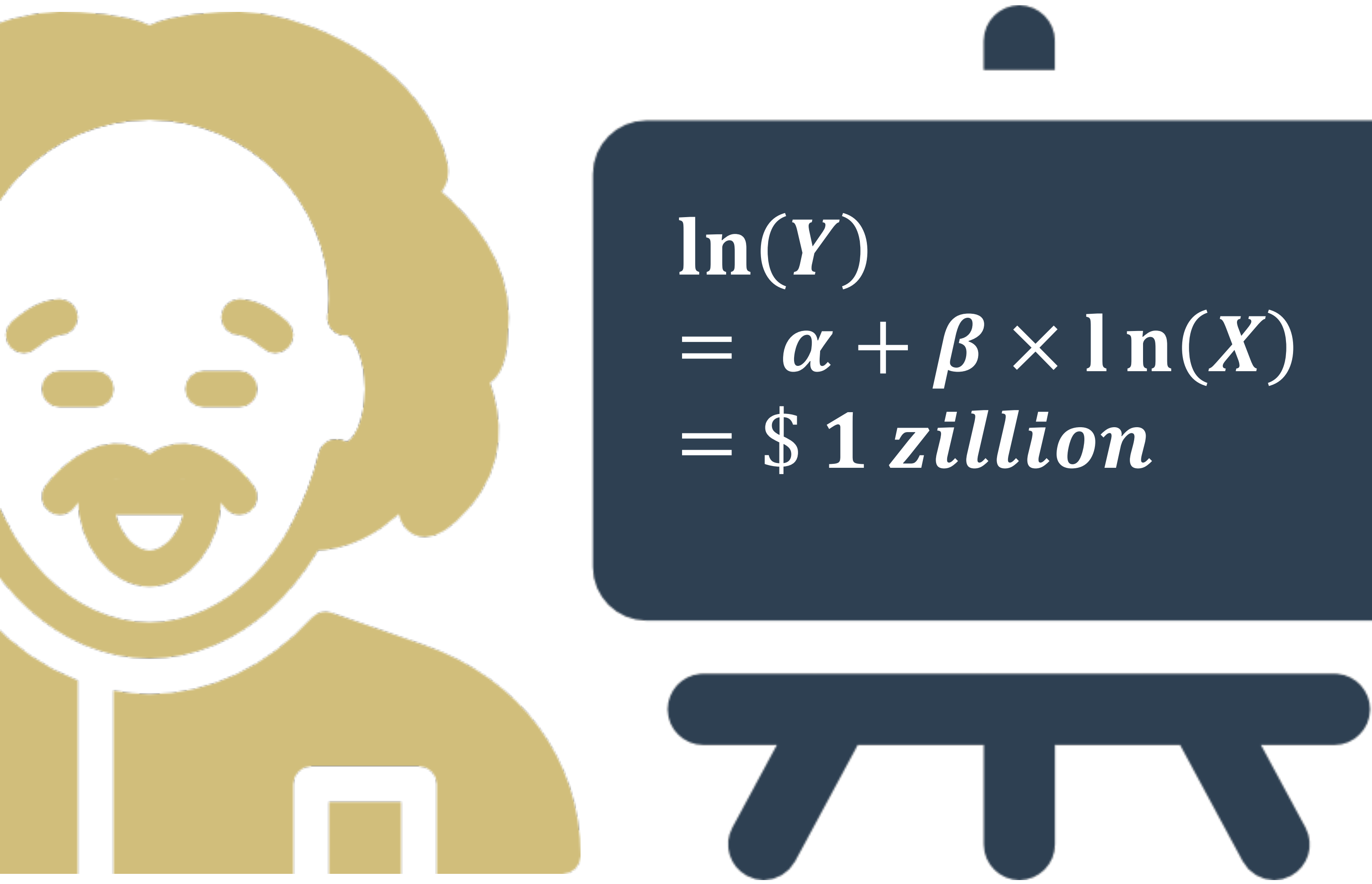
May 2018

The Blockchain Story: What's it all worth?



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YOUR WINDOW TO BLOCKCHAIN INVESTMENTS

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Ether Address:

0x69322C52919c1BFA416e706933347848bABC4Ec8

Bitcoin Address:

15ysF2pH7s6ugNPVWh4EjXn9buyULzDVvN

A. There is nothing impossible to him who will try.

If investor legend Warren Buffet, among other smart people, calls something worthless, it takes a lot of guts trying to value it. We never chose the easy path and we won't start now. In this paper we try to apply various valuation models to Bitcoin, the most widespread crypto asset as of today.

Since Bitcoin does not provide any revenue stream, common valuation models like Discounted Dividend Models (DDM), Discounted Cashflow Models (DCF) or traditional price multiples do not work. Hence, we have to find alternative valuation models. It is not our aim to give a specific price target for Bitcoin. Rather, we want to provide the reader with a couple of tools to put today's Bitcoin price in perspective and to allow the reader to better understand what assumptions in terms of adoption and market share are necessary to justify the current price level. Moreover, the study at hand should help distinguish which crypto asset is rather cheap or expensive relative to the other crypto assets.

The field of crypto asset valuation is in a very early stage. There are three main branches of research tackling the topic:

1) Equation of exchange / percentage of total addressable market (TAM)
2) Multiples (e.g. network value to transaction (NVT) ratio)
3) Network valuation models

In the forthcoming chapters we will look at the different models and apply them to Bitcoin. We built on existing models but refrained from just copying them. We further developed the models by adding our own flavor and thereby contribute to the advancement of this young research field.

B. Equation of Exchange & Percentage of Total Addressable Market (TAM)

Does Bitcoin have a value at all? Its intrinsic value is close to zero. That holds also true for CHF, USD and to some extent Gold. Their value is not dependent on the physical value of the paper slip, the metal value or the code snippet. Rather, the value of those assets purely depends on its demand and supply. Demand stems from the assets' use as a medium of exchange or store of value. If more people demand Gold, its price increases. If the Swiss National Bank (SNB) supplies additional CHF, its price decreases. In the following chapter, we estimate the demand and supply for Bitcoin and explain the valuation model that allows to calculate a price tag based on those considerations.

Valuation Model Basics

Chris Burniske[i] was among the first who gave it a try and published a valuation model for crypto assets. He relied on the "equation of exchange", a well-known economic model that links the size and price level of an economy with the money supply and the velocity. This model basically tells us, how much money is needed to support a certain economy.

$$M \times V = P \times Q$$

M = Money supply (nominal amount)
V = Velocity of money
P = Price level
Q = Index of real expenditures (quantity of newly produced goods and services)
P x Q = GDP of respective region

By rearranging the equation and solving for M, we receive the monetary base necessary to support a crypto economy of size P x Q, at velocity V. **Hence, it shows us the demand for the money, in our case, the demand for Bitcoin:**

$$M = P \times Q / V$$

In a next step, we need to find the proper values for each of the variables. We start by calculating the size of the crypto economy of Bitcoin: We determine the Total Addressable Market (TAM) for Bitcoin – or in other words – the size of the use case for Bitcoin. In our opinion, Bitcoin serves two main purposes: **Store of Value (SOV)** and **Medium of Exchange (MOE)**. Both use cases bring along their individual demand for Bitcoin, which will be evaluated in the next two sections.

Potential market for Bitcoin as store of value (SOV)

To determine the demand for Bitcoin as store of value, we start by looking at the gold market – the most traditional store of value instrument. The world gold supply (above ground) amounts to 187'200t, whereof 21.4% (40'000t) is estimated to be used for private investment purposes.[ii] **Valuing the gold supply with the current gold price results in a gold store of value market of USD 1'695bn** (see Figure 1).

