin is Bitcoin, and a hard fork is announced at the announcement date. At the snapshot date, a new coin with a value of $5 will be paid out. Panel A represents a free money situation. Each day the price of Bitcoin remains at $100. In this situation, the investor has $100 ($105) before (after) the snapshot date. The $5 represent free money. Panel B illustrates a similar situation that results in free money for the investor. However, Bitcoin appreciates after the announcement date. Panel C represents a situation where the price drop of Bitcoin is lower than the value of the forked coin. The investor obtained $3 for free ($5-$2). Panel D depicts a no free money situation. The price drop of Bitcoin equals the value of the forked coin.



(a) Free Money

(b) Free Money with Price Appreciation (Perpetuum Mobile)



(c) Partly Free Money

(d) No Free Money

III. Literature Review

The growing literature on cryptocurrencies can be subdivided into five main strands: bubble dynamics, regulation, cyber criminality, diversification, and market efficiency. Below, I will focus on the literature analysing the efficient market hypothesis (EMH) of cryptocurrency markets, as this strand of academic literature is mostly related to my research question. Urquhart (2016) documents that bitcoin returns are significantly inefficient over the sample period from 2010 until 2016. Interestingly, when the sample was split into a pre and post 2013 sample, the authors find that bitcoin shows signs of becoming efficient. The inefficiency of bitcoin returns was confirmed by several more recent studies (cf. Tiwari, Jana, Das, and Roubaud (2018), Nadarajah and Chu (2017)). Kristoufek and Vosvrda (2019) investigate the efficiency of the six largest cryptocurrencies, finding that none of these cryptocurrencies is efficient when denominated in USD. Surprisingly, the efficiency of a coin depends on the crypto pair used. The authors document that Monero is the least (most) efficient coin when taken USD (BTC) as crypto pair. Similarly, Brauneis and Mestel (2018) investigate 73 cryptocurrencies since 2015 and find that none of these currencies is weakly efficient. Zargar and Kumar (2019) provide evidence against the market efficiency of bitcoin at the intraday level. Sensoy (2019) provides evidence that the bitcoin market is becoming more efficient. Similarly, Wei (2018) investigates 456 cryptocurrencies and show that the market efficiency of large cryptocurrencies is improving.

Surprisingly, the EMH has seldom been tested using an event study in the cryptocurrency market. Since the first event study by Dolley (1933), similar methodologies have been extensively used to evaluate the response of financial instruments to a variety of different events, such as stock splits (Chern, Tandon, Yu, and Webb (2008)), mergers and acquisitions, earnings announcements, and spin-offs (Veld and Veld-Merkoulova (2004)). Event study methodology allows measuring the economic impact of an event on the underlying security prices. Assuming a rational and efficient marketplace, one would expect new information to be reflected in security prices (Mackinlay (1997)). Despite the long history of academic research and its wide application, event studies in cryptocurrencies are rarely found. This is due to several reasons: first, cryptocurrencies are a relatively young asset class with limited historical data available. Second, events in the cryptocurrency market are difficult to conceptualise as there rarely exists an equivalent event in traditional asset classes. Cryptocurrency specific events include token burns, airdrops, 51% attacks, halvings, swaps, and hard forks. Shanaev et al. (2019) examine the effect of 51% attacks on proof-of-work cryptocurrencies. Civitarese (2018) perform an event study to investigate the effect of protocol efficiency on cryptocurrency prices. Joo, Nishikawa, and Dandapani (2020) conduct an event study on cryptocurrencies, including 60 positive or negative events. The authors find that CARs linger multiple days after the announcement and conclude that the information flow in cryptocurrency markets is slow.

Joo et al. (2020) is one of the few papers studying the announcement effect in cryptocurrencies. The authors investigate the announcement effect of positive as well as negative events for three cryptocurrencies. Joo et al. (2020) find that CAARs do not stabilize six days after an event and conclude that the information flow in cryptocurrency markets is slow.

Kiffer, Levin, and Mislove (2017) explore the hard fork on the Ethereum blockchain that created Ethereum Classic on July 20^{th}, 2016. Specifically, the authors investigate what effect the hard fork had on network activity and find that Etereum Classic experienced a considerable drop in the number of nodes in the network. This is manifested in a sharp short-term decrease of blocks mined per hour. Two weeks after the hard fork, the mining difficulty increased (decreased) for Ethereum (Ethereum Classic). Thus, the authors argue that mining power from Ethereum returned to Ethereum Classic. Șoiman, Mourey, Dumas, and Jimenez-Garces (2021) examine the effect of hard forks from bitcoin. The authors collect information on 30 hard forks originating from the bitcoin blockchain and show that forks tend to improve the efficiency of bitcoin. Interestingly, hard forks that occur during the distressed market periods decrease the market efficiency of the parent coin.

Another strand of academic literature related to my paper is event studies on dividend announcements and payments. According to the dividend irrelevance theory Miller and Modigliani (1961), dividend policy does not affect firm value in perfect capital markets. In contrast, Aharony and Swary (1980) show that dividend increases are associated with positive abnormal stock returns.[6] This effect can partially be attributed to a signalling effect, whereby managers convey private information on future earnings. Another interpretation of the positive price reaction due to increasing dividends is the result of lower agency costs. Both interpretations do not hold for cryptocurrencies. A cryptocurrency has neither future earnings nor an agent acting on behalf of the principal.

Turning to dividend payments. In perfect capital markets, stock prices fall at the ex-dividend date by the dividend per share. Elton and Gruber (1970) show that for U.S. stocks, this does not hold true. The authors find that the mean ratio of the ex-dividend price drop to the dividend equals 0.778. Thus, stock prices fall by less than the dividend paid to investors. Elton and Gruber (1970) argue the ratio lower than one is the result of tax effects. Kalay

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[6] This wealth effect of dividend announcement has been confirmed by Dielman and Oppenheimer (1984), and Gosnell, Keown, and Pinkerton (1996).

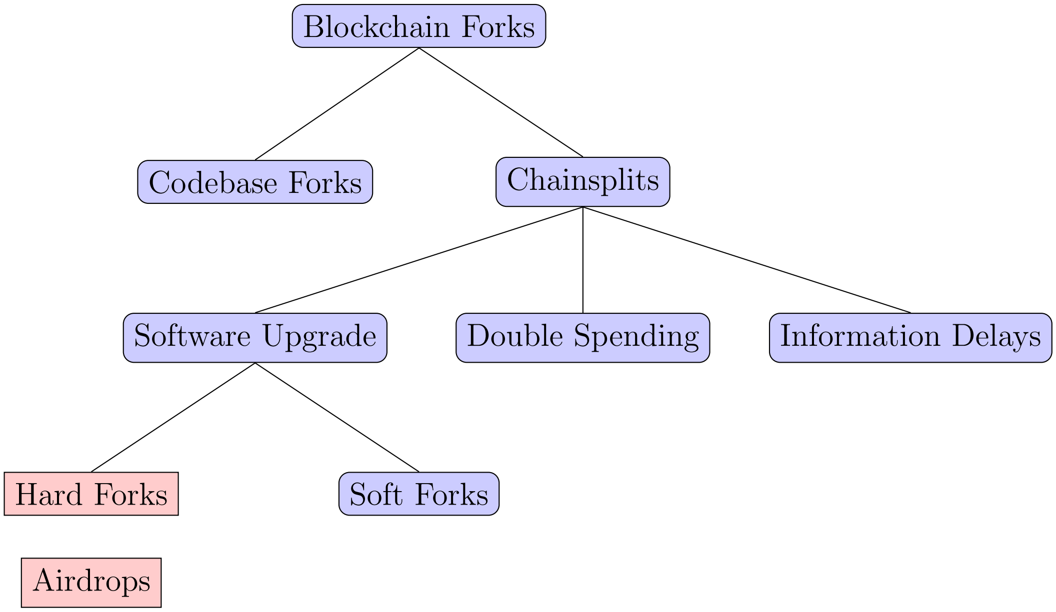
(1982) reports an average ex-dividend price drop to dividend ratio of 0.881 while accounting for potential biases. Frank and Jagannathan (1998) examine the same research question for the Hong Kong stock market, where neither capital gains nor dividends are taxed. The average dividend in Hong Kong from 1980-1993 equals HK$0.12, and the average price drop equals HK$0.06. Thus, in a country without taxes, stock prices fall by less than the value of the dividend.

IV. Blockchain Forks

Figure 2 provides a classification of different types of blockchain forks. Blockchain forks describe two distinct but related events: chainsplits (Sec. IV.B), and codebase forks (Sec. IV.A). For completeness, I shortly describe all events related to blockchain forks.[7] Note that for my empirical analysis, I exclusively focus on hard forks and airdrops (depicted in red in Figure 2). Although semantically and technically hard forks and airdrops are very different, both events have the same consequence for an investor: receiving additional coins at a specific date. Tax authorities treat both events the same way (Firth (2020), 2019-44 IRB 1004).

Figure 2. Classification of Blockchain Forks

This figure classifies different types of blockchain forks following Lewis (2018), and Biais et al. (2019). Overall, blockchain forks can be subdivided into chainsplits, and codebase forks. For my empirical analysis, I exclusively focus on *hard forks*, and *airdrops* (depicted in red). Hard forks and airdrops result in the distribution of newly created (or already existing) coins to holders of the parent coin. My empirical analysis centres around the effect of the distribution of these coins.



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[7] See also Biais, Bisière, Bouvard, and Casamatta (2019), Lewis (2018), and Șoiman et al. (2021) for a detailed description of blockchain forks.

A. Codebase Forks

Codebase forks are frequently confused with hard forks. Thus, I shortly describe codebase forks. All major cryptocurrencies are open-source. Since the codebase of these cryptocurrencies is publicly available, it encourages developers to contribute and further improve the current codebase of the currency. Everyone can copy the existing code of a cryptocurrency software (e.g. Bitcoin) and adapt parameters of the existing code (e.g. blocksize). Running the code creates an entirely new blockchain from a blank ledger with a new genesis block. As an example, the whole Bitcoin code can be found on GitHub. In the context of open-source software, forking a project refers to copying existing code and adjust it according to the ideas of the new project leaders (Ernst, Easterbrook, and Mylopoulos (2010)).

A famous example of a codebase fork is Litecoin. Launched in October 2011, Litecoin reduced the block time to 2.5 minutes (bitcoin: 10 minutes), changed the proof-of-work algorithm to Scrypt (bitcoin: SHA-256), has a maximum supply of 84 million (bitcoin: 21 million), and the block reward halves after 840'000 blocks (bitcoin: 210'000 blocks). Although such codebase forks result in a new coin, these coins are not freely distributed to investors. After litecoin was mined, it was traded like any other cryptocurrency on cryptocurrency exchanges. Further examples of codebase forks include Dash, Namecoin, Peercoin, and Auroracoin.

To sum up, a codebase fork results in two independent blockchains, which do not share the same genesis block. Importantly, holders of the parent coin are not directly affected by chainsplits. There is no distribution of litecoin to holders of bitcoin. Thus, I exclude codebase forks from my empirical analysis.

B. Chainsplits

Consensus on a decentralized ledger is obtained when all participants agree on a specific blockchain. This is not always the case, and chains can split into branches. According to Biais et al. (2019), there a three main reasons why chainsplits occur.

B.1. Information Delay

The confirmation of a new block on the blockchain is not simultaneously broadcasted across the entire network. In practice, this means that a miner in Russia might not be aware that a miner in China already solved the block that he is currently attempting to solve. Therefore, when the miner in Russia has solved the block, the miner might add it to the same parent block as the miner in China. This creates a fork with two competing branches (Biais et al. (2019)).

B.2. Double Spending

The blockchain protocol is designed to prevent *double-spending*. However, suppose an attacker buys an article from a seller, paying for it with bitcoins. The corresponding transaction ($TX_{Article}$) is recorded in a block B. Miners validate block B including $TX_{Article}$. After block B is validated, the seller delivers the article. Secretly, the attacker mines his own blocks excluding $TX_{Article}$ but including another transaction to his own wallet (TX_{Wallet}), which is in conflict with $TX_{Article}$. As soon as the attacker has the article and the longest chain, he broadcasts his own branch to the network. Following the longest chain rule, miners will agree on the attacker's blockchain. In this example, the attacker obtains the article without paying for it (Zhang and Lee (2019), Biais et al. (2019)).

B.3. Software Upgrade

Software upgrades can further be subdivided into soft and hard forks. A soft fork is an upgrade of the software that remains compatible with the older version. Thus, blocks validated by miners running the new version are considered as valid by miners using the old version (Biais et al. (2019)).[8] Following a software upgrade, it can be the case that nodes in the peer-to-peer network forget to upgrade their software. Nodes following the old protocol will produce blocks in the blockchain that is incompatible with the upgraded blockchain (Golosova and Romanovs (2018)).

