



November 2023

Valuation of Cryptoassets: A Guide for Investment Professionals

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Acknowledgments

We extend our warm thanks to the following professionals who kindly shared their views with us as part of our research and who have agreed for their names to appear as sources in this report (in alphabetical order).

Jodie Gunzberg, CFA, Managing Director, CoinDesk Indices

Matt Hougan, Chief Investment Officer, Bitwise Asset Management

Jeff Rundlet, CFA, Head of Accounting Strategy, Cryptio

Katie Talati, Director of Research, Arca

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EXECUTIVE SUMMARY

This guide covers valuation methodologies—currently in discussion or in use among practitioners—for valuing cryptoassets. The rise in popularity of cryptoassets over the past decade raises the issue of how to value the different types of cryptoassets in the market. Investment practitioners who are interested in or investing in cryptoassets should have a thorough and reasonable basis for their investment decision making, grounded in an analysis of the intrinsic value of these assets wherever possible. This guide is designed to equip professionals with the most relevant valuation models and tools to support their analysis.

The methodologies analyzed here are derived from interviews with industry practitioners and a review of the literature analyzing these models. We specifically cover smart contract platforms, decentralized applications, and Bitcoin.

Bitcoin has the largest market share among cryptoassets and has been in existence longer than its counterparts; consequently, it has the most literature covering the question of how to value it and the most models attempting to answer this question of all the cryptoassets thus far.

We include in our analysis models adapted from traditional finance, such as the discounted cash flow model, and models developed specifically for cryptoassets, presenting the benefits and limitations of each. We illustrate these models with example calculations.

Industry surveys conducted in 2022 that we cite in this report showed that institutional adoption of cryptoassets remains mired by issues of regulation, custody, and valuation. The need to bridge the infrastructure and operational gaps between traditional finance and the cryptoasset ecosystem remains. The valuation issue is still a debated topic among industry stakeholders, where some recognize cryptoassets as an investable asset class in portfolio construction, while others question their legitimacy and value proposition. We do not endorse a particular view but seek to inform the debate by setting out relevant valuation methodologies. One of the biggest issues that valuation of cryptoassets faces today is the short duration of their existence, which limits historical data and hence robust statistical testing. However, there have been numerous endeavors to construct valuation models, some unique to the fundamentals of cryptoassets and some borrowed from traditional finance.

Current valuation models and approaches carry a number of limitations and require further development; thus, a single model or metric should not be used in isolation to value any given cryptoasset. Despite the limitations of the valuation models addressed in this report, they offer insights into the functionality and mechanics of the respective assets. Disagreement on existing models should be welcomed and embraced. Such counter analysis and critique can lead to the development of improved valuation approaches, and the introduction of new concepts and more robust datasets will improve our understanding and modeling capabilities over time.

Key Takeaways

- Valuation of smart contract platforms, such as Ethereum, can be approached from two viewpoints: The platform is considered either as a network or as a cash flow asset.
 - When considering smart contract platforms to be a network, a qualitative framework based on on-chain data can be used to assess these platforms on a relative valuation basis. Metcalfe's law, which values a network based on the square of its number of users, can be continually used to value the network relative to its market capitalization.
 - The view of smart contract platforms as a cash flow asset involves using the discounted cash flow (DCF) model. The DCF model considers the transaction fees collected by these platforms as cash flows, allowing for the implementation of the model based on assumptions regarding applicable growth rates and discount rates.
- Valuation of decentralized applications can be performed using either a relative valuation approach or an intrinsic value approach using the DCF model.
 - Such metrics as the price-to-sales, price-to-fees, and market capitalization to net assets ratios can be used to relatively value decentralized applications within the same sector or to compare them with their traditional finance counterparts.
 - The DCF model considers protocol revenue collected by a decentralized application as a

cash flow, enabling the calculation of intrinsic value based on growth and discount rate assumptions.

- For bitcoin, we show the strengths and limitations of four models: the total addressable market approach, the stock-to-flow model, Metcalfe's law, and the cost of production model. Each model is derived from an underlying characteristic of bitcoin and takes differing viewpoints by assessing the

store-of-value or medium-of-exchange approach for bitcoin.

- Basing each model on just one of bitcoin's fundamentals leads to certain limitations; there is no single model that encompasses all the characteristics of bitcoin.
- These models do provide a theoretical understanding of the underlying dynamics of the cryptocurrency and can form part of a fuller analysis of cryptoassets.

1. INTRODUCTION

Over the last decade, the rise of the cryptoasset market has been one of the most defining financial phenomena. The total cryptoasset market capitalization has increased from \$796 billion in 2018 to around \$1 trillion in 2023.¹ In "Cryptoassets: Beyond the Hype,"² Olivier Fines and Stephen Deane make relevant recommendations for fiduciaries and institutional investors, such as the need for "careful analysis of value and portfolio benefits" and posit that "intrinsic value should be related to an in-depth understanding of use cases." Our report analyzes the valuation methods that are in development or are currently being used in the industry and explains how the respective models work, as well as their strengths and weaknesses.

In the absence of a comparative regulatory framework to traditional asset classes, investment professionals who choose to invest in cryptoassets for their own interest or on behalf of their clients should evaluate the valuation methods that can be used in their decision-making process while incorporating other factors, such as their time horizon and risk tolerance.

We believe it is imperative to objectively understand the various valuation approaches in both theory and practice to analyze cryptoassets thoroughly, for retail and institutional investors alike.

