An Equilibrium Valuation of Bitcoin and Decentralized Network Assets: Non-Technical Summary*

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The rapid growth of Bitcoin over the last decade has sparked an intense debate in the investment community and policy circles. Two questions are at the center of this debate. What type of asset is bitcoin? What is its fundamental value? Opinions diverge greatly on whether bitcoins are a currency, a commodity, a security, for example; but a prominent view is that bitcoin and similar "blockchain tokens" are not a new asset class and that they either have zero fundamental value or that their fundamental value cannot be determined. Reaching a consensus on these issues is challenged by the lack of a formal model where the interaction between demand and supply for bitcoins can be analyzed.

Our paper is, to the best of our knowledge, the first to study the general equilibrium of a decentralized network economy and to derive closed-form solutions linking the bitcoin price to market fundamentals. The equilibrium framework the we develop allows to address the previous questions.

On the demand side, consumers value (i) the censorship resistance (CR) of transactions and (ii) the ability to engage in trustless exchanges. Thus, they value the consumption of services in a decentralized peer-to-peer (P2P) network providing these features where a token, such as bitcoin, is stored and transferred. Instead of modeling all of the potential specific uses of the token, which are mostly unobservable, we model the properties and value of the network where the token trades. We focus on a small set of observables that drive network value. First, the number of users, reflecting the strength of network externalities. Second, on the supply side, the miners, who provide computing resources that affect the network's security or trustworthiness ("trust" hereafter) by which we mean value-enhancing properties related to the absence of frauds and resistance to censorship and attacks. Because the network is decentralized, those who provide resources need to be incentivized to do so. They are incentivized by the same token through a non-cooperative game that resembles proof-of-work. The token thus simultaneously serve two functions, a property that we label as *unity*. To find the value of the token, one then needs to solve a fixed-point problem that characterizes the interaction between consumers and miners.

Bitcoin is the first member of a class of assets, decentralized network assets (DNAs), that share the unity property in decentralized networks.[1] The market equilibrium determines both the price and the amount of

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[1] Additional examples with relatively large market capitalization include Ethereum, Litecoin, Dash, and Monero.

network security, which is positively related to the system hashrate. We find that two equilibria exist. In the absence of mining subsidies, a price of zero is always an equilibrium. If, more generally, network trust increases "fast enough" near a price of zero, an equilibrium with a strictly positive price exists. In the second equilibrium, the unity property gives rise to specific asset pricing implications that distinguish DNAs from other assets.

The price increases with the number of network participants and the average censorship aversion value. Furthermore, if consumers expect a higher (lower) network size in the future, the market clearing price increases (decreases) today. This implies that changes in expectations about network size will translate into changes in equilibrium price. The price decreases with the marginal cost of mining, which is driven by factors such as hardware and power costs, due to the reduction in the equilibrium network security, thus reducing the bitcoin valuation. The analysis also suggests that price fluctuations are moderated by mining difficulty level adjustments. Moreover, the price increases in the number of miners, since competition fosters the provision of hashrate and increases trust. In the limit, when mining is perfectly competitive, we show that the cost of mining a bitcoin is a constant proportion of the price and that proportion only depends on the curvature of the cost function and not on other supply-side parameters. To illustrate, if the cost function were given by a β-power of the hashrate, that limit mining cost equals $1/\beta \times$ price.

We show that the non-linear relation between the price and the network hashrate has important consequences. First, it implies that empirical tests on the efficiency of bitcoin prices cannot rely on conventional martingale representations. Second, it can give rise to price spirals that may help to explain the large observed bitcoin price volatility. This effect is because network trust depends on the hashrate supply which, in turn, depends on miners' sensitivity to the price of the verification rewards. Thus, exogenous shocks to fundamentals can initiate price-hashrate spirals.

Finally, there exists an optimal monetary policy. The price is not monotonic in the inflationary reward offered to miners. For small values of the reward, bitcoin injections increase the incentive for miners to provide trust; however, above a given threshold, the effect becomes negative due to the debasing influence of bitcoin inflation. The model thus implies an optimal policy regarding an inflation rate that maximizes the market capitalization of Bitcoin. This is potentially relevant in the optimal design of decentralized blockchain-based ecosystems.

To address a series of questions related to the behavior of bitcoin prices, we calibrate the economy to properties of the Bitcoin network at the end of 2017 when the price was USD 14,200. We find that the price of bitcoins is very susceptible to several fundamental properties of demand and supply. As an illustration, tripling the current network size raises the equilibrium price from USD 14,200 to 77,627. A 100% increase in mining costs, on the other hand, lowers the price to USD 13,330; while in the competitive limit, with an infinite number of miners, the price increases but moderately to USD 14,974. We further discuss the price effect of miner's reward halving, which predictably occurs every four years, and numerically illustrate how one would misprice bitcoin by following a partial equilibrium valuation approach.