In stark contrast and most interesting are hard forks (sometimes also referred to as deliberate chainsplits). Hard forks are the result of major changes to the protocols of blockchain technology and are not backward backwards-compatible. Such radical changes to the protocol of a blockchain network effectively result in two branches, one that follows the previous protocol and one that follows the new version. The result is two blockchains sharing the same genesis block (Ghosh, Gupta, Dua, and Kumar (2020)). Famous examples of hard forks are bitcoin cash, bitcoin SV, and litecoin cash.

Figure 3 depicts the procedure of a hard fork. Take bitcoin cash as an example. On July 22^{nd}, 2017, the Bitcoin Cash hard fork was announced in the Bitcoin forum. The hard fork was the result of a dispute on the Bitcoin Improvement Proposal number BIP141: Segregated Witness (SegWit). The idea behind SegWit was to separate transactions into transactional data and signature data (Ghosh et al. (2020)). Generally, hard forks are described and an-

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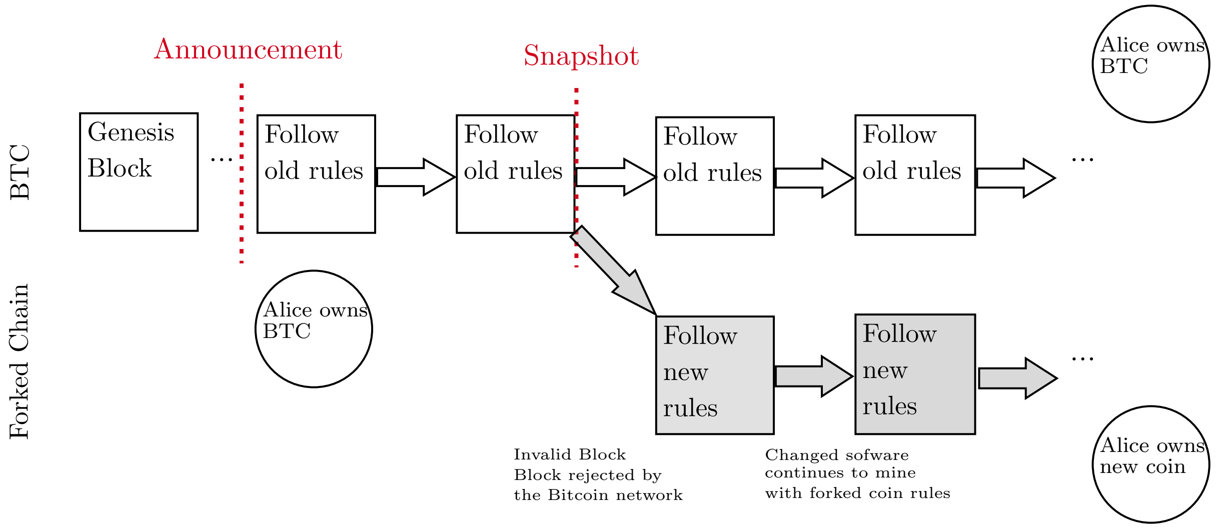
[8] Note that blocks validated by miners running the old version are generally not considered as valid by miners using the new version.

nounced on the Bitcoin forum. In the announcement post, the community get informed from the developers when the hard forks take place. This is done by specifying a specific block height when a so-called *snapshot* will occur. Investors that hold the original coin latest at the snapshot date receive the newly-created coin (Forkdrop (2021b)).

Figure 3. Process of a Bitcoin Hard Fork

This figure depicts the stylized process of a Bitcoin (BTC) hard fork. Squares represent blocks on the Bitcoin blockchain. At some point, the development team announces a hard fork in a project announcement post. The project specifies a new ruleset for the blockchain (e.g. different block size, block time, or consensus algorithm). The snapshot date is often included in the announcement post. It specifies the exact block on which the Unspent Transaction Output (UTXO) snapshot is taken. The UTXO set is duplicated at the snapshot date and updates on two different blockchains following different rules. Before the hard fork, Alice only owned BTC. After the hard fork, Alice owns BTC and the new coin (e.g. Bitcoin Cash). Source: Own representation based on Forkdrop (2021b).



Bitcoin Cash defined the snapshot date at block height 478'558, which was reached on August 1st, 2017. At this block, a snapshot was taken, and every bitcoin holder received for every bitcoin held an additional bitcoin cash.[9] At the snapshot date, one Bitcoin was worth $2,871.30. Bitcoin Cash immediately started trading around $294.60 and closed around $380.01 that day. Today, Bitcoin Cash is traded on several cryptocurrency exchanges and supported by different wallet software. In other words: the Bitcoin Cash fork resulted in the distribution of several million $ to bitcoin investors. Forking bitcoin used to be very easy. Using forkgen, one could specify the coin name, upload the coin logo, and specify coin characteristics (e.g. proof of work algorithm, subsidy amount, subsidy interval, and the premining amount).[10]

Deliberate chainsplits not only take place on the bitcoin blockchain. Ethereum Classic resulted as a hard fork from the cryptocurrency Ether. It was the result of the DAO hack,

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[9] Cash (2020)

[10] Due to the impression that magic money can be created simply by forking bitcoin, forkgen closed down. See the historical website: Forkgen

whereby Ether worth more than $50 million were stolen. The Ethereum community decided to hard fork the blockchain at block height 1'920'000. Ethereum Classic (Ethereum) is based on the original (forked) blockchain. Only the forked Ethereum blockchain included code that restored the stolen ETH to the original coin holders. The success of a hard fork strongly depends on the ability of the developer team to attract miners, investors, exchanges, and wallets supporting the new currency.

In practice, investors must take active steps to claim the newly forked coins. When the original coin holder stores his original coins in a software wallet, the software must be updated to claim the newly forked coin. Other types of wallets, such as custodian wallet services (e.g. Coinbase), may support the new coin. This must not always be the case. Coinbase informed its customers that Bitcoin Cash would not be supported. In contrast, Xapo supported the hard fork and credited Bitcoin Cash to every customer, according to their BTC balance. Moreover, every customer had the option to sell BCH and convert it into BTC or to withdraw BCH.[11] On February 20^{th}, 2019 Coinbase announced that it provides a BCH support.[12] Thus, investors must know that a hard fork will occur, and they must take active steps to claim the new coins.

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[11] XAPO (2017)

[12] Coinbase (2019)

C. Airdrops

From a technical perspective, airdrops are unrelated to chainsplits and codebase forks (Chason (2019)). However, from an investors perspective, airdrops lead to the same outcome as hard forks. As the name suggests, airdrops refer to the distribution of coins or tokens to holders of another cryptocurrency. Airdrops are used for marketing purposes by raising awareness of the project and increasing its user base and economic activity. In other words, airdrops represent a free giveaway of a particular coin. Tax authorities also treat both events the same way. Independently, whether investors receive a cryptocurrency via a hard forked coin or an airdrop the obtained cryptocurrency is treated as gross income (Firth (2020), 2019-44 IRB 1004).

There exist two distinct kinds of airdrops (passive and active airdrops). Passive airdrops refer to projects that distribute cryptocurrencies to specific target groups (e.g. holders of bitcoin) without requiring any active participation from those individuals (Forkdrop (2021a). In the past, there have been several passive airdrops to bitcoin holders (e.g. Obyte (formerly known as Byteball (GYBYTE)), Bitcoin Hush, Bitcoin 2, and United Bitcoin). Most airdrops fail to accrue any value for the recipients. Obyte is an example of an airdrop that gained traction on the secondary market and can be traded on multiple exchanges. Active airdrops, on the other hand, only distribute coins to a subset of a specific target group that participate actively. Active participation ranges from subscribing to a newsletter, using a specific messaging application, or have used the platform in the past (Firth (2020)). An example of an active airdrop is Uniswap (UNI). In 2020, Uniswap airdropped its own token (UNI) to all users that have used Uniswap by performing at least one transaction before September 1^{st}, 2020. Each eligible account received 400 UNIs (Huber (2020)).

Figure 4 depicts the procedure of an airdrop that creates a new, independent blockchain from the Bitcoin blockchain.[13] Generally, the procedure is very similar to a hard fork. First, the airdrop is announced in an online forum. Bitcoin Hush announced its passive airdrop in January 28^th, 2018.[14] In the announcement post, a snapshot date and block is specified. At the snapshot date, all owners of the defined coin are airdropped the new coins. The ownership of the original coin is tracked by the Unspent Transaction Output (UTXO). Project leaders may specify a UTXO transformation function that caps the amount received by investors holding the original coin. Setting a cap ensures that no single actor in the network has dominant ownership of the new coin (Forkdrop (2021a)).

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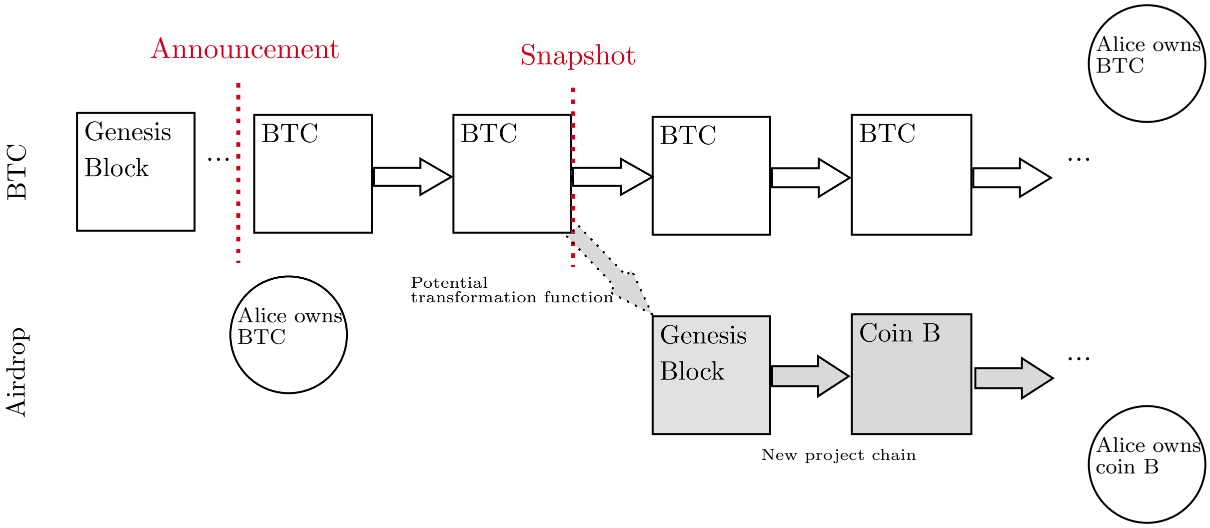
[13] See Forkdrop (2021a) for a detailed description of more complex airdrops.

[14] The announcement on Bitcointalk can be found here.

Figure 4. Procedure of Airdrops

This figure depicts the stylized process of an airdrop. Squares represent blocks on the Bitcoin blockchain. At some point, the development team announces an airdrop. The team specifies the snapshot date when their coins will be distributed. The snapshot date specifies the exact block on which the Unspent Transaction Output (UTXO) snapshot is taken. The UTXO transformation function determines the design of the new blockchain's economy and the distribution of its coins. Note that the blockchain of the airdropped coin has its own genesis block. Source: Own representation based on Forkdrop (2021a).



D. Taxation of Hard Forks & Airdrops

In my analysis, I am exclusively focusing on hard forks (Sec. IV.B.3) and airdrops (Sec. IV.C). As previously mentioned, there exist considerable technical differences between these events. Nevertheless, both events share the commonality that a certain number of newly created coins are distributed to a particular target group for free. Thus, tax authorities frequently do not distinguish whether the new coin was obtained through an airdrop or hard fork.

For the U.S., the Internal Revenue Service (IRS) released guidance regarding the taxation of hard forks and airdrops. The Revenue Ruling 2019-24 states that the taxpayer must report virtual currency received from a hard fork or airdrop as gross income. The revenue ruling differentiates between two scenarios. In the first scenario, the investor has no *dominion and control* of the airdropped coin. This could be the result that the cryptocurrency exchange does not support the newly forked coin. Therefore, the investor does not receive the new coin, and the investor has no taxable income. In the second scenario, the investor has dominion and control over the airdropped coin. If so, the investor obtains taxable income. The value of the taxable income equals the fair market value of the airdropped coin.[15] These new rulings leave several questions unanswered, which can have significant implications for investors. One issue is the following: what value is taxed if the coin is not traded at the time of the hard fork. Second, how are investors treated that have not taken active steps to obtain the airdropped coin and are unaware of having obtained it?