We begin by reviewing the current landscape of institutional investment in cryptoassets and the motivations driving this trend, looking at the types of institutions getting involved, and the effect of the cryptoasset bear market on adoption trends. We then examine valuation models that apply to various elements of the cryptoasset universe, including smart contract platforms, decentralized applications, and bitcoin (the largest cryptoasset by market capitalization). Although stablecoins represent a significant part of the cryptoasset ecosystem, with a total market capitalization of \$126 billion,³ they are not included in the analysis since they are designed to maintain a constant value.⁴

This report is intended to be a guide to inform investors and investment professionals about the tools available to value cryptoassets, regardless of one's views of the merits of cryptoassets in a portfolio context. The report is not an exhaustive review of the valuation methods for cryptoassets; rather, it focuses on the relative and fundamental valuation approaches that are most relevant to practitioners. The analysis is informed by interviews with practitioners and synthesis of current literature. We do not endorse any specific valuation model or method.

1.1. Current Trends of Institutional Investment

Institutional adoption of cryptoassets still remains mired by several issues related to regulation, custody, and valuation. In addition to the need for regulatory clarity, there is a considerable need to bridge the gap between traditional finance and the cryptoasset ecosystem given the significant differences between their infrastructures and operational processes. Additionally, there are security and custody risks associated with trading and holding cryptoassets, as well as the issue of valuation, which we examine in this report.

Previous research published by CFA Institute⁵ highlights some of the concerns institutional investors currently have with respect to investing in cryptoassets. Examples of these concerns include questions around the compatibility of cryptoassets with fiduciary duty, challenges related to custody of client assets, market volatility, know-your-customer (KYC) and anti-money-laundering (AML) monitoring, and the regulatory framework.

Despite these challenges, there is potential for significant investment in cryptoassets. In October 2022, Fidelity Digital Assets published a study that highlights institutional investors' perceptions of and approaches to digital assets. The survey shows that

¹See CoinGecko, "Global Cryptocurrency Market Cap Charts." www.coingecko.com/en/global-charts.

²Olivier Fines and Stephen Deane, "Cryptoassets: Beyond the Hype," CFA Institute (4 January 2023). <https://rpc.cfainstitute.org/en/research/reports/2023/cryptoassets-beyond-the-hype>.

³From CoinGecko.com as of 26 July 2023.

⁴Stablecoins are typically pegged to another currency, such as the US dollar, and are backed by a pool of assets to maintain parity. As their values are intended to remain constant, stablecoins do not lend themselves to the valuation methodologies in this report.

⁵Fines and Deane, "Cryptoassets: Beyond the Hype."

adoption and consideration of digital assets among those surveyed is highest among high-net-worth investors, cryptoasset hedge funds, and financial advisers.⁶ Among those three groups, future preference to buy digital assets consistently had the highest positive change since 2021, whereas future intent to purchase decreased for defined benefit pension plans between 2021 and 2022. Finally, a CFA Institute survey of US-based financial advisers on cryptoassets from November 2022 showed most financial advisers are avoiding cryptoassets and that a generational divide exists, with financial advisers with the least experience (or the youngest ones) most receptive to cryptoassets.⁷

1.2. The Issue of Valuation

The valuation of cryptoassets has emerged as a critical topic owing to the growth in popularity and adoption of cryptoassets. While some industry stakeholders recognize cryptoassets as a legitimate asset class, many remain skeptical of their value proposition, leading to varied opinions and debates in the industry.

One of the main issues arising with the valuation of cryptoassets is the short period of time they have been in existence. For example, Bitcoin was launched in 2009, a time frame of only 14 years since the first cryptoasset was established. Other cryptoassets have much shorter histories; for example, Litecoin was launched in 2012 and Ethereum was launched in 2015. In comparison, equity valuation models have been developed over several decades, having the benefit of time and thus allowing for refinement over the years. Our interviewees acknowledged this challenge, noting that *Security Analysis*, a book by

Graham and Dodd from 1934 that is still being used to this day, was published decades after the establishment of equities as an asset class.⁸

The relatively short period of existence of cryptoassets can make arriving at a valuation model more challenging. Ongoing discussion and debate on valuation models for cryptoassets is therefore necessary, with the expectation that this process will eventually lead to a better consensus on a plausible valuation framework for cryptoassets and the digital finance ecosystem of business models. This report aims to contribute to that process.

1.3. Taxonomy of Cryptoassets

To ensure a comprehensive discussion on valuation models and metrics for cryptoassets, it is important to recognize the varying types of cryptoassets. The varying nature of cryptoassets means that this type of financial instrument may fall under more than one category. We refer to "The Global Crypto Classification Standard by 21Shares & CoinGecko"⁹ to classify cryptoassets included in this report, as shown in **Exhibit 1**.

Our examination of relevant valuation methods is limited to the three types of cryptoassets mentioned in the taxonomy in Exhibit 1, based on the availability of relevant literature and quantitative data. Although additional categories of cryptoassets have gained significant popularity, such as non-fungible tokens (NFTs), limited information and reliance on their qualitative features prevent us from conducting a comprehensive review of their valuation drivers.

⁶Fidelity Digital Assets, "Institutional Investor Digital Assets Study: Key Findings" (October 2022). www.fidelitydigitalassets.com/sites/default/files/documents/2022_Institutional_Investor_Digital_Assets_Study.pdf.

⁷CFA Institute, "New CFA Institute Survey Finds Most Broker Representatives Steer Clear of Cryptoassets" (15 March 2023). <https://rpc.cfainstitute.org/en/research/surveys/new-cfa-institute-survey-finds-most-broker-representatives-steer-clear-of-cryptoassets>.

⁸Benjamin Graham and David L. Dodd, *Security Analysis* (Whittlesey House, 1934).

⁹CoinGecko, "The Global Crypto Classification Standard by 21Shares & CoinGecko" (16 October 2023). www.coingecko.com/research/publications/global-crypto-classification-standard.