Yet another kind of store of value are saving accounts. It is possible that especially digital natives might shift some money from their saving accounts into Bitcoin. In order to get a grasp of that market size of global saving accounts, we looked at the money supply of the major currencies that are used as store of value (USD, JPY, EUR and CHF). Money supply is measured in M1 to M3. While M1 comprises only the most liquid part of the money supply (physical money, checking accounts, demand deposits), M3 comprises also the money that is not immediately available to the owner (time deposits, saving accounts, etc.). **We therefore deduct M1 from M3 to receive the store of value proportion of the money supply.**[iii] The money supply for the evaluated currencies is illustrated in Figure 2.

By applying the respective exchange rates and summing up the various market sizes, we obtain the size of the total store of value market (Figure 3). Luxury goods like cars, watches, paintings, wine, real estate and many other valuable goods are also used as store of value. Since we believe that Bitcoin does not serve as a substitute for this kind of store of value, we will not consider it in our valuation attempt for Bitcoin.

Lastly, we have to consider that the store of value market grows over time. We thus assumed an annual growth rate of 3% which is roughly the average global GDP growth over the past years.

Figure 1: Market size of gold in its usage as store of value

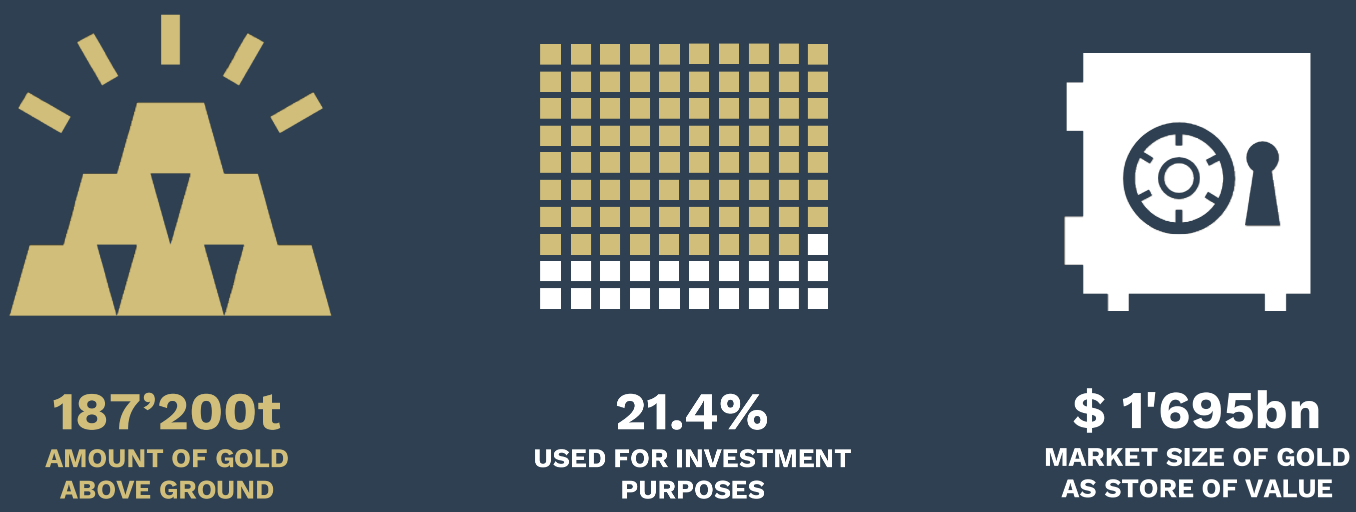


Figure 2: **Money supply (in blue: "store of value")**

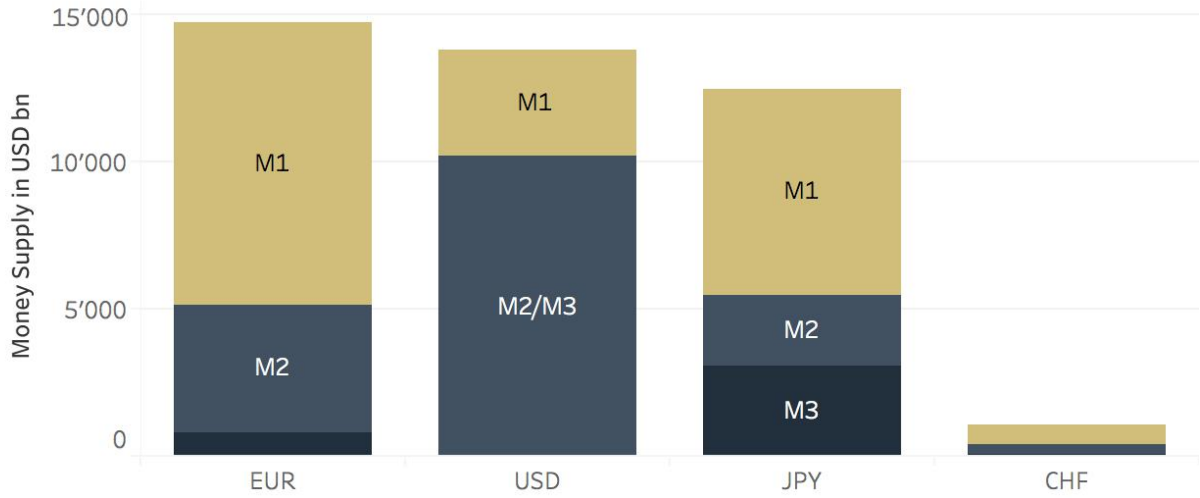


Figure 3: **Total addressable market "store of value"**

STORE OF VALUE
TOTAL ADDRESSABLE MARKET SIZE
$ 22'895bn

Potential market for Bitcoin as medium of exchange (MOE)

As mentioned, we believe that Bitcoin will serve two main purposes. **Besides the above described use case as store of value, one can assume that Bitcoin will also serve as a medium of exchange**, meaning that it will be used to a certain degree for transactions and payments.