According to a report by PwC, only 24% of 29 jurisdictions investigated issued guidance on the taxation of hard forks and airdrops.[16] In Switzerland, newly distributed coins from airdrops are regarded as a digital gift and are non-taxable income. Similarly, coins obtained from hard forks represent a tax-neutral reallocation of assets. Therefore, Switzerland does not tax profits from hard forks or airdrops (Lindner (2020)). Germany also regards hard forks and airdrops as digital gifts and does not tax these profits. In contrast, Canada does not classify the receipt of a new coin as a taxable event. As soon as the newly obtained coin is sold by the investor, the sale is taxed either as ordinary income or capital gain (McDonald (2020)).

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[15] 2019-44 IRB 1004

[16] PwC (2020)

V. Data

First, I obtain daily cryptocurrency data from Coinmarketcap. Coinmarketcap is one of the leading sources for financial cryptocurrency information, providing historical data from January 1^{st}, 2014 to December 31^{st}, 2020. The data includes open, high, low, closing prices, trading volume, and market capitalization. Coinmarketcap lists assets that are classified as a cryptocurrency, have an operational website, and are actively traded on at least one public exchange. Since cryptocurrency prices differ across exchanges (Makarov and Schoar (2020)), Coinmarketcap reports volume-weighted prices across all exchanges and cryptocurrency pairs.[17] Many previous studies on cryptocurrencies have used the same primary data source (e.g. Liu, Liang, and Cui (2020), Gkillas and Katsiampa (2018), Liu, Tsyvinski, and Wu (2019), Liebi (2020), and Hu, Parlour, and Rajan (2019)). Importantly, Coinmarketcap provides information on delisted and currently listed cryptocurrencies. I obtain historical prices for all cryptocurrencies listed on Coinmarketcap. The market return equals the value-weighted return of 3'987 cryptocurrencies. Stablecoins are excluded from the sample.

Second, I collect snapshot dates of hard forks and airdrops from three main sources. As a main source, I obtain information from the website forkdrop.io. The website provides a comprehensive list of hard forks and airdrops, including the exact block height when the fork or airdrop occurs. Additionally, I made use of the traditional cryptocurrency calendars (coinmarketcal.com, coinpredictor.io) to identify events that are missing on forkdrop.io.
In most cases, the announcement date was provided on forkdrop.io. If not, I manually searched the announcement date. The manual announcement search included three sources: bitcointalk, the Twitter account of the newly forked coin, and the official website. The announcement date equals the earliest date from the three sources. Importantly, I exclude hard forks or airdrops from my sample that meet at least one of the following criteria: no announcement date was found, the announcement date is after the actual event date, or if no block height was specified at any date between announcement and event date.

The final sample contains 67 events (hard forks: 51; airdrops: 16). Figure 5 depicts the snapshot dates of all events in my sample. Red lines indicate that the event has bitcoin as the parent coin. In total, 38 hard forks or airdrops resulted from the Bitcoin blockchain. Notice that hard forks are highly clustered around the ICO boom from 2017-2018 (Momtaz (2019)). Table A1 in the Appendix provides a comprehensive list of all hard forks and airdrops in my sample. I report the parent coin and the newly distributed coin. Importantly, Table

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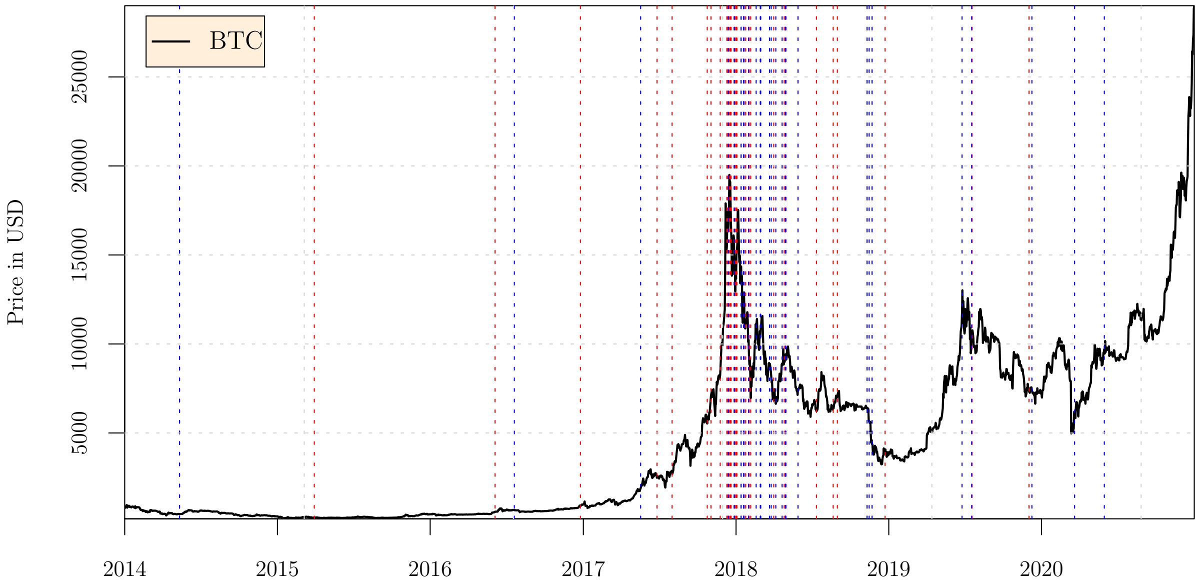
[17] CoinMarketCap (2020)

A1 includes all sources to the announcement as well as the snapshot date. The average (median) time between announcement and snapshot date equals 51 (32) days. Moreover, I conduct a subsample analysis. Thereby, I classify each of the 67 events into two categories (i.e. successful and unsuccessful). A hard fork or airdrop is successful if the distributed coin is traded at any point in time after the snapshot date and Coinmarketcap reports open, high, low, close, and market cap of the distributed coin. In other words, successful hard forks or airdrops distribute a coin with an ex-post positive value. The number of successful hard forks or airdrops equals 32. The remaining 35 events are considered as unsuccessful. Unsuccessful events result in the distribution of coins that have never been traded on an exchange.

Figure 5. Overview of all Snapshot Dates

This figure depicts the price of Bitcoin (BTC) in US Dollars in black. The dashed, vertical lines represent a snapshot date of a hard fork or airdrop. Red lines indicate a hard fork or airdrop from Bitcoin, whereas blue represents a hard fork or airdrop from another cryptocurrency. The total number of snapshot dates equals 67 (hard forks: 51; airdrops: 16); 01-January-2014 to 31-December-2020, 2556 days.



VI. Method

The announcement and distribution effect of coins is measured using an event study methodology as described by Shanaev et al. (2019). Following this paper, as well as more general event study papers Brown and Warner (1985), Peterson (1989), and Mackinlay (1997), I use multiple techniques to ensure the robustness of the results. Abnormal returns of the parent coin are calculated using three different models. First, I follow Mackinlay (1997) by calculating abnormal returns based on the market model, estimated over a 120-day window (from day -131 to day -11). The baseline event window is set to -10 to +5 days. The market index equals the value-weighted return of 3'987 cryptocurrencies. To ensure consistency, I obtain abnormal returns using the constant return model using the same estimation window. Brown and Warner (1985) show that the constant return model often yields similar results compared to more advanced models. This is due to the fact that even more sophisticated models are often unable to reduce the variance of the abnormal returns. Lastly, I report the results when the market adjusted model is used to calculate abnormal returns. Depending on the model used, the abnormal return of cryptocurrency i at time t ($AR_{i,t}$) is defined as follows:

$$\text{Market Model: } AR_{i,t} = R_{i,t} - (\alpha_i + \beta_i R_{m,t}) \tag{2}$$

$$\text{Constant Return Model: } AR_{i,t} = R_{i,t} - \bar{R}_i \tag{3}$$

$$\text{Market adj. Model: } AR_{i,t} = R_{i,t} - R_{m,t} \tag{4}$$

where $R_{i,t}$ is the daily return of cryptocurrency i at time t, and $R_{m,t}$ equals the value-weighted market return. For the constant return model, $\bar{R}_i$ equals the mean return of cryptocurrency i over the estimation window.

I let AAR_t denote the average daily abnormal return on day t, and $CAAR_t$ denote the cumulative average daily abnormal return on day t during the event window:

$$AAR_t = \frac{1}{N}\sum_{i=1}^{N} AR_{i,t} \tag{5}$$

$$CAAR_t = \sum_{t=-10}^{t} AAR_t \tag{6}$$

There exist notable overlaps in the sample periods for different cryptocurrencies. Moreover, events are highly clustered at the end of 2017 and the beginning of 2018. Thus, I assess if each average daily return is significantly different from zero using the traditional t-tests, as well as test statistics proposed by Boehmer, Masumeci, and Poulsen (1991). The authors' test procedure adjusts for event-induced variance. Let $SAR_{i,t}$ denote Brown and Warner (1985) standardised abnormal returns for cryptocurrency i at time t during the event window, and $\hat{S}(SAR_t)$ the cross-sectional standard deviation of the standardised abnormal returns. The Boehmer et al. (1991) t-statistic is defined by Equation 7.

$$t = \frac{1}{\sqrt{N}} \sum_{i=1}^{N} \frac{SAR_{i,t}}{\hat{S}(SAR_t)} \tag{7}$$

where the cross-sectional standard deviation of standardised abnormal returns equals:

$$\hat{S}(SAR_t) = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (SAR_{i,t} - \overline{SAR_t})} \ ; \quad \overline{SAR_t} = \frac{1}{N} \sum_{i}^{N} SAR_{i,t} \tag{8}$$

Following Shanaev et al. (2019), I also report the results when shorter event windows are considered (namely: [0;0], [-10:-1], [-5;-1], [0:1], [0;3], and [0;5]). The first event window equals the event date. I specify two pre-event windows. The pre-event windows capture a potential run-up in the parent coin prior to the snapshot date. The post-event windows provide further insights whether cryptocurrency prices regain the value lost after the snapshot date.

VII. Event Study Analysis

A. Announcement Date

In this subsection, I exclusively focus on the announcement effect of a hard fork or airdrop. Table I shows average abnormal returns (AARs) on each day in the event window around the announcement date. Each Panel in Table I reports AARs based on a different model (Panel A: market model, Panel B: constant return model, Panel C: market adj, model). The results are easy to summarize. Looking at the announcement date, I find no evidence that the announcement of a hard fork or airdrop is associated with positive abnormal returns. Despite the positive returns at the announcement date, they are statistically not significant. In short, independent of the model and reported t-statistics, the AAR at the announcement date is indistinguishable from zero.

There are three potential reasons why I find no significant returns at the announcement date. First, I have wrongly identified the announcement date. Second, information asymmetries in cryptocurrency markets are lower compared to equity markets. Forking a coin is traditionally discussed and voted on within the cryptocurrency community (Yiu (2021)). Thus, information is less surprising in cryptocurrency markets. Third, hard forks and airdrops do not create value. The first argument can be partly ruled out. Besides providing all links to the announcement date in Table A1 in the Appendix, there is no evidence of positive abnormal returns on any day during the event window. This also falsifies the second argument. I do not find any significant AAR in the event window, as well as no significant cumulative average abnormal return (CAAR) after the announcement date.
The third argument is most plausible: the announcement of hard forks or airdrop does not create value. Why should it? As outlined in Sec. II, positive AARs at the announcement date would suggest a perpetuum mobile. The price of the parent coin could be continuously increased by constantly forking the parent coin. Note that from the 67 events investigated, only 32 distributed coins have been traded on an exchange at some point in time. In other words, 35 events resulted in the distribution of coins with a zero value. One might argue that my results are driven by these 35 zero value events. I address this argument in Section VII.C. In short, even when only the 32 successful hard forks and airdrops are considered, no positive announcement effect is documented.

Next, I calculate cumulative average abnormal returns (CAAR) for multiple event windows. Table II reports CAARs for multi-day intervals. I cumulate returns over six intervals. The first event window equals the event date. I also specified three pre-event windows and two post-event windows. Looking at the pre-announcement windows, there is no clear pattern in CAARs. Three days post-announcement, all models demonstrate no significant incline in parent coin prices. Moreover, even 5-days post-announcement, only 53.7% of all parent coins exhibit a positive CAR. In short, the announcement of a hard fork or airdrop has no significant effect on parent coin prices. Figure 6 visualizes the cumulative average abnormal returns (CAARs) around the snapshot date reported in Table I. I document a slightly increasing CAAR during the event window. However, non of the CAARs is statistically significant.

Joo et al. (2020) investigate the effect of positive and negative news on Bitcoin, Ethereum, and Ripple. The authors look at various events and classify these into negative or positive news. Joo et al. (2020) classify hard fork announcements as positive news since it increases liquidity. Despite being potential good news, my results suggest that a hard fork or airdrop announcement does not affect the prices of the parent coin. This result is consistent with the EMH. Considering the free money hypothesis (see. Fig 1), my results provided evidence against the perpetuum mobile cryptocurrency market. However, the announcement date is only one part of the puzzle. Critical is the price reaction of the parent coin at the snapshot date. In the following subsection, I investigate the price reaction of the parent coin at the snapshot date.

