THE ELECTRICITY INTENSITY OF BITCOIN MINING

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Overview

Since the first bitcoin transaction (genesis block) on January 3rd, 2009 the digital currency bitcoin evolved from belittled peer-to-peer "nerd money" over a payment method on illegal dark web marketplaces (e.g, Silk Road) into a global investment hype. Along with, and driven by that development, Bitcoin prices surged from zero in 2009 to roughly $15,200 at bitcoin's ninth birthday celebration on January 3rd, 2018. While bitcoin has become significantly closer to be accepted by mainstream investors, the electricity intensity of bitcoin mining is increasingly criticized.

Bitcoin is organized as an anonymous peer-to-peer payment network of computers without any central controlling authority. Each new transaction of bitcoins among users is timestamped, network-wide (i.e. by each peer) recorded and grouped into so called 'blocks'. The blocks are each cryptographically linked to predecessor transactions up to the first (genesis) block. The procedure creates an irreversible 'chain of blocks': the blockchain. The cryptographical link between the blocks in the chain is based on a so called 'proof-of-work' (PoW) algorithm, which is an *intentionally* computing-intensive mathematical puzzle (hash function) to be solved in order to protect the chain from manipulation and attacks. Peers are incentivized to participate in the network and provide their computing resources by the issuance of Bitcoins, which is referred to as mining reward. Before a new block is added to the chain, the hash function has to be solved. Peers or miners compete for the reward and whichever miner first successfully mines a new block, i.e. solves hash function first, receives the mining reward in form of Bitcoins.

The 'proof-of-work' algorithm is considered to provide a high security to the network, because the chain can only be manipulated if the complete 'work' is redone and associated costs are considered to be virtually prohibitive. The flip side of 'proof-of-work', however, is its electricity intensity. The precise electricity consumption of the bitcoin network, however, is subject of debate and estimates vary by several orders of magnitudes.

This is our motivation for building a model, which is intended to simulate the electricity use of the bitcoin mining industry over time. The model building is still in progress. This abstract shows the first modelling results with respect to marginal costs of bitcoin mining for different generations of mining hardware. These results serve to simulate the technological evolution of mining hardware stock, which, in turn, determines the overall electricity use.

Methods

We developed and parametrized a bottom-up model, which simulates the marginal costs of available and legacy bitcoin mining hardware. The marginal costs are determined by electrical efficiency of the mining hardware and the electricity prices. The marginal costs estimates are used to model the evolution of the mining hardware stock as a function of profitability, i.e. the expected contribution margin of mining. This approach is required in order to compensate for the lack of shipments statistics on mining hardware. It also allows us to estimate mothballing or decommissioning of mining hardware based on economic criteria rather than equipment aging.

Results

Figure 1 exemplifies one key output of our model. The chart shows the bitcoin prices from January, 2014 to January 2018 as well as the model results for the marginal costs of several mining hardware generations from Bitmain, a leading mining hardware producer and miner. The evolution of the marginal costs between hardware generations reflects technological progress (e.g., from AntMiner S1 to S2), whereas the increase of marginal costs within a hardware generation reflects the increasing 'mining difficulty' and the changes in the mining reward inherent to the bitcoin protocol. As can be seen, under historic bitcoin prices and the assumed electricity prices of 0.1 USD/kWh, hardware had only a short period to recover investment cost. For example, the contribution margin for the "AntMiner S2" is less one year positive and, hence, it would have been rational to at least mothball the miner already after roughly 9 months of operation. The chart also illustrates, that the high bitcoin prices since December 2017 result in positive contribution margins of older, less efficient miners that weren't competitive during most of the year 2016 and 2017. Hence, it is plausible to assume that the bitcoin price rally may induce a recommissioning of older and less efficient mining hardware, which in turn leads to an overall less efficient system and higher electricity demand.

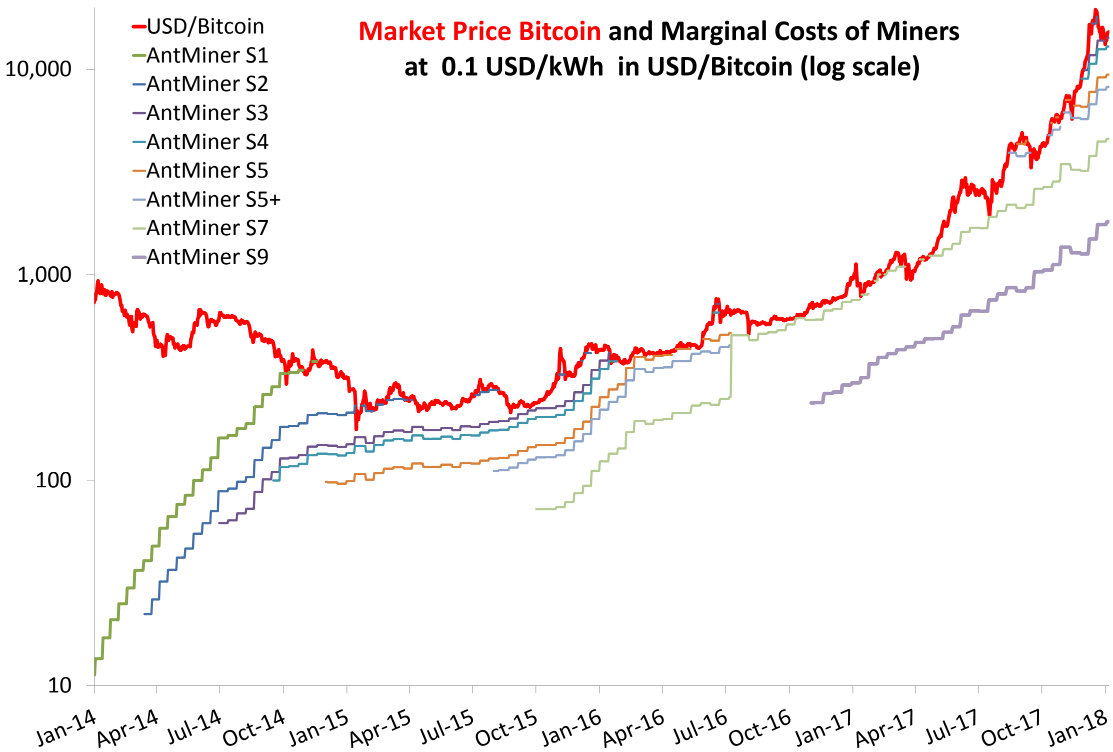

Figure 1: Bitcoin price and marginal costs of several mining hardware generations. Marginal cost curves begin at the hardware release date and are only plotted if their marginal costs are lower than the market price of bitcoins.

Conclusions

The evolution of the bitcoin ecosystem since 2009 is impressive in many respects. The cryptocurrency bitcoin was the first implementation blockchain system and thereby constitutes the nucleus and inspiration of thousands of other cryptocurrency- and/or blockchain-projects. Bitcoin grew from a subcultural phenomenon to globally recognized investment object. The backbone of the bitcoin ecosystem, the peer-to-peer network of miners, evolved into a significant data center industry. The electricity requirements of the mining industry, however, increasingly raise public attention and concern. Surprisingly, the estimates on the direct electricity impact of bitcoins vary widely and associated uncertainties are huge. While our model building is still an ongoing research, the presented results already indicate the complexity of the mining market and its evolution with respect to electricity demand.

References