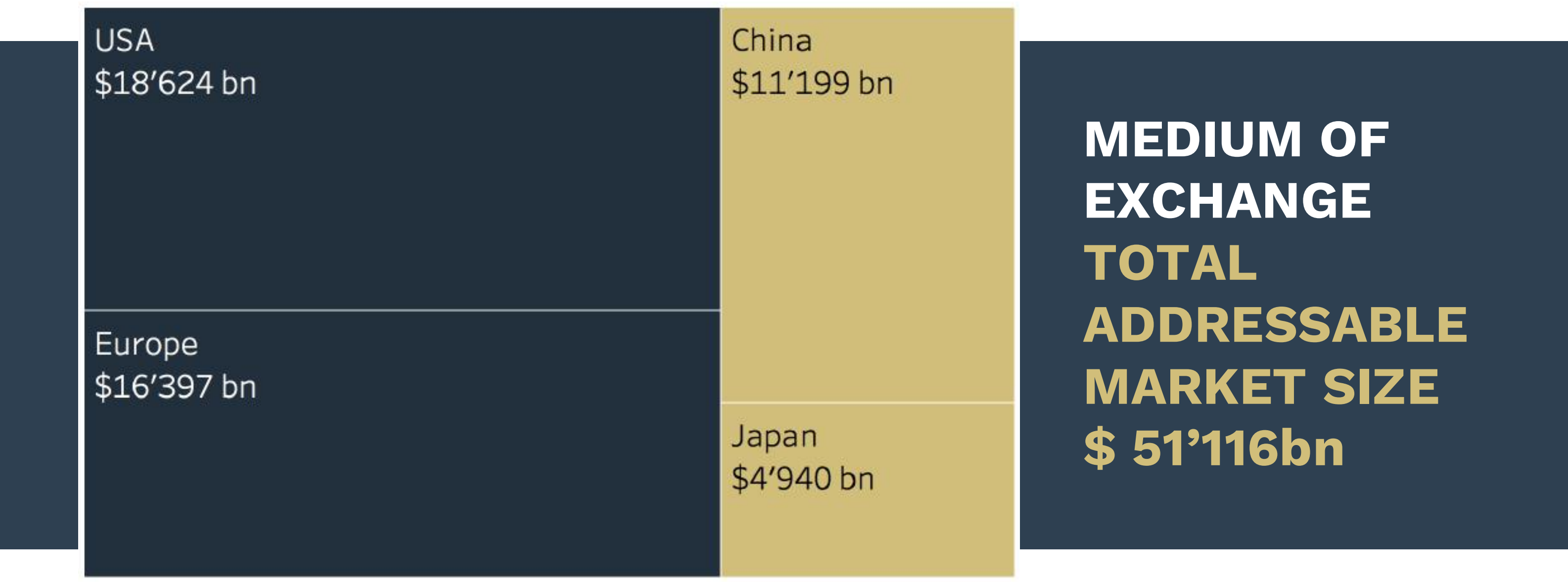
Critics might argue that Bitcoin is not scalable as shown in December 2017 / January 2018 when the Bitcoin blockchain was congested and transaction fees skyrocketed. However, we believe that scalability issues will be resolved over time. A first step in the right direction was the adoption of **SegWit**, which is the basis for off-chain scaling solutions like **Lightning**. We believe that the current situation of Bitcoin is comparable to the early days of the internet. Back in the '90s it required a lot of patience to download a single song, while nowadays we are streaming movies in HD quality.

In order to calculate the money demand related to the medium of exchange use case, we revert to the equation of exchange formula (M x V = P x Q). P x Q represents the GDP of the respective country. Since GDP figures are publicly available, only an assumption for the velocity (V) is required. Velocity is a metric that describes how often the same unit of currency is used to purchase newly domestically-produced goods and services within a year.

The money supply M1 in the United States historically experienced a velocity between 4 and 10 (currently 5.5).[iv] However, we believe that Bitcoin will have a substantially higher velocity compared to the current US number. The US money supply is still exceptionally high as a result of the financial crisis, while velocity is exceptionally low. **Therefore, we chose a velocity of 10 for Bitcoin. This is a conservative approach as a higher velocity leads to a lower valuation of Bitcoin.**

We took into account the GDP figures of the main world economies. As a growth rate, the approximate average historical global GDP growth rate over the past years is assumed (3%).

Figure 4: Total addressable market "medium of exchange"



Market share and adoption rate of Bitcoin

By summing up the store of value (SOV) and medium of exchange (MOE) markets we obtain the total addressable market (TAM) for Bitcoin. However, crypto assets will not take over the entire market for SOV and MOE. Additionally, there are other crypto assets besides Bitcoin competing for market share. We thus have to make assumptions about the market share and adoption speed of crypto assets generally and Bitcoin specifically within the SOV and MOE markets.

Based on the experience from the adoption of other tech innovations, the Bitcoin adoption is modeled by applying an S-curve: In the first phase after the invention, the adoption is very slow. The technology and its potential applications are not yet completely understood. Slowly, very tech-savvy users and "innovators" start to use it (similar to the first years of Bitcoin after its launch in 2009). At a later stage "early adopters" kick in and growth is accelerating. After a while, the "early majority" starts to use the tech innovation. With the entrance of the "late majority" and later on the "laggards", growth is decelerating, and the adoption curve is flattening.

We do not know if and how quickly Bitcoin and other crypto assets start complementing Gold, CHF or USD. However, we have some ideas in mind. We show three different scenarios (base case, optimistic, pessimistic) for the adoption of Bitcoin in the MOE and SOV market, respectively. We estimate the development of Bitcoin's market share over a ten-year horizon.

We assume that the fast growth phase for Bitcoin will start in 2018 (SOV) and 2019 (MOE). Depending on the scenario and use case, we estimate that it will take between five and ten years to reach the target market share.

In the **base case scenario**, we believe that Bitcoin has the potential to become an alternative for Gold and other store of value units in particular for digital natives. In countries like Japan or South Korea, a large proportion of teenagers already owns crypto assets. It is very possible that Bitcoin becomes the equivalent to gold for the digital natives' generation. In the base case scenario, we assume that crypto assets take over 5% of the traditional store of value market and Bitcoin will be clearly the preferred crypto asset for that specific purpose (90%). We believe it is possible that crypto assets generally will make up an even bigger part of the medium of exchange market (10%) in the future. However, Bitcoin's market share thereof will be smaller since there are more alternative crypto assets for this specific use case (e.g. stable coins, Litecoin, Bitcoin Cash, Dash, etc.). While we believe that there will be one major crypto asset that is used as store of value, there is room for several crypto assets that serve as medium of exchange. Going forward, stable coins might play an important role since price volatility of crypto assets is a major hurdle for mass adoption.

In the **optimistic scenario**, we assume that over the next 10 years mass adoption of crypto assets will be happening and will not be limited to digital natives. A substantial part of the current store of value market will be shifted into crypto assets (20%) and crypto assets become a major medium of exchange (30%). In the **pessimistic scenario**, we assume that Bitcoin vanishes over the next years and will neither be used as store of value nor as medium of exchange.

For each scenario, we provide probability estimates. To the base case scenario, we assign a probability of 50%, to the optimistic scenario a probability of 10% and to the pessimistic scenario a probability of 40%. There is still a lot of uncertainty and skepticism involved when it comes to the future mainstream adoption of crypto assets. Accordingly, there is a high likelihood that future mainstream adoption will fail, which is why we chose a rather high likelihood for the pessimistic scenario.

Figure 6: Adoption curve assumptions for the "store of value" use case of Bitcoin

SOV

SCENARIO	TOTAL CRYPTO SHARE	BITCOIN SHARE OF CRYPTO	ADOPTION TIME	SCENARIO WEIGHT
OPTIMISTIC	20%	90%	5 YEARS	10%
REALISTIC	5%	90%	7 YEARS	50%
PESSIMISTIC	0.01%	90%	10 YEARS	40%
WEIGHTED	4.5%	90%	8 YEARS	