Table I Average Abnormal Returns around Announcement Date

This table reports average abnormal returns (AAR) and cumulative average abnormal returns (CAAR) in per cent around the event date. The event date equals the announcement date of the hard fork or airdrop. The event window ranges from 10 trading days before through 5 trading days after the event. Abnormal returns are estimated with three different models. Panel A estimated abnormal returns using the market model. Panel B (C) is based on the constant return model (market adjusted model). The total number of events equals 67. Test statistics are reported in two different ways to account for event-date clustering and event-induced variance (t-test, Boehmer et al. (1991)). *, **, *** denote statistical significance at 10, 5 and 1 per cent, respectively.

	Panel A: Market Model				Panel B: Constant Return Model				Panel C: Market Adj. Model			
Day	AAR	CAAR	t-stat	Boehmer Masumeci Paulsen statistics	AAR	CAAR	t-stat	Boehmer Masumeci Paulsen statistics	AAR	CAAR	t-stat	Boehmer Masumeci Paulsen statistics
-10	1.56	1.56	(1.32)	(0.46)	0.74	0.74	(0.54)	(-0.35)	1.81	1.81	(1.54)	(0.68)
-9	0.96	2.52	(1.23)	(0.38)	1.10	1.84	(1.13)	(1.36)	1.01	2.81	(1.38)	(0.48)
-8	1.05	3.57	(1.19)	(1.42)	1.12	2.96	(1.03)	(0.91)	1.09	3.91	(1.3)	(1.51)
-7	0.71	4.28	(0.75)	(0.62)	1.81	4.78	(1.61)	(2)**	0.88	4.79	(0.97)	(0.9)
-6	1.18	5.46	(0.94)	(1.51)	1.65	6.43	(1.22)	(1.43)	1.23	6.01	(0.99)	(1.55)
-5	-1.28	4.17	(-2.04)**	(-0.64)	-1.43	5.00	(-1.26)	(-0.73)	-1.21	4.81	(-1.86)*	(-0.46)
-4	-0.69	3.48	(-1.39)	(-1.51)	-0.80	4.20	(-0.93)	(-1.3)	-0.41	4.40	(-0.74)	(-1.02)
-3	-0.88	2.60	(-1.98)*	(-1.57)	-0.84	3.36	(-1.16)	(-0.72)	-0.79	3.61	(-1.83)*	(-1.26)
-2	-0.11	2.48	(-0.26)	(0.49)	0.51	3.87	(0.68)	(0.85)	0.08	3.69	(0.18)	(0.56)
-1	0.49	2.97	(0.76)	(1.27)	0.62	4.49	(0.67)	(1.01)	0.66	4.35	(1.06)	(1.29)
0	0.51	3.48	(0.45)	(0.21)	1.84	6.33	(1.4)	(1.55)	0.81	5.16	(0.74)	(0.35)
1	0.66	4.15	(0.46)	(0.12)	0.59	6.92	(0.38)	(0.31)	0.89	6.04	(0.62)	(0.41)
2	0.74	4.89	(0.59)	(-0.02)	0.12	7.04	(0.08)	(0.08)	0.79	6.83	(0.63)	(0.09)
3	-0.41	4.48	(-0.49)	(0.44)	0.07	7.11	(0.06)	(0.14)	-0.22	6.61	(-0.28)	(0.73)
4	2.13	6.61	(1.54)	(0.92)	1.62	8.73	(0.98)	(0.27)	2.37	8.98	(1.75)*	(1.26)
5	0.40	7.01	(0.31)	(-0.35)	0.46	9.20	(0.35)	(0.22)	0.72	9.69	(0.56)	(-0.05)

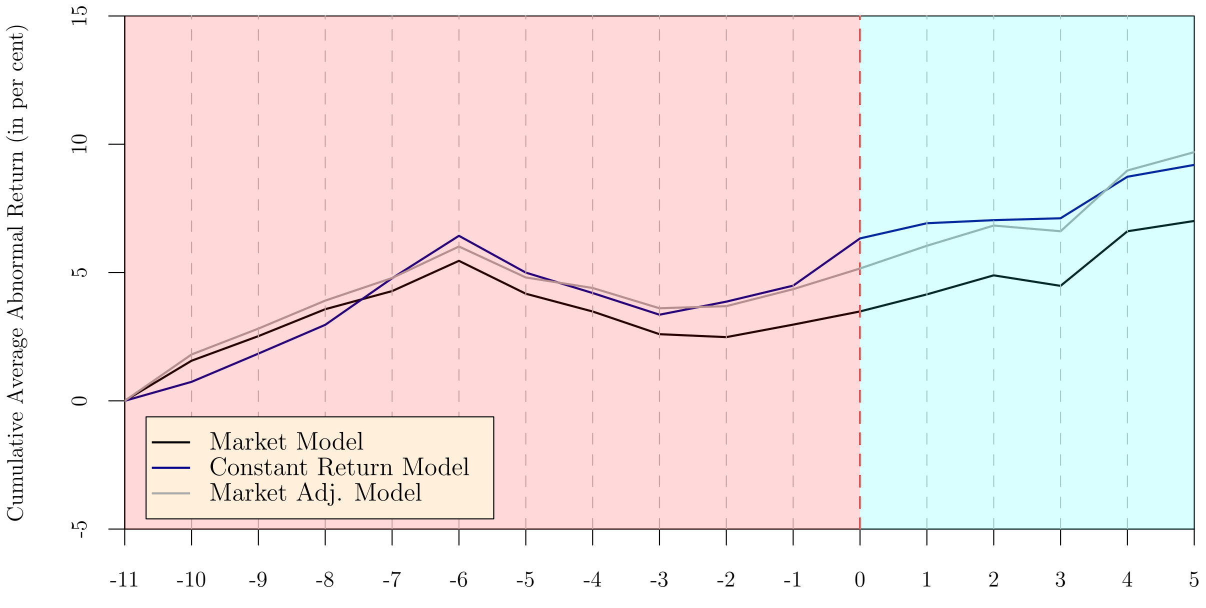
Table II CAAR for Event Windows around Announcement Date

This table reports the results of a multi-day event-study analysis. The total number of events equals 67. Event date equals the announcement date of a hard fork or an airdrop. Panel A estimated abnormal returns using the market model. Panel B (C) is based on the constant return model (market adjusted model). Test statistics are reported in parentheses. The third row in each panel reports how many CARs are below zero in per cent. *, **, *** denote statistical significance at 10, 5 and 1 per cent, respectively.

	Event Window	[0;0]	[-10;-1]	[-5;-1]	[0;1]	[0;3]	[0;5]
Market Model	CAAR	0.51	2.97	-2.49*	1.18	1.51	4.04
	t-stat	(0.45)	(0.99)	(-1.88)	(0.57)	(0.65)	(1.21)
	negative	55.22	53.73	64.18	47.76	43.28	46.27
Const. Return Model	CAAR	1.84	4.49	-1.94	2.43	2.63	4.71
	t-stat	(1.4)	(1.29)	(-0.7)	(1.1)	(0.87)	(1.18)
	negative	49.25	52.24	53.73	47.76	49.25	52.24
Market adj. Model	CAAR	0.81	4.35*	-1.66	1.69	2.26	5.34*
	t-stat	(0.74)	(1.79)	(-1.1)	(0.85)	(1.03)	(1.67)
	negative	52.24	43.28	53.73	49.25	43.28	46.27

Figure 6. CAAR around Announcement Date

This figure depicts cumulative average abnormal returns (CAAR) in per cent around the event date. The event date equals the announcement date of the hard fork or airdrop, and the event window ranges from 10 trading days before through 5 trading days after the event. Note that the day -11 equals zero and is added for visualization purposes. Abnormal returns are estimated with three different models. The black (blue) line estimates abnormal returns using the market model (constant return model). In dark grey, I depict CAARs based on the market adjusted model. The announcement date is at day 0 and illustrated by a vertical, dashed red line. The total number of events equals 67.



B. Snapshot Date

In the previous section, I have documented no significant AAR at the announcement date of a hard fork or airdrop. Next, I test for the relationship between snapshot dates and subsequent abnormal returns. At the snapshot date, a snapshot of the ledger is taken in order to distribute the newly created coins to the owners of the parent coin. Thus, the snapshot date equals the last day the hard forked or airdropped coin can be claimed.

Table III reports average abnormal returns on each day in the event window around the snapshot of a hard fork or an airdrop. At the snapshot (day=0), AARs are strongly negative. Depending on the model, AARs range from -4.5% using the market adjusted model to -4.65% based on the market model. At the snapshot date, the t-test, as well as the Boehmer et al. (1991) test, indicate statistical significance at the 1% level. These results are consistent across the three models. Before the snapshot date, I document no significant AAR on any day. Thus, investors do not systemically buy or sell the parent coin before the snapshot date to profit from the hard forked or airdropped coin, at least not ten trading days before the event. The snapshot date also has an effect on abnormal returns one and four days after the event. On day 1, the negative AARs are strongly negative and comparable to the effect at the event date. Average abnormal returns one day after the snapshot date (t=1) equal -3.32% (-3.59%) based on the market adjusted model (market model). This also holds for day 4, with AARs being negative but considerably lower than the event date. Judged from the negative AAR at the event date, the results suggest that hard forks and airdrops are priced. Over the event window, the cumulative average abnormal return (CAAR) is between -8.91% and -19.21%, depending on the model used to determine abnormal returns.

Next, I consider multi-day intervals within the event window. Table IV reports CAARs for six different intervals. The first event window equals the snapshot date ([0;0]). The second and third windows are before the snapshot. Before the snapshot date ([-10;-1],[-5;1]), all CAARs are insignificant. Moreover, the market model indicates that only 52.24% exhibit a positive cumulative abnormal return over the event window [-10;-1]. This confirms that there exists no price increase of the parent coin before the snapshot date. After the snapshot date, all models confirm a negative price reaction of the parent coin. One day after the snapshot date, CAARs range from -8.23% to -7.82%, dependant on the model. Three days after the snapshot date, cryptocurrencies, on average, are traded 10.01% below their pre-snapshot level. Five days after the snapshot date ([0;5]), the CAAR equals -12.29% and only 29.85% of all currencies recover to their pre-snapshot date level. Overall, the snapshot date effect is extremely consistent across all models.

Figure 7 visualized the CAARs reported in Table III. I plot event days on the x-axis and CAARs on the y-axis. Before the snapshot date (day -10 to day -1), CAARs are relatively constant. Based on the market model, the CAAR at day -1 equals -0.8%. At the snapshot date and one day after (day +1), CAARs significantly decrease. The economic magnitude of AAR at the snapshot date, hard forks and airdrops negatively affect the parent coin. Looking at post snapshot dates (day +1 to day +5), the AARs are negative but tend to converge towards zero. The only exception is day 4. As a result, the CAARs remain negative but become less steep following the snapshot date.

As previously outlined, my sample includes 67 hard forks and airdrops. However, only 32 events resulted in the distribution of ex-post valuable coins. In other words, 35 events resulted in the distribution of coins that have never been traded on an exchange. In the next section, I show that cryptocurrency markets differentiate between valuable and worthless cryptocurrencies.

Table III Average Abnormal Returns around Snapshot Date

This table reports average abnormal returns (AAR) and cumulative average average abnormal returns (CAAR) in per cent arount the event date. The event date equals the snapshot date of the hard fork or airdrop. The event window ranges from 10 trading days before through 5 trading days after the event. Abnormal returns are estimated with three different models. Panel A estimated abnormal returns using the market model. Panel B (C) is based on the constant return model (market adjusted model). The total number of events equals 67. Test statistics are reported in two different ways to account for event-date clustering and event-induced variance (t-test, Boehmer et al. (1991)). *, **, *** denote statistical significance at 10, 5 and 1 per cent, respectively.