Exhibit 1. Classification of Cryptoassets by Level 1 of the Global Crypto Classification Standard

Category	Description	Examples	Comparable Traditional Sector
Smart contract platforms	"A base blockchain with built-in general purpose programmability that allows developers to write smart contracts and launch decentralized applications"	Ethereum (ETH), Solana (SOL), Polygon (MATIC), TRON (TRX), Cosmos (ATOM)	Information technology
Decentralized applications	"Internet-native infrastructure that does not rely on a centralized institution, such as a bank, broker, and similar intermediaries, and provides access to products and services (including financial services)"	Uniswap (UNI), Aave (AAVE), Compound (COMP), SushiSwap (SUSHI), Convex Finance (CVX)	Finance
Cryptocurrencies	"Blockchains or protocols specialized in transferring value. The demand for cryptocurrencies can stem from their utility as a means of exchange, unit of account, or store of value."	Bitcoin, Litecoin, Monero, Zcash, Stellar, Dash, XRP	Money

Source: CoinGecko, "The Global Crypto Classification Standard by 21Shares & CoinGecko."

2. THE INTERVIEW PROCESS

The core purpose of the research was to learn about the valuation models currently being applied to digital assets from professionals who are involved in the digital finance industry or have cryptoasset exposure. We conducted a series of interviews with professionals from various backgrounds and asked them to explain their views on current valuation models, their concerns, and cryptoasset allocation in portfolios. One caveat of this approach is that the opinions expressed may be biased by individuals' current or prior involvement with cryptoassets.

Through these interviews, we found areas of agreement among practitioners and observed a common trend in thinking around the valuation of cryptoassets:

- Among all interviewees surveyed, bitcoin remains the most popular cryptoasset in terms of interest or portfolio exposure, followed by ether. The market capitalization of both assets is a critical factor, especially compared with the next-largest asset in terms of capitalization, which is Tether (USDT),¹⁰ at approximately \$83 billion, compared with a market cap of \$528 billion for bitcoin and \$198 billion for ether, as of 19 September 2023.¹¹
- The lack of historical data is the biggest inhibitor to valuation frameworks for cryptoassets.
- Interviewees' target portfolio allocation to cryptoassets ranges between 2.5% and 5%, with a 5% allocation being considered the upper threshold from a risk management perspective. A portfolio allocation of less than 1.5% is deemed to be too small to have any considerable effect on returns for the additional risk taken by including cryptoassets.
- Decentralized applications can be valued using their cash flows or based on either relative valuation within the sector or relative valuation to traditional finance counterparts.
- There is a lack of consensus on the valuation of smart contract platforms because of the two competing views of what a smart contract platform is: a cash flow asset or a network.
- For bitcoin, the valuation model found most relevant to interviewees was the addressable market approach to either gold or M2 money supply,¹² depending on the investor's perspective on bitcoin as an alternative to gold ("digital gold") or a medium of exchange. This finding illustrates the uniqueness of bitcoin in that there is no consensus on its use case, which leaves it open to a diversity of valuation approaches. Furthermore, practitioners express doubts about the predictive value of the stock-to-flow model¹³ for bitcoin.

¹⁰Tether (USDT) is a stablecoin pegged to the US dollar. Its primary purpose is to maintain the value of \$1 at all times. Bitcoin is an unbacked asset, meaning it relies on supply and demand rather than on another asset for its value. See Parma Bains, Arif Ismail, Fabiana Melo, and Nobuyasu Sugimoto, "Regulating the Crypto Ecosystem: The Case of Unbacked Crypto Assets," FinTech Notes 2022/007, International Monetary Fund (26 September 2022). www.imf.org/en/Publications/fintech-notes/Issues/2022/09/26/Regulating-the-Crypto-Ecosystem-The-Case-of-Unbacked-Crypto-Assets-523715.

¹¹These data are from CoinMarketCap.com.

¹²M2 is a measure of the US money stock that includes M1 (currency and coins held by the non-bank public, checkable deposits, and travelers' checks) plus savings deposits (including money market deposit accounts), small time deposits under \$100,000, and shares in retail money market mutual funds" (Federal Reserve Bank of St. Louis). www.stlouisfed.org/financial-crisis/data/m2-monetary-aggregate.

¹³See Glassnode, "Bitcoin: Stock-to-Flow Ratio [USD]." <https://studio.glassnode.com/metrics?a=BTC&m=indicators.StockToFlowRatio>.

3. VALUATION MODELS

Here, we evaluate valuation models currently being used in the industry, focusing on those we believe to be most relevant for valuation purposes based on industry feedback. Furthermore, we evaluate models in existing literature and aim to address their relevance and limitations.

To organize our findings, we outline these models according to the type of cryptoasset:

- Smart contract platforms—tokens associated with foundational protocols used as a base layer for blockchain technologies
- Decentralized applications—internet native infrastructure that gives access to services without the need for an intermediary
- Bitcoin—the largest cryptoasset by market capitalization, with the most literature covering valuation aspects

3.1. Smart Contract Platforms

Smart contract platforms are defined as blockchain protocols (rules governing the operation of the platform) that facilitate the execution of smart contracts using tokens native to that platform. Smart contract platforms "power an ecosystem of decentralized applications across a diverse set of use cases. Tokens in the industry are colloquially associated with 'Layer 1 [base layer] platforms.'"¹⁴

Smart contract platforms belong to a broader class of blockchain infrastructure, which refers to "foundational protocols and utilities that support the development, interoperability, scale, and growth of

blockchain technologies."¹⁵ In addition to smart contract platforms, these include scaling protocols,¹⁶ interoperability protocols,¹⁷ and bridges.¹⁸ **Exhibit 2** shows examples of each.

Our analysis focuses on smart contract platforms as the foundational technology of blockchain infrastructure. The smart contract platforms we include are Ethereum, Solana, Cardano, Avalanche, and BNB Chain.