INCEPTION YEAR: 2009 / FAST GROWTH PHASE START YEAR: 2018

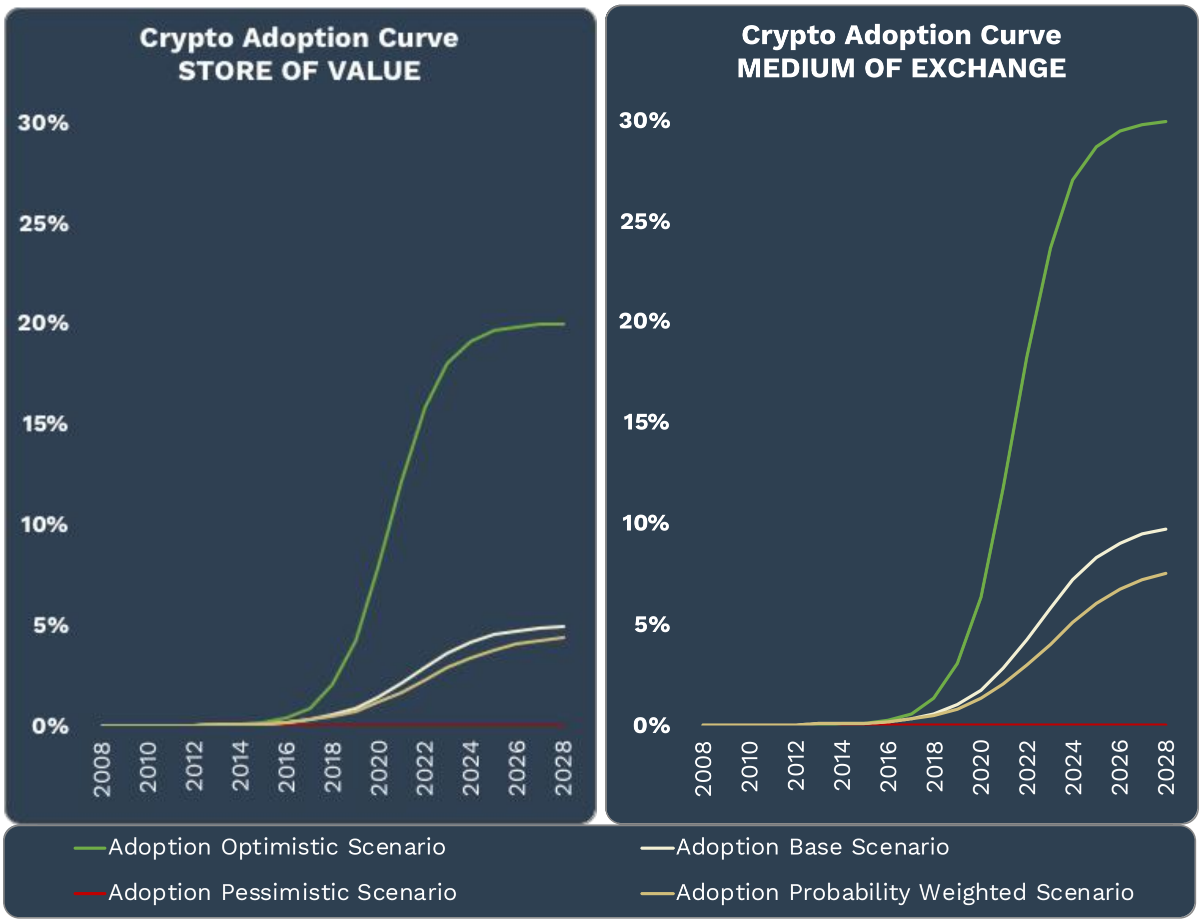
Figure 7: Adoption curve assumptions for the "medium of exchange" use case of Bitcoin

MOE

SCENARIO	TOTAL CRYPTO SHARE	BITCOIN SHARE OF CRYPTO	ADOPTION TIME	SCENARIO WEIGHT
OPTIMISTIC	30%	30%	5 YEARS	10%
REALISTIC	10%	30%	7 YEARS	50%
PESSIMISTIC	0.01%	30%	10 YEARS	40%
WEIGHTED	8%	30%	8 YEARS	

INCEPTION YEAR: 2009 / FAST GROWTH PHASE START YEAR: 2019

Figure 8: Adoption curves



A look at the supply side

Until now, we only looked at the demand side of Bitcoin. However, we also have to consider the supply side. **Similar to how the CHF exchange rate is dependent on the size of the monetary base, the price of crypto assets depends on the amount of outstanding coins.**

By dividing the monetary base necessary for fulfilling the SOV and MOE demands by the number of coins in float, we achieve a valuation per coin. This is a rather easy exercise, as the issuance of Bitcoins follows a specific rule.

Currently, approximately 17 million coins are outstanding and with the current block reward, roughly 650’000 coins are mined per year. The block reward will be halved for the next time in 2020 and then again approximately every four years (every 210’000 blocks). This leads to a decreasing inflation until the total supply is eventually capped at 21 million coins.

Expected return

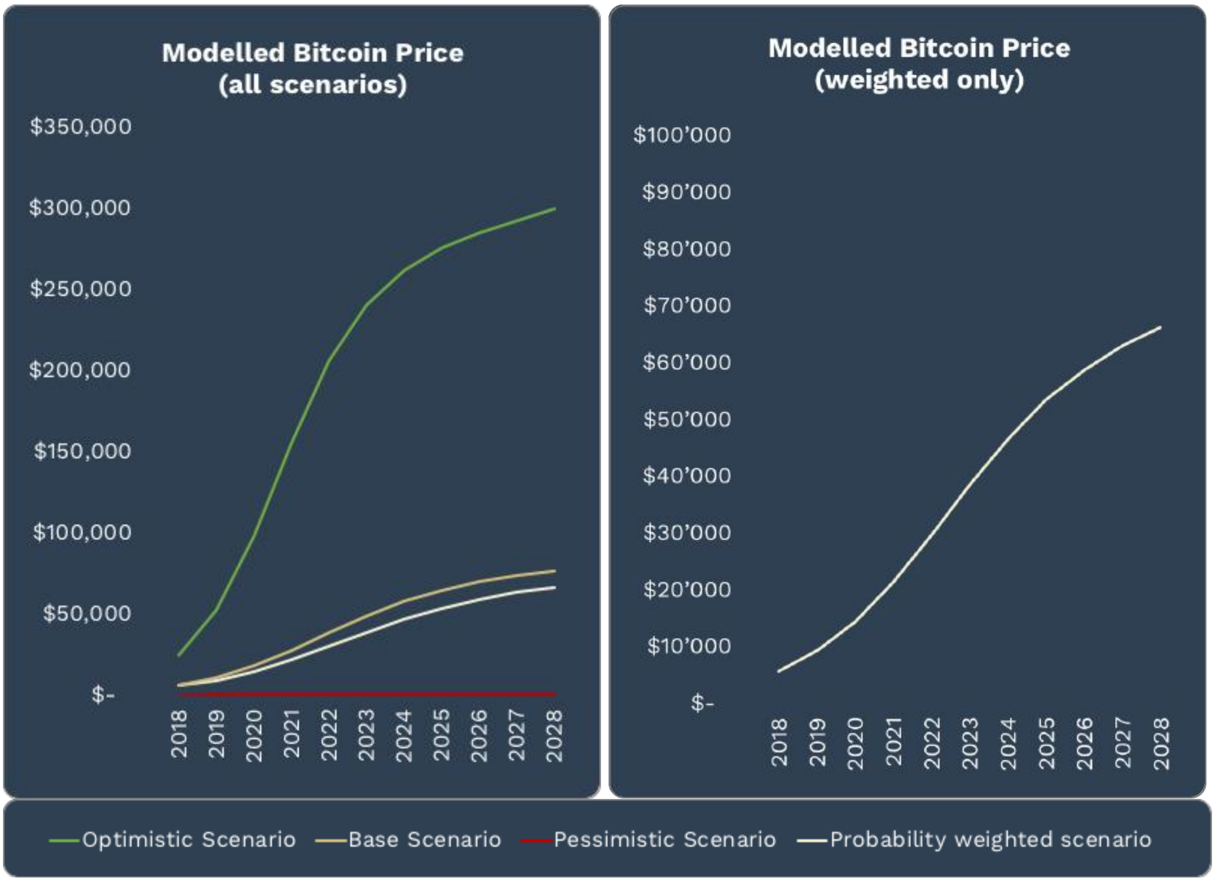
By combining our demand and supply side forecast for a 10-year horizon, we receive an estimated future Bitcoin price (Figure 9). It shows that despite the chosen cautious assumptions for the probability of a success, **the future probability weighted Bitcoin price is estimated at around USD 65’000. Almost 90% comes from the store of value use case.**

In order to obtain today's Bitcoin price, we need to choose a sensitive discount rate. There is a substantial need for further research with respect to appropriate discount rates for crypto asset projects. However, this is outside the scope of the research paper at hand. Nevertheless, **we can reverse engineer the expected return rate for the next ten years based on the current Bitcoin price.**

Firstly, we consider the market price as given (USD 6'973 / snapshot = 31st March 2018) and reverse engineer the discount rate that is necessary in order to achieve the current market price with the above described assumptions. **The calculations show that, in the probability weighted scenario, an investor should expect roughly a 25% performance per year over the next 10 years.**

One might argue that the discount rate should be much higher, since Bitcoin is comparable to a venture capital project. There are two major differences: Bitcoin had a working product for several years and shows much higher liquidity compared to venture capital projects. It is very easy to sell Bitcoins instantly, whereas a typical venture capital investor is stuck for over ten years and therefore requires a larger liquidity premium.