	Panel A: Market Model				Panel B: Constant Return Model				Panel C: Market Adj. Model			
Day	AAR	CAAR	t-stat	Boehmer Masumeci Paulsen statistics	AAR	CAAR	t-stat	Boehmer Masumeci Paulsen statistics	AAR	CAAR	t-stat	Boehmer Masumeci Paulsen statistics
-10	-0.71	-0.71	(-1.23)	(-0.66)	-0.79	-0.79	(-1.1)	(-1)	-0.53	-0.53	(-0.95)	(-0.5)
-9	0.74	0.03	(0.61)	(0.35)	0.32	-0.47	(0.23)	(0.06)	1.05	0.52	(0.86)	(0.73)
-8	-0.29	-0.27	(-0.34)	(-0.06)	-1.48	-1.95	(-1.14)	(-1.01)	-0.06	0.46	(-0.07)	(0.28)
-7	0.33	0.07	(0.42)	(-1.09)	0.55	-1.40	(0.53)	(0.47)	0.61	1.07	(0.75)	(-0.62)
-6	0.73	0.79	(1.03)	(0.52)	-0.16	-1.56	(-0.18)	(-0.09)	0.77	1.83	(1.19)	(0.49)
-5	0.28	1.08	(0.4)	(1.5)	-0.34	-1.89	(-0.33)	(0.15)	0.70	2.53	(0.94)	(1.78)*
-4	-0.17	0.91	(-0.23)	(-0.94)	-0.40	-2.30	(-0.39)	(0.14)	0.06	2.59	(0.09)	(-0.67)
-3	-0.99	-0.08	(-1.43)	(-0.77)	-1.36	-3.66	(-1.3)	(-0.84)	-0.62	1.97	(-0.91)	(-0.3)
-2	-0.13	-0.22	(-0.1)	(-0.03)	-0.20	-3.86	(-0.14)	(0.15)	0.33	2.31	(0.26)	(0.61)
-1	-0.59	-0.80	(-0.8)	(-0.12)	-0.75	-4.61	(-0.69)	(-0.17)	-0.46	1.85	(-0.62)	(-0.07)
0	-4.65	-5.45	(-3.19)***	(-3.81)***	-4.55	-9.16	(-2.78)***	(-2.69)***	-4.50	-2.65	(-3.11)***	(-3.54)***
1	-3.59	-9.04	(-2.62)**	(-3.84)***	-3.50	-12.66	(-2.56)**	(-2.16)**	-3.32	-5.97	(-2.63)**	(-3.7)***
2	-0.87	-9.90	(-1.31)	(-1.68)*	-1.72	-14.37	(-1.83)*	(-1.47)	-0.58	-6.55	(-0.9)	(-1.13)
3	-0.91	-10.82	(-1.24)	(-1.24)	-0.86	-15.24	(-0.83)	(-0.09)	-0.52	-7.07	(-0.74)	(-0.8)
4	-1.65	-12.47	(-3.24)***	(-2.72)***	-2.96	-18.20	(-3.56)***	(-2.87)***	-1.46	-8.53	(-3.25)***	(-2.42)**
5	-0.63	-13.10	(-0.87)	(-0.89)	-1.02	-19.21	(-0.97)	(-1.06)	-0.38	-8.91	(-0.52)	(-0.69)

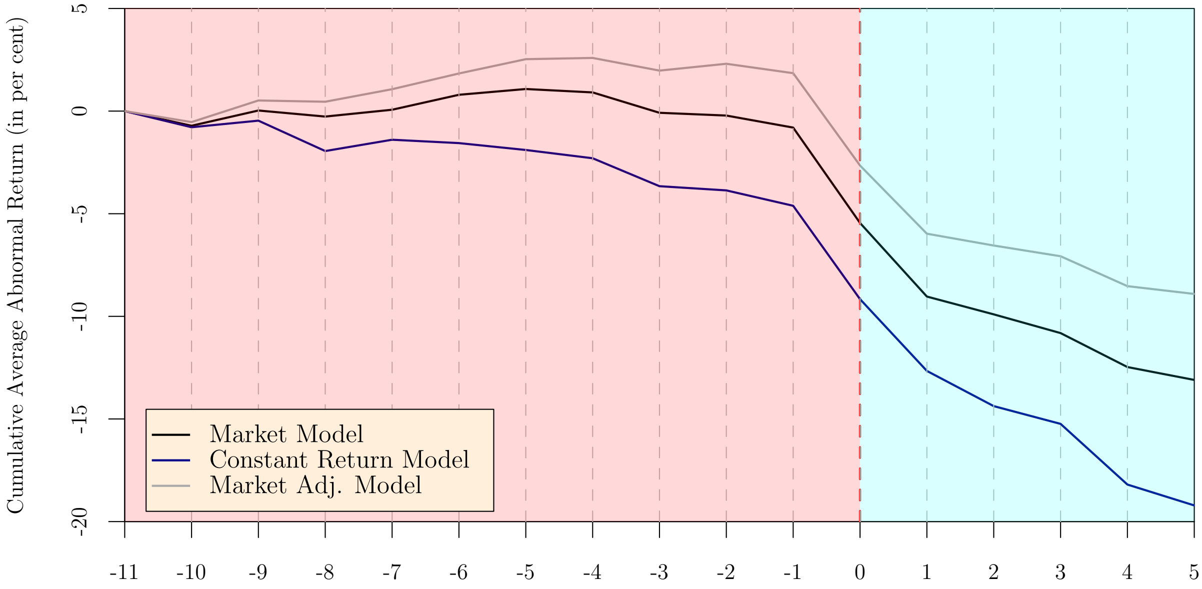
Table IV CAAR for Event Windows around Snapshot Date

This table reports the results of a multi-day event-study analysis. The total number of events equals 67. Event date equals the snapshot date of a hard fork or an airdrop. Panel A estimated abnormal returns using the market model. Panel B (C) is based on the constant return model (market adjusted model). Test statistics are reported in parentheses. The third row in each panel reports how many CARs are below zero in per cent. *, **, *** denote statistical significance at 10, 5 and 1 per cent, respectively.

	Event Window	[0;0]	[-10;-1]	[-5;-1]	[0;1]	[0;3]	[0;5]
Market Model	CAR	-4.65***	-0.8	-1.6	-8.23***	-10.01***	-12.29***
	t-stat	(-3.19)	(-0.25)	(-0.79)	(-3.21)	(-3.25)	(-3.37)
	negative	67.16	47.76	56.72	73.13	67.16	70.15
Const. Return Model	CAR	-4.55***	-4.61	-3.05	-8.05***	-10.63***	-14.6***
	t-stat	(-2.78)	(-1.16)	(-1.16)	(-3.04)	(-3.17)	(-3.65)
	negative	59.7	59.7	58.21	59.7	62.69	61.19
Market adj. Model	CAR	-4.5***	1.85	0.01	-7.82***	-8.92***	-10.75***
	t-stat	(-3.11)	(0.61)	(0.01)	(-3.2)	(-3.15)	(-3.29)
	negative	64.18	46.27	44.78	68.66	68.66	70.15

Figure 7. CAAR around Snapshot Date

This figure depicts cumulative average abnormal returns (CAAR) in per cent around the event date. The event date equals the snapshot date of the hard fork or airdrop, and the event window ranges from 10 trading days before through 5 trading days after the event. Note that the day -11 equals zero and is added for visualization purposes. Abnormal returns are estimated with three different models. The black (blue) line estimates abnormal returns using the market model (constant return model). In darkgray, I depict CAARs based on the market adjusted model. The snapshot date is at day 0 and illustrated by a vertical, dashed red line. The total number of events equals 67.



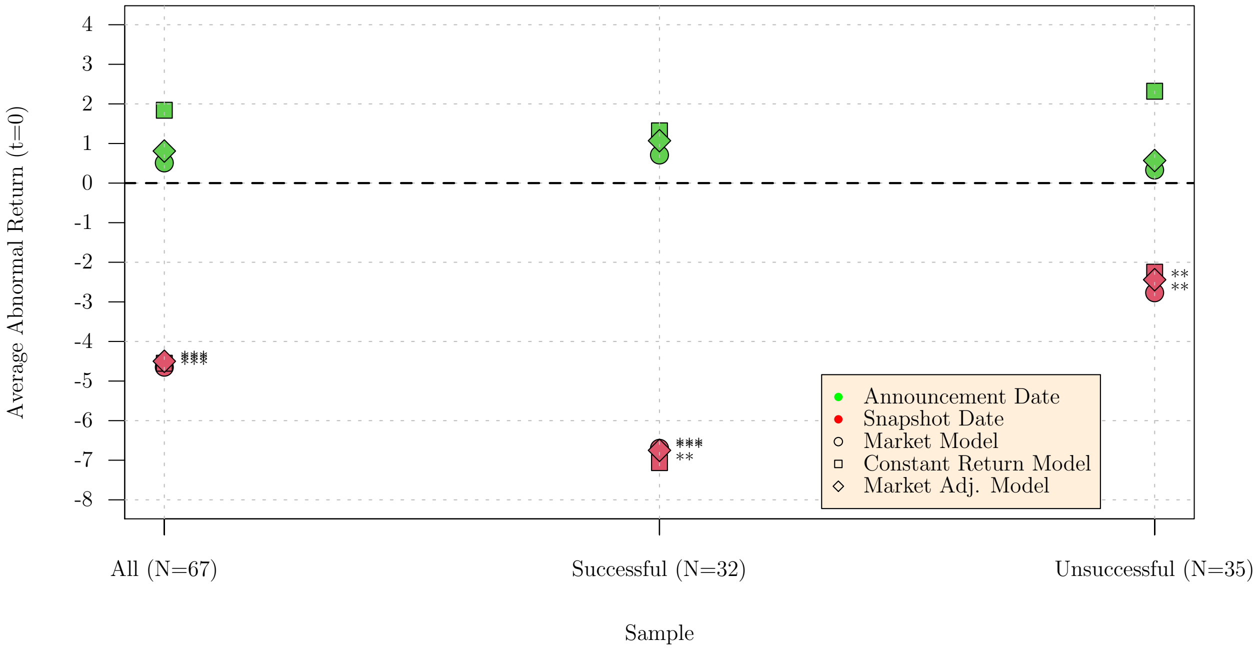
C. Subsample Analysis

In this subsection, I conduct a subsample analysis. I classify each of the 67 events as either successful or unsuccessful. Successful hard forks and airdrops are events that result in the distribution of coins traded at the snapshot date or have ex-post been listed on a cryptocurrency exchange. Importantly, Coinmarketcap must report open, high, low, close, and market capitalization to be considered successful. For example, I classify Bitcoin Cash as a successful hard fork because Bitcoin Cash is currently listed on at least one exchange, and Coinmarketcap reports price data. Thus, successful events result in the distribution of coins with a positive value to investors. In contrast, unsuccessful hard forks and airdrops equal events that result in the distribution of zero-value coins. These coins are never traded on an exchange within my sample period. The motivation behind my subsample analysis is as follows: In a frictionless market, the distribution of a new but worthless coin should not affect the parent coin. This is analogous to a firm that announces a zero dividend payment and later pays a zero dividend. Such a hypothetical payout amount should lead to abnormal returns indistinguishable from zero at the announcement and the payment date. The same argument holds for cryptocurrencies. However, the distribution of a coin with a positive discounted value should have an economically more negative effect on the parent coin at the snapshot date. I use a look-ahead bias to test these conjectures.

Figure 8 summarises the results from the subsample analysis. For each sample, I depict AARs at the event date. Green (red) represents the AARs for the announcement (snapshot) date. The symbol of each data point characterises the model used to calculate abnormal returns. Moreover, I label each AAR with the corresponding significance level. Looking at the announcement date, I document no significant abnormal returns at the announcement date. This finding is consistent across all models and all samples. Based on the market model, the AAR at the announcement date of successful (all) events equals 0.71% (0.51%). From an economic perspective, these differences are of minor significance. Overall the results confirm that the announcement of a hard fork or airdrop has no effect on the parent coin. Importantly, this finding is independent of whether the coin is valuable in the future or not. I turn to AARs at the snapshot date in Figure 8. First, I find that the AARs are lower for the successful sample compared to the whole sample. This finding is consistent across all models. As an example: based on the market model, the distribution of an ex-post valuable coin immediately decreases the prices of parent coins by 6.7%. For the whole sample, the AAR at the snapshot date equals -4.65%, using the same model. Note that all AARs at the snapshot date are significant at least at the 5% level for the successful sample. The results for the unsuccessful sample are surprising. Although this sample only includes coins that

Figure 8. Average Abnormal Returns for Subsamples

This figure depicts average abnormal returns in per cent around the event date (t=0) for three subsamples. The successful (unsuccessful) sample includes all hard forks and aidrops that have (never) been traded on an exchange after the announcement date. The announcement (snapshot) date is visualized in green (red). The symbol characterises the model used to estimate abnormal returns. *, **, *** denote statistical significance of the abnormal return at 10, 5 and 1 per cent, respectively. Test statistics are based on Boehmer et al. (1991).



have never been listed on an exchange, the distribution of these zero-value coins negatively affects the parent coin. For the market model (constant return model), the AAR at the snapshot date equals -2.77% (-2.25%). Overall, all AARs are higher for the unsuccessful sample compared to the whole sample. Detailed results to construct Figure 8 are provided in the Appendix (see Table: A2, A3, A4, A5).

The results can be summarized as follows. The magnitude of the AAR at the announcement date is independent of the coin's success. However, it plays a role for the effect at the snapshot date. The AAR at the snapshot date is lower for successful coins compared to unsuccessful coins. This provides evidence that cryptocurrency markets efficiently differentiate between successful and unsuccessful coins.