Ethereum, launched in 2015, was the first smart contract platform and continues to dominate in terms of market capitalization and total value locked (TVL).¹⁹ According to TheBlock.co, as of 19 September 2023, smart contract platforms have total value locked of \$35.72 billion, out of which Ethereum has \$21.39 billion. However, Ethereum faces congestion and high transaction fees in periods of high demand, which has led to the creation of other smart contract platforms to compete with Ethereum. Other platforms, such as Solana, Cardano, and Avalanche, have emerged with the aim to innovate and compete in this growing segment by offering, for example, different consensus mechanisms, burning mechanisms, and higher processing speeds. Platforms may have lower transaction fees as a trade-off to stimulate high user activity and growth. Higher processing speeds indicate the smart contract platform's capacity for processing transactions and its ability to accommodate an increasing number of users without slowing down the network.

Smart contract platforms allow for developers to create decentralized applications, including decentralized finance, gaming, and storage solutions. According to CoinMarketCap, as of 19 September 2023, the market capitalization of smart contract

¹⁴MSCI, "Datanomy Methodology: Guiding Principles and Methodology for Datanomy" (November 2022): 12. www.msci.com/documents/1296102/33887102/Datanomy+Methodology.pdf.

¹⁵For a description of blockchain technologies, see M. Hougan and D. Lawant, "Cryptoassets: The Guide to Bitcoin, Blockchain, and Cryptocurrency for Investment Professionals," CFA Institute Research Foundation brief (2021): 4–7.

¹⁶"A scaling protocol is a separate blockchain that helps augment the network capacity of a settlement blockchain by orders of magnitude while inheriting the security it guarantees of the latter." See CoinGecko, "The Global Crypto Classification Standard by 21Shares & CoinGecko."

¹⁷"Interoperability protocols: Networks specialized in interblockchain connectivity allow chains to communicate with each other by transmitting states or messages. These networks come in cross-chain bridge networks or hub-and-spoke models, where hubs connect spokes of application-specific blockchains." See CoinGecko, "The Global Crypto Classification Standard by 21Shares & CoinGecko."

¹⁸"A blockchain bridge is a protocol that outlines minting and burning procedures so that the token supply can be constant between two different platforms. Bridges serve as a transition between the different blockchain protocols." See CoinMarketCap, "Bridges." <https://coinmarketcap.com/alexandria/glossary/bridges>.

¹⁹Total value locked represents the value of assets that are currently being staked in a specific protocol. The TVL for a platform would be the sum of TVLs of all decentralized applications built on the respective platform. TVLs can be found at [DefiLlama.com](https://defillama.com), [Glassnode.com](https://glassnode.com), and other websites. See CoinMarketCap's "Crypto Glossary": <https://coinmarketcap.com/academy/glossary>.

Exhibit 2. Blockchain Infrastructure Sector Classification

Sector	Examples	Traditional Industry Counterpart
Smart contract platforms	Ethereum, Cardano, Solana	Cloud services
Scaling protocols	Starkware, Polygon, Arbitum	Cloud services
Interoperability protocols	Cosmos, Polkadot, Avalanche	Cloud services
Bridges	Celer, Multichain, Portal Token Bridge	Cross-border remittance payments

Source: CoinGecko, "Global Crypto Classification Standard by 21Shares & CoinGecko."

tokens was \$257 billion, with a daily trading volume of around \$4 billion. These smart contract platforms compete with each other and aim to provide better services based on such factors as scalability, processing speeds, and costs.

A smart contract platform has its own native asset for several reasons. First, it allows the platform to create and control its monetary system, making it customizable and specific to its features. Second, it enables standardization and interoperability within the platform's ecosystem because the native asset can directly support execution of the smart contract. Third, smart contract platforms require validators to validate transactions; the native asset is used to pay the validators to secure the blockchain according to the reward mechanism of the platform. Finally, it lets users participate in the governance of the platform, meaning that users can have a say in the platform's decision-making processes. Without the use of a native asset in these instances, it would be difficult to maintain the platform efficiently and according to the specific feature for which the platform was built.

The following are the top five smart contract platforms by market capitalization:

1. *Ethereum*: Ethereum was launched in 2015, and its native asset is ether (ETH). As the longest-operating smart contract platform, Ethereum had the first-mover advantage and thus currently has the highest market cap and TVL among smart contract platforms. The Ethereum Foundation is a non-profit organization supporting Ethereum by allocating resources to projects and funding research, development, and education. The transaction fees on Ethereum (paid in ETH) pertain to transactions on the platform itself and are not received by the Ethereum Foundation as cash flows.²⁰
2. *BNB Chain*: Launched in 2019, BNB Chain is a smart contract platform created by Binance. Its native asset is BNB, which can be used in decentralized applications and as a transactional currency on the Binance Smart Chain. It focuses on low transaction fees, and since it is backed by Binance, it facilitates easy integration with other Binance products and services.
3. *Cardano*: Cardano was launched in 2017, and its native asset is ADA. Cardano optimizes for scalability and energy efficiency, meaning that it is capable of processing a higher number of transactions as the number of users on the platform increases and requires less energy compared with other smart contract platforms. Furthermore, it enables greater bandwidth capacity, allowing transactions to include substantial amounts of supportive data. Its primary use case is to serve as a currency for payments and transactions for decentralized applications built on the Cardano blockchain. Cardano's organization has built products for identity verification and supply chain tracking, while also being used to address financial inclusion in developing countries, allowing access to lending and borrowing services for the "underbanked."
4. *Solana*: Solana was launched in 2020, and its native asset is SOL. Solana optimizes for scalability by using larger block sizes, allowing 50,000 transactions per second. The higher scalability leads to lower congestion and lower fees for users.
5. *Avalanche*: Avalanche was launched in 2020, and its native asset is AVAX. Similar to its counterparts, Avalanche supports decentralized applications on its network, but it aims to have high throughput and low latency, meaning it is

²⁰See the Ethereum Foundation's website: <https://ethereum.foundation/>.

optimized to process a high volume of data with minimal delay. Its business model is based on low fees and high volume.