Figure 9: Modelled Bitcoin Price



C. Multiples

In the next chapter, we take a look at the Network Value to Transactions (NVT) Ratio and other multiples. The NVT ratio got introduced by Chris Burniske and became in the crypto asset world what the P/E ratio is in the equity world.[v]

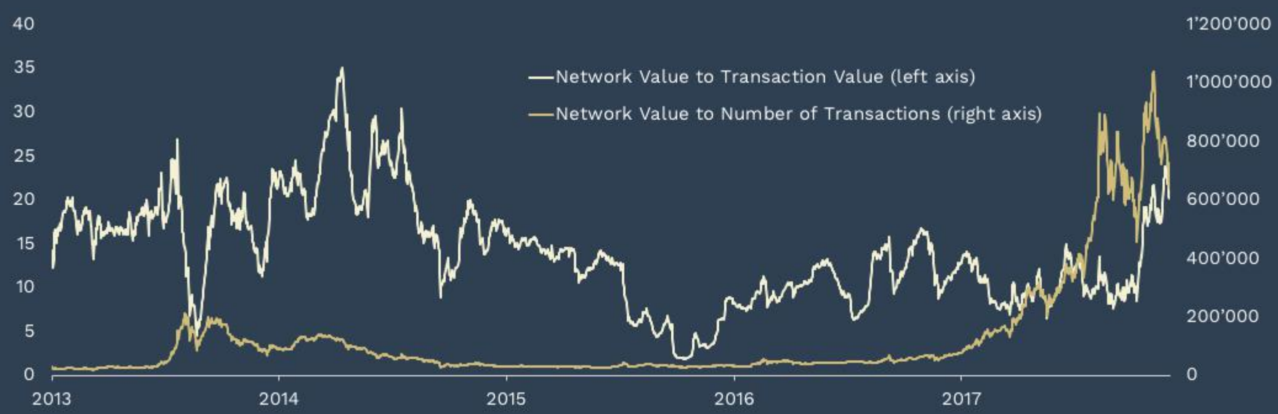
Ratio analysis is by far less detailed than a discounted cash flow model or the equation of exchange analysis we just did. However, it is very intuitive and gives you a good indication when observing the valuation of the same project over a certain time period or when comparing different projects. The NVT ratio puts the network value in relation to the dollar value of crypto asset transactions.

NVT = Network Value / Daily Transaction Volume (in USD)

The daily transaction volume in USD serves as a proxy of how much utility a network provides to its users. Since the daily transaction volume figures do only consider on-chain transactions, the volume traded on exchanges is not reflected in this figure. However, in a first step this is exactly desired, since the exchange trades are often of a speculative nature and do not increase the utility of a project.

We start by looking at the development of the NVT ratio for Bitcoin over time. **In Figure 10, one can see that Bitcoin's valuation is from a historical perspective on a normal level when the network value is compared with the transaction value (average daily transaction volume over the last 30 days).** However, when we compare the network value to the number of transactions (average daily transaction number over the last 30 days), Bitcoin suddenly looks expensive in a historical context. As a next step, we compare Bitcoin's NVT ratios to other crypto assets' ratios to obtain insights into Bitcoin's relative valuation.

Figure 10: NVT Ratios

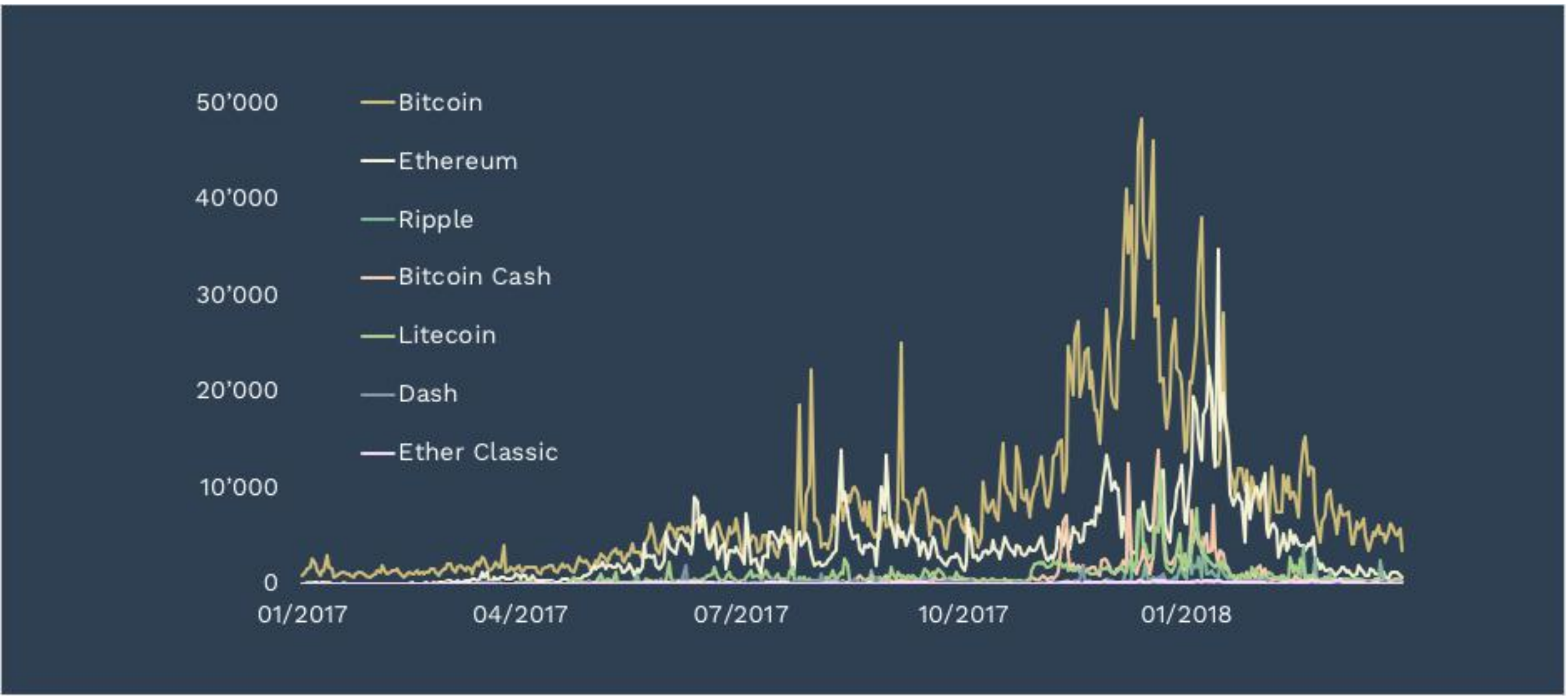


In **Figure 11**, one can see that when we compare the current network value to the average daily transaction value of the last year, Litecoin and Ethereum have the lowest relative valuations. However, with the depressed prices since the beginning of the current year, transaction volumes in USD have significantly decreased for most crypto assets. This is particularly true for Ethereum, Bitcoin Cash and Litecoin (see **Figure 12**). When only considering the average of the daily transaction value over the last 30 days rather than the last year, Ether Classic and Bitcoin have the lowest valuations.