VIII. Price Drop Analysis

The ex-hard fork behaviour of parent coins should be related to the amount paid out. A higher value of the distributed coin should be associated with a higher price drop of the parent coin at the snapshot date. In an efficient and frictionless market, the price drop of the parent coin should equal the value of the distributed coin. For stocks and dividend payments, this is not the case. On average, stock prices drop less than the value of the dividend on the ex-dividend date. Elton and Gruber (1970) find that the mean ratio between ex-dividend price drop and the dividend amount equals 0.778. The authors argue that this reflects a tax effect in stock markets. Kalay (1982) investigates the same sample period and documents an average ratio of 0.881. As outlined in Sec IV.D, profits from hard forks and airdrops are not taxed in most countries. Therefore, market frictions from taxes are lower for cryptocurrencies compared to stock markets. Following Elton and Gruber (1970), I define the price drop ratio as follows:

$$
\begin{aligned}
&\text{Price Drop Ratio}_i = \frac{P_{i,0} - P_{i,1}}{P_{\text{Hard Fork/ Airdrop from = i}}} \\
&\text{where: } P_0 = \text{Closing price one day before the snapshot date.} \\
&\text{where: } P_1 = \text{Closing price on the snapshot day.} \\
&\text{where: } P_{\text{Hard Fork/ Airdrop}} = \text{Closing price of the distributed coin.}
\end{aligned} \tag{9}
$$

The numerator in Eq. 9 represents the daily price change of the parent coin i. The price change is measured from one day prior to the snapshot date to the snapshot date. The denominator in Eq. 9 represents the first closing price of the forked or airdropped coin to holders of the parent coin i. In some cases, the value of the distributed coin is not determined at the snapshot date. If this is the case, I take the closing price of the distributed coin at the first trading day.

Table V provides descriptive statistics of the price drop ratio for four different sample. Panel A in Table V reports summary statistics for successful hard forks and airdrops. That is, the distributed coins obtained a positive value at some point in time. The median price of the distributed coins ($P_{\text{Hard Fork}}$) equals \$1.5. However, there exists considerable variation across the prices of the distributed coins. The value of the distributed coins range from close to \$0 to \$942. The median price drop ratio equals 0.187. This number suggests that the price drop at the payout date is much lower than the value of the distributed coin. This result remains relatively unchanged, when I exclude hard forks and airdrops during the crisis period from December 31st, 2017 to March 1st, 2018. Panel B shows that the median price drop ratio equals 0.192. Panel C shows that the median value of the distributed coin equals \$0. In Panel D, I report summary statistics for a subsample where the price drop ratio lies within 0 and 1. For this subsample, the median (mean) price drop ratio is 0.3 (0.34).

In short, the results suggest that free money in the cryptocurrency market exists. This is reflected in a much lower price drop of the parent coin relative to the distributed value through hard forks and airdrops. I argue that due to the tax absence in cryptocurrency markets, market frictions can not fully explain this inefficiency. My result has significant implications for investors. Investors that do not claim the hard forked coin, are unaware that they own it, or simply loose dominance over the new coin miss out on profit. More importantly, an investor who never claims the distributed coin lose through hard forks and airdrops. This is due to the negative abnormal return of the parent coin at the snapshot date.

Table V Price Drop Analysis

$P_{\text{Hard Fork}}$ denotes the price of the hard forked or airdropped coin at the snapshot date. If not available, it equals the closing price at the first trading day of the new coin. P_0 denotes the closing price one day before the snapshot date. P_1 denotes the closing price at the snapshot date. I consider four samples. Panel A reports descriptive statistics on the successful sample. The successful sample includes all coins with a positive value at some point in time. In Panel B I additionally exclude the crisis period from 2017-12-31 to 2018-03-01. Panel C reports descriptive statistics for the whole sample. Panel D only includes hard forks and airdrops, where the $\frac{P_0-P_1}{P_{\text{Hard Fork}}}$ ratio lies between 0 and 1.

	Median	St.Dev.	Minimum	Maximum
Panel A: Successful Coins; N=32				
$P_{\text{Hard Fork}}$	1.497	187.739	0.005	942.217
$P_0 - P_1$	0.061	365.923	-1291.8	1321.74
$\frac{P_0-P_1}{P_{\text{Hard Fork}}}$	0.187	5290.355	-1174.352	29828.134
Panel B: Non-Crisis Sample; N=25				
$P_{\text{Hard Fork}}$	0.602	199.648	0.005	942.217
$P_0 - P_1$	0.111	142.89	-336.6	403.68
$\frac{P_0-P_1}{P_{\text{Hard Fork}}}$	0.192	5980.855	-1174.352	29828.134
Panel C: All Coins; N=67				
$P_{\text{Hard Fork}}$	0	133.169	0	942.217
$P_0 - P_1$	0.01	452.531	-1324.899	1321.74

	Median	Mean	St.Dev.
Panel D: $\frac{P_0-P_1}{P_{\textbf{Hard Fork}}} \in$ [0;1]; N=8			
$P_{\text{Hard Fork}}$	30.562	76.718	127.786
$P_0 - P_1$	8.184	31.897	54.814
$\frac{P_0-P_1}{P_{\text{Hard Fork}}}$	0.301	0.34	0.249

IX. Conclusion

I examine cryptocurrency price reactions to the announcement and distribution of hard forked and airdropped coins. The announcement date equals the day when the airdrop or hard fork is announced in an online post. The snapshot date refers to the last day when a newly forked coin or airdrop can be claimed by investors. I exclusively focus on the price reaction of the parent coin. Thereby, I answer if hard forks and airdrops are equivalent to free money.

The empirical results provide a uniform and consistent picture. The announcement of a hard fork or airdrop has no significant impact on cryptocurrency prices. Even when focusing on different subsamples, this finding remains consistent. I argue that this result does not suggest that cryptocurrency markets are inefficient. It is the opposite. Positive and significant abnormal returns at the announcement date suggest a perpetuum mobile. Infinite value could be created by splitting Bitcoin into infinite chains. This would result in an infinite price increase of Bitcoin. Therefore, no positive abnormal return at the announcement date is consistent with efficient markets.

I am turning to the snapshot date, which equals the last day the new coin can be claimed. At the snapshot date, the prices of the corresponding parent coin immediately decrease by 4.65%. The cumulative average abnormal return over the 5-day post snapshot date equals -12.29%. The CAARs are consistently negative across all event windows for close to 70% of the sample coins. My result remains robust even when using the constant return or market-adjusted model and demonstrate market efficiency.

Finally, I compare the price drop of the parent coin to the amount paid out. I document that the median ratio between ex-snapshot price drop and price of the distributed coin equals 0.187. In other words, the parent coin drops by much less than the value of the distributed coin.

My findings have significant implications for the understanding of cryptocurrency markets. First, hard forks and airdrops are, to some extend, magic money-making machines. The price drop of the parent coin is much lower than the value paid out through hard forks and airdrops. Interestingly, this can also have negative consequences for cryptocurrency investors. At the payout date, the price of the parent coin significantly decreases. Therefore, hard forks and airdrops have eroded the performance of cryptocurrency investors, who have never claimed the newly distributed cryptocurrencies.

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X. Appendix

Figure A1. CAR of Bitcoin around the Bitcoin Cash Hard Fork

Bitcoin Cash forked from Bitcoin on August 1^{st}, 2017 1:16pm UTC. At that date, each holder of a bitcoin received an additional and newly created bitcoin cash. At the snapshot date, the price of a bitcoin fell by 5.5%, which equals a price drop of $157.08. Bitcoin cash immediately started trading around $294.60 and closed at $380.01 on August 1^{st}, 2017. This figure shows cumulative abnormal returns of bitcoin 10 days prior and 5 days following the snapshot date. The CAR of BTC equals the cumulated sum of the abnormal returns. Abnormal returns are calculated using the market model, and market adjusted model.

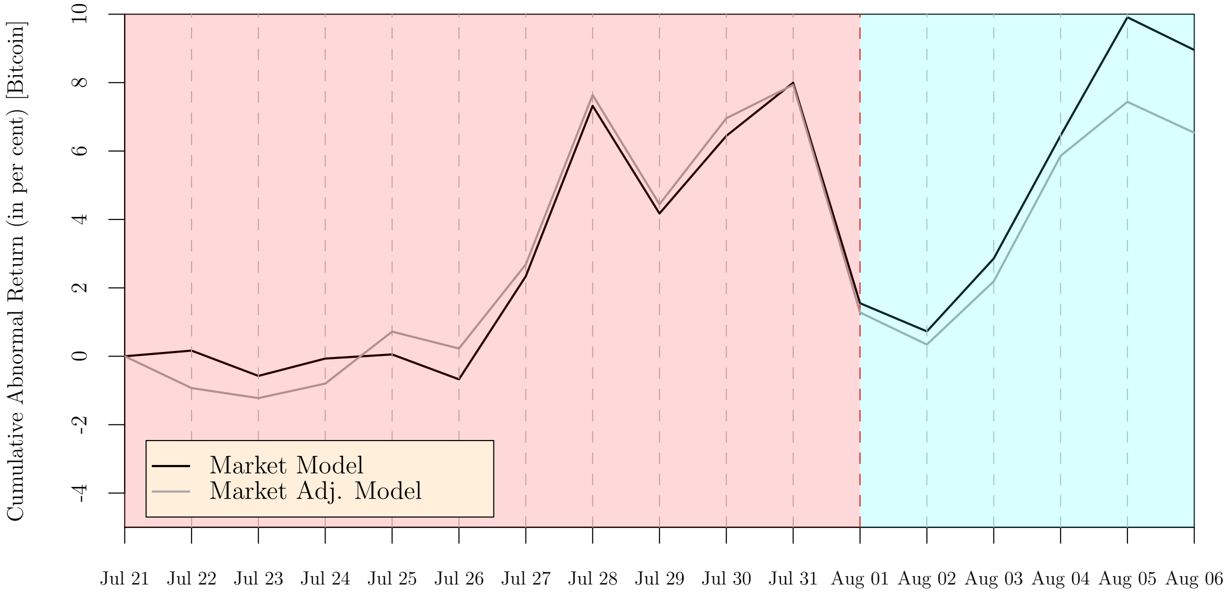

Table A1 List of all Hard Forks and Airdrops

This table provides a comprehensive list of all hard forks and airdrops in my sample. The parent coin refers to the cryptocurrency must hold to obtain the forked or airdropped coin. The fork name column refers to the newly distributed. The ratio column reports how many new coins are received for holding 1 parent coin. The event type indicates if the event is a hard fork or airdrop. The last three column report announcement date, snapshot date, and at which block hight the snapshot took place. Note that the link to the sources can be found by clicking on the announcement or snapshot date.