3.1.1. Valuation Models

Smart contract platforms have multiple use cases, including peer-to-peer transactions, executing transactions in decentralized applications, trading assets, and rewarding validators who add blocks to the blockchain. There are two main viewpoints on smart contract platforms. The first view looks at a smart contract platform as a business and aims to evaluate the native asset through definable cash flows derived from its business model. This viewpoint would see transaction fees as a source of revenue. The second viewpoint identifies a smart contract platform as a network and measures its value and growth through network effects. Viewed through this lens, lower transaction fees attract more users and thus could increase revenues and value.

3.1.2. Valuing Blockchains as a Cash Flow Asset

Understanding Transaction Fees as Cash Flows

One way to conduct valuation on blockchain platforms is to consider them as a cash flow asset, where income is generated through selling block space.²¹ Block space is required for any transaction to take place on the platform and is paid for in the form of a transaction fee denominated in the native asset of the platform. When there is an increase in demand for the platform, these users compete for block space by increasing the fees they are willing to pay.

The total transaction fee is typically split into a base fee and a priority fee. The base fee is "burned"²² (often likened to a share buyback), and the priority fee is given to the validator for validating the transaction, which secures the network. Blockchain platforms have various characteristics and operate differently depending on their purpose, meaning that the division of transaction fees will depend on each platform. To further understand this concept, we look at what happens to a transaction on Ethereum.

A transaction fee on Ethereum is known as a "gas" fee, with gas being a unit of measure for the computational effort required to process the transaction. The equation to calculate the transaction fee is

$$\text{Transaction fee} = \text{Units of gas used} \times (\text{Base fee} + \text{Priority fee}).$$

Fees on the Ethereum platform are denoted in gwei. Gwei, short for gigawei, is a small unit of ether. One ether is equal to 10^9 gwei. A simple transaction, such as sending ETH to a friend, would require using a minimum of 21,000 units of gas; more complex transactions would use more gas. The base fee part of the transaction fee is dynamic; it is set by the platform and changes according to the demand for the network (the higher the demand for the network, the higher the base fee). Continually, the priority fee, which goes to the validator (also referred to as a supply-side fee), can be adjusted by the user depending on how fast the user wants the transaction to be processed.

Exhibit 3 shows the breakdown of fees for an Ethereum transaction at 3:23 p.m. EDT on 18 May 2023. Users can have their transaction processed faster for a higher fee. As the exhibit illustrates, for a transaction to take place at a higher speed, the user would have to pay 5 gwei as the priority fee instead of 1 gwei for a lower speed.

Consider a simple transaction of sending someone ether. To calculate the transaction fees in ETH, we

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Exhibit 3. Transaction Fees Breakdown on Ethereum

	Low	High
Base fee	74 gwei	74 gwei
Priority fee	1 gwei	5 gwei
Base + Priority	75 gwei	79 gwei
Time	3 mins.	30 secs.
Total fee	\$2.83	\$2.98

Source: Etherscan (<https://etherscan.io/gastracker>).

²¹Block space is space on a blockchain where you can run code and store data.

²²"Burned" refers to the permanent removal of coins from the circulating supply, and usually the purpose is deflationary; removing coins from circulation will lead to price appreciation of the cryptoasset.

take the minimum units of gas required (21,000), multiply this amount by the sum of the base fee and the priority fee (assuming "low speed" processing time), and divide it by 10^9 .

$$\begin{aligned}\text{Transaction fee} &= 21,000 \times (74 + 1) \\ &= 1,575,000 \text{ gwei.}\end{aligned}$$

Converting to ETH: $1,575,000/10^9 = 0.001575$ ETH.

This basic transaction of sending ETH would cost 0.001575 ETH, which is equal to \$2.83 as of the time of writing.

In a proof-of-stake system, new blocks²³ are added to the blockchain by network participants referred to as "validators," who are required to run software and lock (stake) tokens to participate in validating. They are rewarded for performing these tasks through the staking reward (expressed in annual percentage rate, or APR).

In the case of Ethereum, validators earn ether through two sources: the consensus layer and the execution layer. Consensus rewards are given to validators to participate and maintain network security, and execution rewards are given to validators for executing transactions and related tasks.

$$\begin{aligned}\text{Staking rewards/APR} \\ &= \text{Newly issued ETH (consensus rewards)} \\ &\quad + \text{Priority fees (execution rewards)}.\end{aligned}$$

Exhibit 4 shows the breakdown of staking rewards expressed in APR terms.

Intrinsic Valuation: DCF Model for Ethereum

Discounted cash flow valuation views the intrinsic value of a security as the present value of its expected future cash flows. To further analyze how the DCF model works in the context of smart contract platforms, we apply the same methodology to Ethereum.

Ethereum uses a portion of its fees to reduce supply (i.e., "burning" tokens received as transaction fees, akin to a share buyback) and pay staking rewards (akin to income) to validators. As noted previously, it also issues new ETH to validators for performing consensus tasks.

Exhibit 4. Breakdown of Staking APR Using On-Chain Data, as of April 2023

Total supply	120.04 million
Total ETH staked	18.1 million
Burnt ETH	2,875.3
Daily priority fees	404.8
Daily issuance	1,790
Staking APR (issuance)	3.61% ^a
Staking APR (fees)	0.82% ^b
Staking APR (issuance + fees)	4.43%

^aCalculated as $\{[1,790 \text{ (daily issuance)} \times 365]/18.1 \text{ million (total ETH staked)}\} \times 100$.

^bCalculated as $\{[404.8 \text{ (daily priority fee)} \times 365]/18.1 \text{ million (total ETH staked)}\} \times 100$.

Note: All units in ETH.