Figure 11: NVT ratios across crypto assets (as of 31th March 2018)

	Market Value	Average daily Transactions Value (last year)	Network Value to Transactions Value (last year)	Average daily Transactions Value (last 30 days)	Network Value to Transactions Value (last 30 days)
Bitcoin	$116'820'000'000	$9'795'898'266	11.9	$5'818'027'926	20.1
Ethereum	$38'914'900'000	$4'604'217'103	8.5	$1'114'392'228	34.9
Ripple	$19'962'300'000	$284'329'109	70.2	$307'373'879	64.9
Bitcoin Cash	$11'892'100'000	$1'211'037'529	9.8	$286'558'414	41.5
Litecoin	$6'627'590'000	$955'732'381	6.9	$304'440'413	21.8
Dash	$2'480'030'000	$125'775'565	19.7	$56'031'472	44.3
Ethereum Classic	$1'452'690'000	$74'418'550	19.5	$87'474'657	16.6

Figure 12: Daily transaction values in millions (over time)



Cross-sectional NVT ratios using transaction numbers

In a next step, we slightly change the NVT measure. Instead of putting the market value in perspective with the daily transactions volume in USD, we do the same exercise with the number of transactions. The daily number of transactions is a more robust measure, as it takes a lot of effort to artificially boost the number of transactions, while in theory the average transaction volume in USD can be manipulated with one single large transaction.

Using this measure, Ethereum, Ethereum Classic and Litecoin look comparably cheap. Bitcoin is in the mid-field. On a side note, it is also striking that the number of daily transactions for Ethereum is more than twice as high compared to Bitcoin.

NVT adjusted = Network Value / (No. of Transactions x 365)

Figure 13: **Adjusted NVT ratios across crypto assets (as of 31th March 2018)**

	Market Value	Average daily No. Transactions (last year)	Network Value to No. of Transactions ratio (last year)	Average daily No. Transactions (last 30 days)	Network Value to No. of Transactions ratio (last 30 days)
Bitcoin	$116'820'000'000	269'081	1'189	183'565	1'744
Ethereum	$38'914'900'000	571'314	187	653'608	163
Ripple	$19'962'300'000	27'094	2'019	17'903	3'055
Bitcoin Cash	$11'892'100'000	21'741	1'499	19'850	1'641
Litecoin	$6'627'590'000	36'626	496	32'180	564
Dash	$2'480'030'000	7'144	951	7'728	879
Ethereum Classic	$1'452'690'000	38'336	104	47'103	84

On another side note: Extracting the transaction value from a blockchain is difficult, as most crypto assets' blockchains do not keep balances but only distinguish between spent and unspent outputs: When I have a balance of 100 Bitcoins and want to transfer 10 Bitcoins, 10 Bitcoins are transferred to the recipient while 90 Bitcoins are transferred to the change address that belongs to me. If both addresses that receive coins are new, there is no way to figure out which one is the change address and which one is the recipient address. One appropriate solution: The change address volume is only ignored when it is possible to clearly distinguish the two addresses. This is the case if there is no new address used for the change address. Such methodology leads to an overestimation of the transaction value volume. However, it leads to consistency and is best suited for cross-sectional and cross-time comparisons, as long as change habits across currencies are roughly stable. Due to the overestimation of the transaction value volume, the NVT resulting from the calculations serves as a lower boundary.[vi]

Alternative multiples

We believe that even more innovative ratios are necessary to embrace this new asset class. For a crypto asset it is essential to have a large and active community base. It is a key variable for the adoption in the wider public. The number of transactions is a first indicator for the user base. For crypto assets, social media activities are crucial. A big part of the communication takes place via Twitter and Reddit. Therefore, we put the daily Twitter activity and the number of Reddit subscribers in perspective to the network value. Additionally, an active developer community is key, since it helps to further develop the project. Github is the platform where developers contribute to a crypto asset project. By measuring the Github stars, we get a feeling for the developer interest in a project.

Figure 15 shows that Bitcoin has still by any of the above standards the largest community. It does not only have the most social media activities, but also the largest developer community measured by Github stars and the largest hashrate. The hashrate, however, is a misleading measure since the availability of ASIC (Application-specific integrated circuit) devices varies from project to project, which distorts the picture. That's an explanation why Ether and Ether Classic have a much lower hash rate compared to for instance Bitcoin Cash.

From Figure 15, it can be implied that Litecoin is by almost any measure the crypto asset with the lowest valuation. Bitcoin Cash on the other hand seems expensive by any measure. Assets with a lower valuation than Bitcoin Cash, like Litecoin or Dash, have much more daily tweets. The same holds true for the Github stars. At the same time Ethereum seems undervalued relative to Bitcoin. All the multiples with the exception of the "Network Value to Hashrate" point in the same direction.

The more people that use a crypto asset, the more valuable it is for new users to join the network since they are instantly connected with more people. Therefore, the value of a network heavily depends on the user network. This is something we want to investigate in more depth in the next chapter on network valuation models.

Figure 15: Alternative multiples

	Number of daily tweets	Network to daily tweets ratio	Number of Reddit subscribers	Network to Reddit Subscriber Ratio	Number of Github stars	Network to Github star ratio	Hashrate	Network Value to Hashrate
Bitcoin	52'796	2.21	793'058	1.47	30'340	3.85	2.82E+19	4
Ethereum	21'190	1.84	350'065	1.11	16'442	2.37	2.52E+14	154'438
Ripple	2'852	7.00	184'427	1.08	2'666	7.49	n/a	n/a
Bitcoin Cash	1'863	6.38	32'518	3.66	543	21.90	2.34E+18	5
Litecoin	4'220	1.57	197'274	0.34	2'957	2.24	2.10E+14	31'515
Dash	3'704	0.67	20'743	1.20	968	2.56	1.74E+15	1'428
Ethereum Classic	105	13.84	18'450	0.79	297	4.89	1.01E+13	144'202

D. Network Valuation Models

An alternative method to obtain a valuation for Bitcoin are network valuation models. The value of a network grows proportionally to the number of users that a network has – as seen with the first telecommunication systems (e.g. phones) as well as with modern social networks (e.g. Facebook).

Introduction to Metcalfe's law

There are several models to value a network, the most famous one being Metcalfe's law. **It states that the value of a network is proportional to the square of the number of users.** Each user of a network with **n** members can make **n-1** connections with other users. If all those connections are equally valuable, the total network value is proportional to **n*(n-1)**, which is asymptotically **n-squared**.[vii]

The network effect is best explained with a phone line. If I'm the only one with a phone, the phone is useless. If a second person owns a phone, I can already make a phone call. If there are 5 people owning a phone, there are already 20 possible connections. If the network grows to 10 people, there will be 90 connections and for 20 phone owners, there will be 380 connections. While the number of phones only quadrupled, the number of possible connections is 19 times higher. The reason for this is the network effect. **With each member that joins the network, the utility the network brings to each existing member rises as well, because they benefit from an additional connection.**

One of the limitations of Metcalfe's law is that it assumes that every connection is equally valuable. However, this is often not true in practice. If we again take the example of the phone line, some connections do not bring the same utility to the network. How does it help if a farmer sitting in the Swiss alps is connected to a business man in Beijing? Most likely they will not be able to communicate due to the language barrier and even if they would be able to communicate, it is very likely that they do not have any interest in talking to each other.