Parent Name	Parent Ticker	Fork Name	Fork Ticker	Ratio	Block Height	Announcement Date	Snapshot Date	Block hight
Bitcoin	BTC	CLAMs	CLAM	4.6 for 1	Passive Airdrop	2014-03-24	2014-05-12	300377
Bitcoin	BTC	Qeditas	QED	1 for 1	Passive Airdrop	2015-03-21	2015-03-30	350000
Bitcoin	BTC	Stellar	XLM	191 for 1	Passive Airdrop	2016-04-26	2016-06-04	419168
Bitcoin	BTC	Obyte	GBYTE	1.865 for 1	Registered Airdrop	2016-09-05	2016-12-25	444942
Bitcoin	BTC	Stellar	XLM	986 for 1	Passive Airdrop	2017-03-28	2017-06-26	472879
Bitcoin	BTC	Bitcoin Cash	BCH	1 for 1	Hardfork	2017-07-22	2017-08-01	478558
Bitcoin	BTC	Bitcoin Gold	BTG	1 for 1	Hardfork	2017-10-18	2017-10-24	491407
Bitcoin	BTC	BitCore	BTX	0.5 for 1	Passive Airdrop	2017-04-23	2017-11-02	492820
Bitcoin	BTC	Bitcoin Diamond	BCD	10 for 1	Hardfork	2017-11-22	2017-11-24	495866
Bitcoin	BTC	Bitcoin Platinum	BTP	1 for 1	Hardfork	2017-10-25	2017-12-10	498577
Bitcoin	BTC	Bitcoin Hot	BTH	100 for 1	Hardfork	2017-12-03	2017-12-12	498848
Bitcoin	BTC	Bitcoin Pay	BTP	10 for 1	Hardfork	2017-11-29	2017-12-15	499345
Bitcoin	BTC	Bitcoin Faith	BTF	1 for 1	Hardfork	2017-12-12	2017-12-18	500000
Bitcoin	BTC	BitEthereum	BITE	4 for 1	Hardfork	2017-10-26	2017-12-20	500283
Bitcoin	BTC	Bitcoin God	GOD	1 for 1	Hardfork	2017-12-07	2017-12-27	501225
Bitcoin	BTC	Bitcoin Cash Plus	BCP	1 for 1	Hardfork	2017-11-14	2017-12-28	501407
Bitcoin	BTC	Bitcoin Nano	BN	1,000 for 1	Hardfork	2017-12-23	2017-12-31	501888
Bitcoin	BTC	Bitcoin Boy	BCB	100 for 1	Hardfork	2017-11-18	2018-01-02	502233
Bitcoin	BTC	United Bitcoin	UBTC	1 for 1	Hardfork	2017-12-18	2018-01-03	502315
Bitcoin	BTC	BitVote	BTV	1 for 1	Hardfork	2018-01-01	2018-01-19	505050
Bitcoin	BTC	Bitcoin Interest	BCI	1 for 1	Hardfork	2017-12-19	2018-01-20	505083
Bitcoin	BTC	Bitcoin Atom	BCA	1 for 1	Hardfork	2017-12-04	2018-01-24	505888
Bitcoin	BTC	Bitcoin Pro	BTP	1 for 1	Hardfork	2018-01-28	2018-01-31	506984
Bitcoin	BTC	Bitcoin Hush	BTCH	1 for 1	Passive Airdrop	2018-01-26	2018-02-01	507089
Bitcoin	BTC	Bitcoin 2	BTC2	1 for 1	Hardfork	2018-02-03	2018-02-05	507850
Bitcoin	BTC	Bitcoin Dollar	BTD	1 for 1	Hardfork	2018-01-22	2018-02-28	511565
Bitcoin	BTC	Classic Bitcoin	CBTC	10,000 for 1	Hardfork	2018-03-10	2018-04-01	516095
Bitcoin	BTC	Smart Bitcoin	SBC	1 for 1	Hardfork	2018-04-21	2018-04-26	520000
Bitcoin	BTC	Fox BTC	FBTC	1 for 1	Hardfork	2018-04-15	2018-04-30	520419
Bitcoin	BTC	MicroBitcoin	MBC	10,000 for 1	Hardfork	2018-05-19	2018-05-29	525000
Bitcoin	BTC	Bitcoin Dao	BTD	1 for 1	Hardfork	2018-05-06	2018-07-12	531650

Table A1 List of all Hard Forks and Airdrops

(continued)

Parent Name	Parent Ticker	Fork Name	Fork Ticker	Ratio	Event Type	Announcement Date	Snapshot Date	Block Height
Bitcoin	BTC	Bitcoin RM	BCRM	1 for 1	Registered Airdrop	2018-07-24	2018-08-21	537746
Bitcoin	BTC	Bitcoin Zero	BZX	1 for 1	Hardfork	2018-06-05	2018-08-31	539360
Bitcoin	BTC	AnonymousBitcoin	ANON	1 for 1	Hardfork	2018-05-15	2018-11-10	540870
Bitcoin	BTC	Bitcoin Air	XAP	1 for 1	Hardfork	2018-10-04	2018-11-22	551000
Bitcoin	BTC	Bitcoin Post-Quantum	BPQ	1 for 1	Hardfork	2018-12-10	2018-12-23	555000
Bitcoin	BTC	MimbleWimbleCoin	MWC	40 for 1	Registered Airdrop	2019-02-02	2019-07-19	586081
Bitcoin	BTC	Hex	HEX	10,000 for 1	Passive Airdrop	2018-07-25	2019-12-02	606227
Litecoin	LTC	CLAMs	CLAM	4.6 for 3	Passive Airdrop	2014-05-09	2014-05-12	300377
Litecoin	LTC	Litecoin Cash	LCC	10 for 1	Hardfork	2018-02-03	2018-02-18	1371111
Litecoin	LTC	Litecoin Private	LTCP	1 for 1	Hardfork	2018-02-26	2018-04-21	1407299
Peercoin	PPC	Bitcoin Air	XAP	0.05 for 1	Passive Airdrop	2018-10-04	2018-11-22	551000
Nxt	NXT	Ignis	IGNIS	0.5 for 1	Passive Airdrop	2017-08-11	2017-12-28	1636363
Dogecoin	DOGE	CLAMs	CLAM	4.6 for 2	Passive Airdrop	2014-05-09	2014-05-12	300377
Dogecoin	DOGE	Dogethereum	DOGX	0.0001 for 1	Hardfork	2018-02-19	2018-03-26	2151868
Dash	DASH	SAFE	SAFE	1 for 1	Hardfork	2018-01-11	2018-01-20	807085
Einsteinium	EMC2	MIL Coin	MIL	3 for 1	Hardfork	2019-03-25	2019-06-25	2402717
Monero	XMR	Monero Classic	XMC	1 for 1	Hardfork	2018-04-04	2018-04-06	1546000
Monero	XMR	MoneroV	XMV	10 for 1	Hardfork	2018-02-14	2018-04-30	1564965
SpreadCoin	SPR	BitcoinSpread	NA	1 for 1	Hardfork	2017-12-31	2018-01-31	2200
Ethereum	ETH	Ethereum Classic	ETC	1 for 1	Hardfork	2016-06-17	2016-07-20	1920000
Ethereum	ETH	EtherGold	ETG	1 for 1	Hardfork	2017-10-13	2017-12-14	4730666
Ethereum	ETH	Ether Zero	ETZ	1 for 1	Hardfork	2017-12-18	2018-01-19	4936270
Ethereum	ETH	Ethereum Crystal	CRT	1 for 1	Hardfork	2018-02-28	2018-03-22	5300000
Steem	STEEM	Hive	HIVE	1 for 1	Hardfork	2020-03-17	2020-03-20	41818752
Neo	NEO	Ontology	ONT	0.2 for 1	Passive Airdrop	2017-11-27	2018-03-01	1974823
Zcash	ZEC	Ycash	YEC	1 for 1	Hardfork	2019-04-11	2019-07-18	570000
Zclassic	ZCL	ZenCash	ZEN	1 for 1	Hardfork	2017-03-09	2017-05-18	110000
Zclassic	ZCL	Bitcoin Private	BTCP	1 for 1	Hardfork	2017-12-19	2018-02-28	272991
Zclassic	ZCL	AnonymousBitcoin	ANON	2 for 1	Hardfork	2018-05-14	2018-11-10	382307
Bitcoin Cash	BCH	Bitcoin Candy	CDY	1,000 for 1	Hardfork	2018-01-09	2018-01-13	512666
Bitcoin Cash	BCH	Bitcoin Class	BCS	1 for 1	Hardfork	2018-04-24	2018-04-29	528000
Bitcoin Cash	BCH	Bitcoin SV	BSV	1 for 1	Hardfork	2018-08-16	2018-11-15	556766
Achain	ACT	Abitcoin	ABTC	1 for 1	Hardfork	2018-01-02	2018-01-13	1498888

Table A1 List of all Hard Forks and Airdrops

(continued)

Parent Name	Parent Ticker	Fork Name	Fork Ticker	Ratio	Event Type	Announcement Date	Snapshot Date	Block Height
Electroneum	ETN	Electronero	ETNX	1 for 1	Hardfork	2018-04-23	2018-05-29	307000
Ignis	IGNIS	Coalculus	COAL	1 for 1	Passive Airdrop	2019-12-05	2019-12-09	1035000
Grimm	GRIMM	Defis	XGM	1 for 1	Hardfork	2020-05-10	2020-05-30	430000

Table A2 Successful Coins: Average Abnormal Returns around Announcement Date

This table reports average abnormal returns (AAR) and cumulative average abnormal returns (CAAR) in per cent around the event date. The event date equals the announcement date of the hard fork, and the event window ranges from 10 trading days before through 5 trading days after the event. Abnormal returns are estimated with three different models. Panel A estimated abnormal returns using the market model. Panel B (C) is based on the constant return model (market adjusted model). The total number of events equals 32. Importantly, I am only considering hard forks and airdrops that were successful. That is, that the airdropped or forked coin were traded at least at one point in time prior or after the announcement date. Test statistics are reported in two different ways to account for event-date clustering and event-induced variance (t-test, Boehmer et al. (1991)). *, **, *** Denote statistical significance at 10, 5 and 1 per cent, respectively.

	Panel A: Market Model				Panel B: Constant Return Model				Panel C: Market Adj. Model			
Day	AAR	CAAR	t-stat	Boehmer Masumeci Paulsen statistics	AAR	CAAR	t-stat	Boehmer Masumeci Paulsen statistics	AAR	CAAR	t-stat	Boehmer Masumeci Paulsen statistics
-10	2.24	2.24	(1.38)	(1.03)	1.21	1.21	(0.67)	(0.15)	2.41	2.41	(1.44)	(0.94)
-9	1.53	3.77	(1.57)	(0.96)	1.05	2.26	(0.73)	(0.93)	1.73	4.14	(1.81)*	(1.1)
-8	-0.92	2.85	(-1.14)	(0.21)	-0.47	1.79	(-0.42)	(-0.13)	-0.78	3.36	(-0.95)	(0.22)
-7	1.54	4.39	(0.83)	(1)	2.61	4.40	(1.21)	(1.57)	1.76	5.13	(0.98)	(1.23)
-6	2.29	6.68	(0.99)	(1.54)	2.76	7.15	(1.16)	(1.27)	2.40	7.53	(1.05)	(1.52)
-5	-1.35	5.32	(-1.44)	(-0.48)	-2.00	5.15	(-1.1)	(-0.68)	-1.34	6.19	(-1.39)	(-0.53)
-4	-0.38	4.94	(-0.55)	(-0.82)	-0.26	4.90	(-0.21)	(-0.2)	-0.13	6.06	(-0.17)	(-0.66)
-3	-1.23	3.71	(-1.89)*	(-0.91)	-1.00	3.90	(-1.16)	(-0.64)	-0.82	5.24	(-1.36)	(-0.5)
-2	-0.29	3.42	(-0.5)	(0.68)	0.17	4.07	(0.15)	(0.66)	-0.20	5.04	(-0.34)	(0.4)
-1	0.07	3.49	(0.07)	(0.67)	0.60	4.67	(0.47)	(0.56)	0.37	5.41	(0.35)	(0.78)
0	0.71	4.21	(0.55)	(0.16)	1.32	5.99	(0.83)	(0.89)	1.07	6.48	(0.86)	(0.36)
1	0.33	4.54	(0.13)	(0.4)	0.11	6.10	(0.04)	(0.34)	0.62	7.10	(0.26)	(0.55)
2	0.79	5.33	(0.91)	(1.1)	-0.31	5.80	(-0.17)	(0.24)	0.87	7.97	(0.94)	(0.99)
3	-1.67	3.65	(-1.2)	(-0.21)	-1.45	4.34	(-0.73)	(-0.45)	-1.16	6.81	(-0.86)	(0.11)
4	2.06	5.71	(0.84)	(-0.39)	1.13	5.47	(0.4)	(-0.41)	2.41	9.22	(1)	(-0.1)
5	2.48	8.19	(0.96)	(0.8)	2.06	7.53	(0.8)	(0.79)	3.02	12.24	(1.19)	(1.02)

Table A3 Successful Coins: Average Abnormal Returns around Snapshot Date

This table reports average abnormal returns (AAR) and cumulative average average abnormal returns (CAAR) in per cent around the event date. The event date equals the snapshot date of the hard fork or airdrop. The event window ranges from 10 trading days before through 5 trading days after the event. Abnormal returns are estimated with three different models. Panel A estimated abnormal returns using the market model. Panel B (C) is based on the constant return model (market adjusted model). The total number of events equals 32. I exclusively focus on successful events, whereby a coin is distributed that obtains a positive value at any point in the sample period. Test statistics are reported in two different ways to account for event-date clustering and event-induced variance (t-test, Boehmer et al. (1991). *, **, *** denote statistical significance at 10, 5 and 1 per cent, respectively.