Source: Mustafa Bedawala and Aaron Salot, "Ethereum's Economics and Staking Model," Visa (2023). <https://usa.visa.com/solutions/crypto/cryptoeconomics.html>.

We consider the cash flows (CF) as the sum of transaction fees plus the newly issued ETH, represented in the following equation:

$$\text{CF} = \text{Transaction fees} + \text{Newly issued ETH.}$$

$$\text{CF} = [\text{Base fee} + \underbrace{\text{Priority fee} + \text{Issuance of ETH}}_{\text{Staking rewards}}]$$

Thus, validators receive the priority fee portion of the total transaction fee (execution rewards) and the issuance rewards for consensus tasks. These staking rewards—all paid in ETH—represent cash flow to the validators.

Previous models, such as that of Allis,²⁴ consider cash flows that go to long-term holders either through staking rewards (income) or burning tokens (share buybacks), thus encompassing a more expansive view of cash flow. All the revenue from transaction fees is either burned (causing a theoretical

²³According to CoinDesk, a block refers to "a collection of data that contains a timestamp and other encrypted information about recent transactions that need to be validated by the network before being added onto the chain".

²⁴Ryan Allis, "ETH's Intrinsic Value Comes from Cash Flows," Coinstack (13 May 2021). <https://coinstack.substack.com/p/intrinsic-value-comes-from-cash-flows>.

increase in ether value as supply decreases) or given out as execution rewards. Additionally, validators will receive their share of new ether issued every year (approximately 1,700 ETH per day)²⁵ to secure the blockchain (consensus rewards). The model estimates the sum of these cash flows over a 20-year period, starting with a high growth rate of 50%, a discount rate of 12%, and no exit multiple for a more conservative estimate of value over the 20-year horizon.

Cumberland²⁶ conducted a DCF analysis on total fees paid that are either burned or given out as staking yield. The study assumes a discount rate of 10% and a terminal growth rate of 3%. The growth rate estimates include growth on Layer 1 (Ethereum) and growth on Layer 2 platforms (scaling solutions for Ethereum), thus encompassing a broader estimate of growth.

As these studies (and our preceding analysis) demonstrate, the cash flow component of the discounted cash flow model can be subject to the analyst's interpretation. One view is to consider only the cash flows received by an ETH holder (such as a validator) who stakes her assets and receives the priority fee and issuance of ETH. This view would exclude from cash flow the increase in the value of ETH due to the "burning" of the base fee. The second view involves including the theoretical increase in value from Ethereum's burning mechanism in the cash flow component. This approach is reflected in both the Allis and Cumberland models.

The issuance mechanism and the burn mechanism determine the inflationary nature of Ethereum based on the transaction volume on the network.

A comparison with traditional finance would be to examine a stock's value using its dividend yield. In this context, an analyst might consider the burning mechanism as a buyback that has a positive effect on Ethereum's value and may choose to incorporate it into his analysis.²⁷

For our analysis, to estimate the growth rate, we examine Ethereum transaction fees²⁸ between 2020 and 2023. Ethereum transaction fees were \$592.84 million in 2020 and \$9.90 billion in 2021, an increase of 1,565.76%. In 2022, fees were \$4.30 billion, representing a 56.57% decrease. Annualized transaction fees for 2023 (as of the time of writing) were \$2.3 billion. This leads to a compound annual growth rate (CAGR) between 2020 and 2023 of 56.99%, which we use as our growth rate in 2023, smoothing out the year-on-year growth rates between 2020 and 2023. For this example, we assume that the current high growth rates will stabilize over time and, accordingly, reduce the growth rate by 10% each year as use of the blockchain matures.

Under the assumptions of Allis,²⁹ the cash flows we calculate are as follows. Total transaction fees in 2023 amounted to \$2.3 billion. This amount includes burned ETH and the total priority fees given to validators. Issuance of ETH amounts to approximately 1,700 ETH per day.³⁰ This amount translates to 625,000 ETH per year, totaling \$1.03 billion worth of ETH issued every year (based on the ETH price as of 19 September 2023). Under this model, the total cash flows equal transaction fees plus newly issued ETH to validators, amounting to \$3.36 billion for the year 2023.

Using the Damodaran Online dataset, accessible through the CFA Institute Research Foundation Investment Data Alliance,³¹ we can obtain input data to estimate model parameters. The discount rate in our model, 12.24%, is calculated using the capital asset pricing model using data for market betas from Refinitiv for 35 small-cap software sector firms and risk premium estimates from the Damodaran Online dataset (see Appendix 2 for details). We use a terminal exit multiple of 22.4×, which represents the software (internet) sector average EV/EBITDA for the same sample of small-cap software firms. We apply the terminal exit multiple to the Year 5 cash flow.

For comparability, the Damodaran Online dataset provides a current estimate (at the time of analysis)

²⁵The estimate of 1,700 ETH issued per day is from the Ethereum Foundation. The actual amount fluctuates each day. See <https://ethereum.org/en/roadmap/merge/issuance/>.

²⁶Cumberland, "Valuing Ethereum into the Merge" (31 May 2022). <https://cumberland.io/insights/research/valuing-ethereum-into-the-merge>.

²⁷A. Manconi, U. Peyer, and T. Vermaelen, "Are Buybacks Good for Long-Term Shareholder Value? Evidence from Buybacks around the World," ECGI Working Paper Series in Finance, Working Paper No. 436/2014 (March 2018). www.ecgi.global/sites/default/files/working_papers/documents/finalmanconipeyervermaelen_0.pdf.

²⁸Obtained from <https://tokenterminal.com/terminal/financial-statements>.

²⁹Allis, "ETH's Intrinsic Value Comes from Cash Flows."

³⁰Obtained from <https://ethereum.org/en/upgrades/merge/issuance/>.