Metcalfe's law was very controversial and for a long time neither empirically proven nor rejected. Metcalfe himself then applied his law to real data. He took the monthly active users of Facebook and compared this figure to the revenues generated by Facebook (proxy for network value), which turned out to be a very good fit.[viii]

Original Metcalfe's Law:
Network Value = x * Users^2
(x = to be fitted)

Application of original Matcalfe's law to Bitcoin

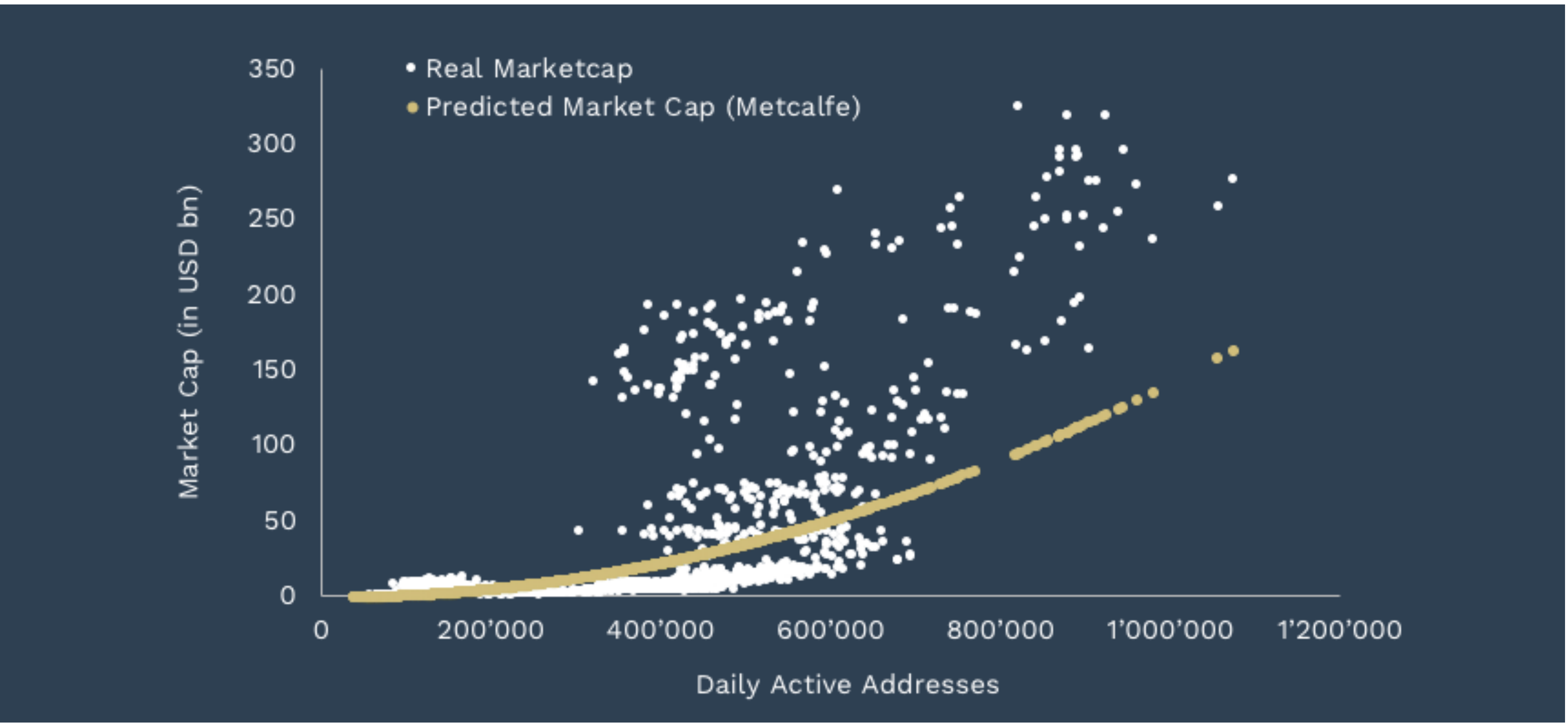
We apply the original Metcalfe's law to Bitcoin to obtain a network valuation for the crypto asset. The number of active addresses serves as "users", while the market capitalization of Bitcoin serves as "network value". With linear transformation, we derive the value for x, which is **0.143**. With this formula, we are now able to predict the value of Bitcoin for a specific number of users. We tested the model using data from the last five years.

Original Metcalfe's Law (Bitcoin): Network Value = 0.143 * Users^2

(x = 0.143)

In Figure 16, we see the modelled values according to Metcalfe's law (in gold) compared to the Bitcoin's real value (in white) over the observed time frame. We see a clear relationship. The measure R^2 (coefficient of determination) is a measure that helps us explain the goodness of fit of using the number of active addresses to explain the network value. R^2 amounts to 0.58 in our model and shows that there is a strong relationship between active addresses and the network value of Bitcoin. **However, as clearly illustrated in the figure, Metcalfe's law seems to overestimate the value for a small user base and underestimate the value for large user bases.**

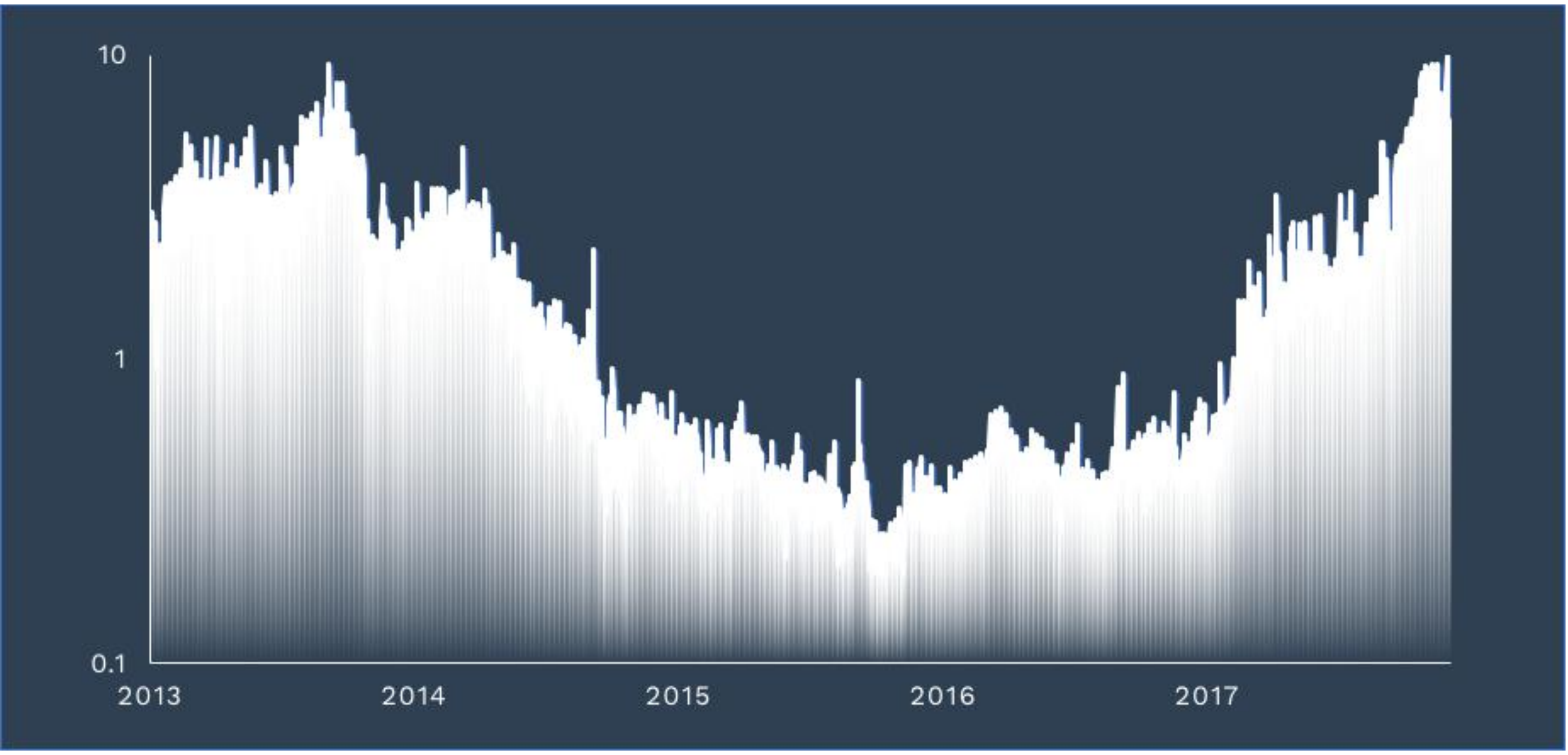
Figure 16: **Original Metcalfe's law fitted to Bitcoin**