	Panel A: Market Model				Panel B: Constant Return Model				Panel C: Market Adj. Model			
Day	AAR	CAAR	t-stat	Boehmer Masumeci Paulsen statistics	AAR	CAAR	t-stat	Boehmer Masumeci Paulsen statistics	AAR	CAAR	t-stat	Boehmer Masumeci Paulsen statistics
-10	0.57	0.57	(0.82)	(1.37)	0.65	0.65	(0.62)	(0.86)	0.79	0.79	(1.04)	(1.36)
-9	-0.65	-0.08	(-1.17)	(-0.43)	-1.36	-0.71	(-1.38)	(-0.8)	-0.18	0.61	(-0.32)	(-0.01)
-8	0.90	0.82	(0.59)	(0.48)	-1.83	-2.54	(-0.8)	(-1.01)	0.94	1.55	(0.6)	(0.45)
-7	-0.06	0.76	(-0.06)	(-0.55)	-0.12	-2.67	(-0.09)	(0.49)	0.22	1.77	(0.22)	(-0.19)
-6	0.55	1.31	(0.49)	(0.6)	-1.17	-3.84	(-0.97)	(-0.69)	0.58	2.35	(0.61)	(0.92)
-5	1.37	2.67	(1.12)	(2.14)**	0.67	-3.16	(0.4)	(0.53)	1.92	4.27	(1.44)	(2.46)**
-4	-0.14	2.53	(-0.15)	(-0.23)	-1.52	-4.69	(-0.91)	(-0.46)	0.30	4.57	(0.34)	(0.29)
-3	-0.69	1.85	(-0.98)	(-0.51)	-0.88	-5.57	(-0.71)	(-0.22)	-0.32	4.25	(-0.45)	(-0.11)
-2	0.35	2.20	(0.14)	(0.74)	0.96	-4.61	(0.37)	(0.8)	0.91	5.16	(0.37)	(1.06)
-1	0.73	2.93	(0.59)	(1.47)	0.20	-4.41	(0.11)	(0.45)	0.97	6.13	(0.77)	(1.56)
0	-6.70	-3.77	(-2.33)**	(-2.87)***	-7.06	-11.48	(-2.21)**	(-2.17)**	-6.75	-0.62	(-2.37)**	(-2.88)***
1	-3.75	-7.52	(-1.76)*	(-2.58)**	-2.80	-14.27	(-1.36)	(-0.87)	-3.24	-3.86	(-1.66)	(-2.33)**
2	0.31	-7.20	(0.28)	(0.58)	-0.31	-14.58	(-0.23)	(0.55)	0.53	-3.33	(0.51)	(0.89)
3	-0.45	-7.65	(-0.52)	(-0.92)	0.15	-14.43	(0.15)	(0.21)	0.20	-3.13	(0.21)	(0.07)
4	-1.93	-9.58	(-2.4)**	(-1.98)*	-2.07	-16.50	(-1.84)*	(-1.31)	-1.70	-4.83	(-2.53)**	(-2.14)**
5	-1.46	-11.04	(-1.29)	(-0.82)	-2.44	-18.94	(-1.72)*	(-1.88)*	-1.04	-5.87	(-0.94)	(-0.37)

Figure A2. Successful Coins: CAAR around Snapshot Date

This figure depicts cumulative average abnormal returns (CAAR) in per cent around the event date. I only consider successful hard forks or airdrops, which have a positive value at some point in time. The total number of events equals 32. The event date equals the snapshot date of the hard fork or airdrop, and the event window ranges from 10 trading days before through 5 trading days after the event. Note that the day -11 equals zero and is added for visualization purposes. Abnormal returns are estimated with three different models. The black (blue) line estimates abnormal returns using the market model (constant return model). In dark gray, I depict CAARs based on the market adjusted model. The snapshot date is at day 0 and illustrated by a vertical, dashed red line.

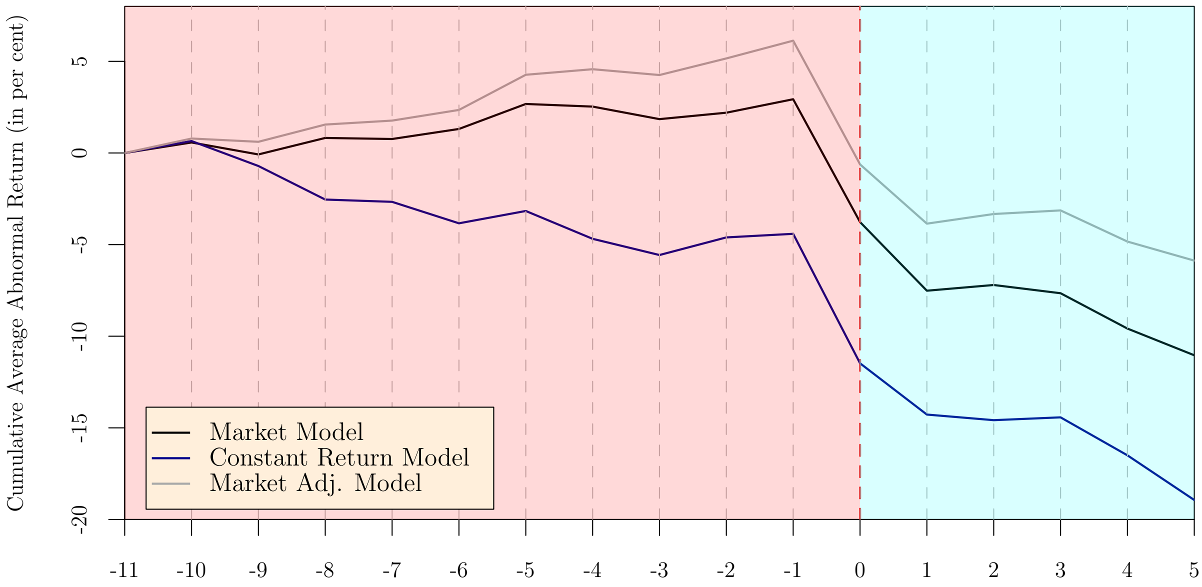

Table A4 Unsuccessful Coins: Average Abnormal Returns around Announcement Date

This table reports average abnormal returns (AAR) and cumulative average abnormal returns (CAAR) in per cent around the event date. The event date equals the announcement date of the hard fork, and the event window ranges from 10 trading days before through 5 trading days after the event. Abnormal returns are estimated with three different models. Panel A estimated abnormal returns using the market model. Panel B (C) is based on the constant return model (market adjusted model). The total number of events equals 35. Importantly, I am only considering hard forks and airdrops that were unsuccessful. That is, that the airdropped or forked coin were never traded on an exchange after the announcement date. Test statistics are reported in two different ways to account for event-date clustering and event-induced variance (t-test, Boehmer et al., 1991. *, **, *** Denote statistical significance at 10, 5 and 1 per cent, respectively.

	Panel A: Market Model				Panel B: Constant Return Model				Panel C: Market Adj. Model			
Day	AAR	CAAR	t-stat	Boehmer Masumeci Paulsen statistics	AAR	CAAR	t-stat	Boehmer Masumeci Paulsen statistics	AAR	CAAR	t-stat	Boehmer Masumeci Paulsen statistics
-10	0.94	0.94	(0.55)	(-0.43)	0.31	0.31	(0.15)	(-0.61)	1.25	1.25	(0.75)	(-0.03)
-9	0.44	1.38	(0.36)	(-0.58)	1.14	1.45	(0.86)	(0.99)	0.35	1.60	(0.32)	(-0.65)
-8	2.85	4.23	(1.95)*	(1.72)*	2.58	4.03	(1.44)	(1.22)	2.80	4.40	(2.04)**	(1.78)*
-7	-0.05	4.18	(-0.08)	(-0.26)	1.09	5.12	(1.18)	(1.23)	0.07	4.48	(0.13)	(-0.22)
-6	0.16	4.34	(0.14)	(0.54)	0.65	5.77	(0.45)	(0.71)	0.15	4.63	(0.13)	(0.63)
-5	-1.22	3.12	(-1.43)	(-0.43)	-0.90	4.87	(-0.64)	(-0.34)	-1.08	3.55	(-1.22)	(-0.15)
-4	-0.98	2.15	(-1.36)	(-1.44)	-1.29	3.58	(-1.05)	(-1.76)*	-0.67	2.88	(-0.82)	(-0.84)
-3	-0.57	1.58	(-0.92)	(-1.27)	-0.71	2.87	(-0.61)	(-0.42)	-0.77	2.11	(-1.22)	(-1.23)
-2	0.05	1.63	(0.07)	(-0.07)	0.82	3.69	(0.84)	(0.52)	0.34	2.45	(0.5)	(0.38)
-1	0.87	2.49	(1.22)	(1.12)	0.64	4.34	(0.48)	(0.84)	0.93	3.39	(1.28)	(1.02)
0	0.33	2.82	(0.18)	(0.15)	2.32	6.66	(1.12)	(1.26)	0.57	3.95	(0.32)	(0.18)
1	0.97	3.79	(0.6)	(-0.55)	1.03	7.68	(0.56)	(0)	1.12	5.08	(0.7)	(-0.21)
2	0.70	4.49	(0.31)	(-0.91)	0.51	8.20	(0.21)	(-0.17)	0.71	5.79	(0.32)	(-0.74)
3	0.75	5.24	(0.81)	(1.04)	1.47	9.67	(1.09)	(0.94)	0.64	6.43	(0.75)	(1.08)
4	2.19	7.43	(1.53)	(1.72)*	2.07	11.73	(1.09)	(0.76)	2.33	8.76	(1.68)	(1.93)*
5	-1.50	5.94	(-2.45)**	(-2.52)**	-1.00	10.74	(-1.25)	(-1.23)	-1.39	7.36	(-2.25)**	(-2.29)**

Table A5 Unsuccessful Coins: Average Abnormal Returns around Snapshot Date

This table reports average abnormal returns (AAR) and cumulative average average abnormal returns (CAAR) in per cent arount the event date. The event date equals the snapshot date of the hard fork, and the event window ranges from 10 trading days before through 5 trading days after the event. Abnormal returns are estimated with three different models. Panel A estimated abnormal returns using the market model. Panel B (C) is based on the constant return model (market adjusted model). The total number of events equals 35. Importantly, I am only considering hard forks and airdrops that were unsuccessful. That is, that the airdropped or forked coin were never traded on an exchange after the announcement date. Test statistics are reported in two different ways to account for event-date clustering and event-induced variance (t-test, Boehmer et al. (1991)). *, **, *** Denote statistical significance at 10, 5 and 1 per cent, respectively.

	Panel A: Market Model				Panel B: Constant Return Model				Panel C: Market Adj. Model			
Day	AAR	CAAR	t-stat	Boehmer Masumeci Paulsen statistics	AAR	CAAR	t-stat	Boehmer Masumeci Paulsen statistics	AAR	CAAR	t-stat	Boehmer Masumeci Paulsen statistics
-10	-1.89	-1.89	(-2.16)**	(-2.02)*	-2.10	-2.10	(-2.26)**	(-2.12)**	-1.74	-1.74	(-2.24)**	(-1.96)*
-9	2.02	0.13	(0.89)	(0.66)	1.86	-0.24	(0.75)	(0.51)	2.18	0.43	(0.95)	(0.84)
-8	-1.39	-1.26	(-1.55)	(-0.52)	-1.16	-1.40	(-0.85)	(-0.4)	-0.98	-0.54	(-1.2)	(-0.05)
-7	0.69	-0.57	(0.55)	(-0.96)	1.17	-0.23	(0.78)	(0.12)	0.97	0.43	(0.76)	(-0.66)
-6	0.89	0.32	(0.99)	(0.2)	0.76	0.52	(0.58)	(0.34)	0.94	1.36	(1.07)	(-0.04)
-5	-0.71	-0.38	(-0.94)	(0.2)	-1.26	-0.73	(-1.03)	(-0.24)	-0.42	0.94	(-0.58)	(0.32)
-4	-0.19	-0.57	(-0.17)	(-0.97)	0.62	-0.11	(0.49)	(0.74)	-0.16	0.78	(-0.15)	(-1)
-3	-1.28	-1.85	(-1.09)	(-0.6)	-1.80	-1.91	(-1.08)	(-0.87)	-0.89	-0.11	(-0.79)	(-0.28)
-2	-0.58	-2.42	(-0.59)	(-1.75)*	-1.27	-3.18	(-0.85)	(-1.23)	-0.19	-0.30	(-0.19)	(-0.88)
-1	-1.80	-4.22	(-2.33)**	(-1.97)*	-1.61	-4.80	(-1.28)	(-0.93)	-1.76	-2.07	(-2.26)**	(-2.03)*
0	-2.77	-6.99	(-3.07)***	(-2.57)**	-2.25	-7.05	(-2.13)**	(-1.66)	-2.44	-4.51	(-2.84)***	(-2.1)**
1	-3.44	-10.43	(-1.94)*	(-2.81)***	-4.13	-11.18	(-2.25)**	(-2.13)**	-3.40	-7.91	(-2.05)**	(-2.85)***
2	-1.94	-12.37	(-2.66)**	(-2.35)**	-3.00	-14.19	(-2.34)**	(-2.15)**	-1.59	-9.49	(-2.11)**	(-2)*
3	-1.34	-13.71	(-1.13)	(-0.87)	-1.79	-15.98	(-1.03)	(-0.27)	-1.18	-10.67	(-1.11)	(-1.03)
4	-1.41	-15.11	(-2.15)**	(-1.87)*	-3.77	-19.75	(-3.11)***	(-2.7)**	-1.24	-11.91	(-2.04)**	(-1.55)
5	0.13	-14.98	(0.15)	(-0.42)	0.28	-19.47	(0.19)	(0.38)	0.23	-11.68	(0.23)	(-0.64)