³¹See <https://rpc.cfainstitute.org/en/research-foundation/investment-data-alliance>.

of 13.09% for the cost of equity³² for the US software (internet) sector as a whole and an EV/EBITDA multiple of 14.84 (for the same sector). These estimates provide an illustration of the range of plausible values for use in the DCF model. Using the DCF approach, we can calculate the present value of ether as follows:

$$PV = \sum_{t=1}^T \frac{CF_t}{(1+r)^t} + \frac{TV}{(1+r)^T}$$

where

CF_t = Cash flow in period t

r = Discount rate

PV = Present value

TV = Terminal value

A worked example is provided in **Exhibit 5**.

According to these calculations, the value of ETH would be \$1,947.91, which compares with a closing market price on 19 September 2023 of approximately \$1,642.60, implying the token is undervalued.

Note that, as with any discounted cash flow analysis, the output is sensitive to the model parameters, and it is a matter of professional judgment which assumptions a practitioner chooses to apply.

Apart from using EV/EBITDA as a terminal exit multiple, akin to an exit value for liquidation of a capital investment, we can also use a perpetual growth rate that assumes the security is held in perpetuity. In this case, to calculate the terminal value, we would substitute the exit multiple that is applied to the Year 5 cash flow for the Gordon growth model

equation.³³ For example, if we use a perpetual growth rate of 6.99% (i.e., continuing the process of reducing the previous year's growth rate by 10% and then applying that growth rate into perpetuity as a steady-state growth rate) and maintain other model parameters, we arrive at a value of \$1,800.34 per ETH. This example is illustrated in **Exhibit 6**.

Another formulation of a DCF model is the H-model, adapted from the dividend discount model in equity valuation. The H-model assumes a supernormal growth phase (g_s), which we assume to last for the five years outlined in this analysis, declining linearly each year to a constant long-term growth rate (g_l) from Year 5 onward. In this formulation, the half-life of the supernormal growth phase (H) is 2.5 years. The model is calculated as

$$PV_t = \frac{CF_t(1+g_s) + CF_t H(g_s - g_l)}{r - g_l}$$

Using the same beginning period growth rate (g_s) and perpetual growth rate (g_l) as the previous models, we arrive at a valuation of \$1,502.46 per ETH, as illustrated in **Exhibit 7**.

The purpose of these illustrations is not to specify a particular approach or set of parameters but to show a variety of plausible DCF frameworks that analysts may use and adapt.

As these models imply, changes in either the discount rate, growth rates, or the time horizon can lead to significant changes in present values, and the components of cash flow are subject to analyst discretion. Furthermore, the assumptions in the DCF model may be biased by the investor's own outlook on the cryptoasset industry itself. Ultimately, investment

Exhibit 5. Discounted Cash Flow Model for Ethereum

DCF Model, Five-Year Holding Period with Exit Multiple		2023	2024	2025	2026	2027	2028
Cash Flow (\$ millions)		3,363.11	5,279.75	7,760.70	10,631.38	13,500.79	15,794.58
Growth rate			56.99%	46.99%	36.99%	26.99%	16.99%
Terminal value	22.4						353,482.62
PV of cash flows			4,704.0	6,160.4	7,518.8	8,506.8	207,307.1
Total PV (\$ millions)	234,197.06						
Outstanding supply (millions)	120.23						
Price per ETH (\$)	1,947.91						
Discount rate	12.24%						

³²The cost of equity is considered most appropriate for the discount rate in this model because Ethereum does not issue debt.

³³In the Gordon growth model, a form of the discounted dividend model where the cash flows (dividends, D) are assumed to grow at a constant rate (g) into perpetuity, the present value as of year t is given by $PV_t = D_t / (r - g)$.

Exhibit 6. Discounted Cash Flow Model for Ethereum (Gordon Growth Model Example)

DCF Model, Perpetual Holding Period, Gordon Model		2023	2024	2025	2026	2027	2028
Cash Flow (\$ millions)		3,363.11	5,279.75	7,760.70	10,631.38	13,500.79	15,794.58
Growth rate			56.99%	46.99%	36.99%	26.99%	16.99%
Terminal growth rate in perpetuity							6.99%
Terminal value							321,878.42
PV of cash flows			4,704.0	6,160.4	7,518.8	8,506.8	189,565.0
Total PV (\$ millions)	216,454.9						
Outstanding supply (millions)	120.23						
Price per ETH (\$)	1,800.34						
Discount rate	12.24%						

Exhibit 7. Discounted Cash Flow Model for Ethereum (H-Model Example)

DCF Model, Perpetual Holding Period, H-Model	
Cash Flow $t = 0$ (\$ millions)	3,363.11
Supernormal growth rate	56.99%
Years	5
Half-life of supernormal growth rate, H	2.5
Long-term growth rate	6.99%
Total PV (\$ millions)	180,640.65
Outstanding supply (millions)	120.23
Price per ETH (\$)	1,502.46
Discount rate	12.24%

professionals should be cognizant of these factors and use prudent judgment, using independent parameters from reputable sources when formulating their analyses.

3.1.3. Valuing Blockchain Platforms as a Network

Those who view a blockchain platform as a network consider the native asset like the official currency of a nation. For example, ether would be the "official currency" of the "nation" (or "economy") of Ethereum, where all transactions in the economy take place using the official currency. This view entails that the growth of the nation would lead to appreciation in the price of the underlying currency or native asset. Viewed in this context (i.e., the native asset is the

local currency), we can measure smart contract platforms on a relative basis with one another based on various on-chain metrics.