Evolution of the original Metcalfe's law results over time

It is interesting to see how the market value differs from the value predicted by the Metcalfe model over time. By setting the market value in relation to the modelled value, we get the Price-to-Metcalfe-Value-Ratio. A ratio above one is an indicator for an overvaluation. If the ratio is below one, it is a sign for an undervaluation. Figure 17 shows that between 2015 and 2016 the market price was trading at a discount relative to the predicted price by the Metcalfe model. However, in the boom cycles in 2013 as well as in 2017 the Bitcoin market price traded at a massive premium. **The Bitcoin market price was sometimes ten times higher than predicted by the Metcalfe model.** However, one should not forget that all transactions on exchanges do not lead to an on-chain transaction and are therefore not considered in the Price-to-Metcalfe-Value-Ratio. Specifically, this means if 1mn people buy on an exchange Bitcoins because they believe in its function as a store of value, this will not lead to a lower Price-to-Metcalfe ratio. Only, once they transfer their Bitcoins away to a wallet or another exchange, this leads to an on-chain transaction. Moreover, the number of active addresses represents the current state only and does not factor in any growth expectations.

Figure 17: **Original Price-to-Metcalfe-Value-Ratio over time**



Improving the original Metcalfe's law to better fit Bitcoin

In the introduction to the Metcalfe model we discussed its limitations. Critics argued that the assumption that the value of the network growths proportionally to the squared number of users is overestimating the network value. The reasoning behind this is that not all connections have the same value. We believe that with Bitcoin this is less of an issue compared to other networks. A user can easily trade with anyone across the globe. Still, we want to investigate this further and check whether there is a better fit than the original Metcalfe model.

We take again the Metcalfe model as a basis. But rather than assuming that the network value grows proportionally to the square of the user base, we solve for the proper value (the power that fits best) by performing a linear transformation (see formulas below).

The beta factor estimated with our model amounts to 1.37. This is indeed lower than the beta factor of 2 indicated by the original Metcalfe's Law. The original Metcalfe model and our own model have the identical R^2 values, because R^2 only measures the relative goodness of fit. **However, the standard error of the estimator (S) measures the goodness of fit in absolute terms. It shows that our own model (S=0.8451) fits the data better compared to the original Metcalfe model (S=0.9572).**

Our model has been fit to the sample – a better fit is therefore no surprise. Only time will tell whether our model or the original Metcalfe's model is better suited to model the price of the Bitcoin network.

Own Network Value Model:
$\text{Network Value} = x * \text{Users}^{\beta}$

$(x = e^{\alpha})$

$\ln(\text{Network Value}) = \alpha + \beta * \ln(\text{Users})$

$(\alpha, \beta$ = to be fitted)

Own Network Value Model (Bitcoin):
$\text{Network Value} = e^{5.81} * \text{Users}^{1.37}$

$(x = e^{\alpha})$

Sub-period analysis

To check for robustness of our model, we divided the observation period into several sub-periods. We used the Price-to-Metcalfe-Value-Ratio from Figure 17 to determine the sub-periods and evaluated in which regime the model works best. The sub-period analysis yields the results shown in Figure 18.

It is very striking that the R^2 of the last time period (2017-2018) is much lower compared to the previous two sub-periods. The standard error of the estimate (S) is also higher in that sub-period. **It seems that the relationship between the active addresses and the price of Bitcoin substantially weakened during the boom phase of 2017.** The beta factor however is roughly stable across all three subperiods and constantly below the beta factor of 2, which was originally suggested by Metcalfe.

Figure 18: **Subperiod Analysis**

Time Period	Beta	R-Squared	S
01.01.2017 - 31.03.2018	1.52	12%	0.8897
01.01.2015 - 31.12.2016	1.36	78%	0.2187
29.04.2013 - 31.12.2014	1.43	70%	0.4273

E. Conclusion

We looked at three different strings of research that tackle the valuation problem of crypto assets from a different angle. We showed the reader what kind of assumptions are necessary in order to justify the current price level of Bitcoin. Moreover, we tried to point out strength and weaknesses of different valuation approaches. Whenever possible, we made suggestions for further improvements of the models.

While the equation of exchange approach is very detailed and gives the reader a good idea of what assumptions in terms of adoption are necessary, this valuation model relies heavily on the assumed expected return. **The appropriate expected return is an area that opens great opportunities for further research.**

The ratios are fairly easy to calculate and are a great help for cross-sectional or cross-time comparisons. However, they are not only rather simplistic but also prone to biases.

Eventually, we looked at network valuation models. **We showed that Metcalfe's law has indeed a good explanatory power.** Our own model improves the fit for Bitcoin.

The discipline of valuation models for crypto assets is in its baby shoes. It is work in progress and every experience we gain now helps us in further developing these models. We believe that there is more room for improvement and we are certain that only by sharing the knowledge, this discipline can progress.

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Lidia brings in vast experience in quantitative finance, asset management and complex tech projects. Before co-founding a startup in the field of machine learning applications, Lidia was Managing Partner of a Swiss advisory boutique specialized in quantitative finance. Earlier in her career she worked for major investment firms (J.P. Morgan, Swiss Re, Man Investments) in various asset management roles in Zurich, London and Hong Kong. Lidia holds a PhD from the University of St. Gallen, specializing in investment strategies and asset management, and acts as advisor to blockchain startups in that field.

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Christian's career path proves his strong passion for financial markets. He worked 15+ years for Credit Suisse in Zurich and New York where he held positions in trading, investment consulting and research. He is a senior trader with vast experience in risk managing derivative trading books in different asset classes (equity, precious metals, foreign exchange). Due to his explicit tech skills, he was substantially involved in the digitalization of the bank's structured product platform and the automation of trading processes. Christian holds a Master of Arts in Banking & Finance from the University of St. Gallen.

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