The growth of smart contract platforms is based on network effects,³⁴ and positive network effects take place in a procyclical mechanism. The native asset is required for transactions on the platform, and network validators receive fees for verifying blocks. The fees attract more validators, and the higher number of validators leads to more security on the network. The security of the network will attract developers to build decentralized applications on the platform, which again attracts more users, increasing demand for the native asset, and thus creating a positive network effect. As more transactions take place on the platform, the number of tokens burned will also

³⁴The network effect is the phenomenon whereby the more people use a company's product or service, the more the product's or service's value rises for both existing and new users.

increase, limiting supply and supporting appreciation in the native token's price.

The decentralized and transparent nature of blockchain platforms allows interested participants to view and understand how the platform is performing, based on on-chain data, and assess its health and usage.

On-chain metrics are data points derived from the information generated by the blockchain network, such as the size of the blockchain, the number of blocks, or number of active addresses. The time-series nature of on-chain metrics allows interested participants to gain insight into the historical activity of a blockchain. When viewing blockchain platforms as a network, on-chain metrics facilitate the analysis of competing smart contract platforms on a relative basis based on such factors as demand, supply, activity on the platform, and their "tokenomics."³⁵

Exhibit 8 shows demand-side metrics of Ethereum, Solana, BNB Chain, Avalanche, and Cardano, including active addresses (as a proxy for the number of users), fees, total value locked, and number of active developers.

These demand-side metrics are indicators of how the platform is currently performing, and changes in these metrics can point to future performance and growth prospects.

For example, an increasing number of developers building decentralized applications on smart contract platforms is an indicator of increasing demand for the platforms' native token. Total value locked represents the total value of cryptoassets staked³⁶ across all decentralized applications built on a specific platform. As shown in Exhibit 8, the platform with the highest TVL is Ethereum, followed by BNB Chain. TVL is an indicator of value and usage of the platform, and under a network effects model, higher TVL correlates with higher future value and usage.

Developer activity simply refers to the number of developers who are building applications on a blockchain platform, and it can indicate future activity. As more applications are built on a specific platform, users are attracted to those applications, ultimately increasing demand for the platform. Similar to total value locked figures, Ethereum is the leader in terms of active developers, followed by Cardano. Active

Exhibit 8. Demand-Side Metrics for Smart Contract Platforms

	Ethereum	Solana	Cardano	BNB Chain	Avalanche
Market capitalization (as of 19 Sep. 2023)	\$197.6 billion	\$8.24 billion	\$8.93 billion	\$33.34 billion	\$3.24 billion
TVL (as of 19 Sep. 2023)	\$21.39 billion	\$310.29 million	\$152.26 million	\$2.86 billion	\$496.3 million
Fees (annualized)	\$2.33 billion	\$14.9 million	\$1.54 million	\$576.7 million	\$91.1 million
Active addresses (daily avg., Sep. 2023)	354,580	84,740	116,000	935,670	34,750
Core developers (Sep. 2023)	182	69	173	55	52
Market cap to TVL ratio	9.23	26.5	58.64	11.6	6.52
Price-to-fees ratio	84.8×	505.03×	5295.57×	299.78×	641.18×

Sources: DefiLlama; Token Terminal.

³⁵For more on valuation framework, see K. Talati and N. Hotz, "The ETH Merge and Valuing Layer 1 Blockchains," video, Arca (13 October 2022). www.arca.com/layer1-val-recording?submissionGuid=e154ca89-b747-4070-a28a-2ff6106fa3d9.

³⁶Staking refers to locking up cryptoassets to serve as a validator to the blockchain and receiving a share of transaction fees as a return on the principal amount. See Hannah Lang and Elizabeth Howcroft, "Explainer: What Is 'Staking,' the Cryptocurrency Practice in Regulators' Crosshairs?," Reuters (10 February 2023). www.reuters.com/business/finance/what-is-staking-cryptocurrency-practice-regulators-crosshairs-2023-02-10/#:~:text=What%20is%20staking%3F,via%20third%2Dparty%20staking%20services.

addresses³⁷ are an indicator of current activity and historical expansion and contraction of the platform. They are a common proxy for the number of users on the smart contract platform. An increase in addresses over time indicates higher demand for the native asset, with the expectation of an increase in its price.

Finally, transaction fees are charged on each transaction taking place on the platform. The fees, paid in the native token, are an indirect indicator for the growth of the platform. However, as we highlighted earlier, the fee structure of each smart contract platform differs. For example, Ethereum has higher fees compared with the other platforms (shown on the next page). The fee structure affects the total fees generated by the blockchain platform, inhibiting comparability, and thus fees should not be used as the sole indicator of value.

Tokenomics

"Tokenomics," short for token economics, is the structure of a cryptocurrency's economy, which determines the incentives that set out how the token will be distributed and the utility of the tokens that influence its demand.³⁸ The main variables of a cryptoasset's tokenomics are supply, inflation, token

burns, allocation of tokens to the founding team and venture capital firm³⁹ (as applicable), vesting period,⁴⁰ and staking yield. These factors are decided by the protocol team and are typically outlined in a white paper before launch.

Most smart contract platforms are based on a proof-of-stake mechanism that requires the staking of the native asset to validate and process transactions. Users act as validators when they stake the respective asset to the smart contract platform and receive a return for locking up their asset, referred to as a staking yield. The staking yield depends on the total amount of the native asset staked and the total amount of rewards released to validators. Both factors are subject to change, depending on the inflation of the native asset and the number of transactions taking place on the smart contract platform. A simple calculation for staking yield is $\text{Staking yield} = (\text{Block rewards} / \text{Total network amount staked}) \times 100$.

Exhibit 9 illustrates the tokenomics of the smart contract platforms we analyzed earlier.

One of the biggest factors that affects cryptoasset prices is the supply of the cryptoasset in question. If there is a limited supply of the cryptoasset and assuming demand remains constant or grows, the

Exhibit 9. Tokenomics for Smart Contract Platforms

	Ethereum	Solana	Cardano	BNB Chain	Avalanche
Maximum supply	n/a	n/a	45,000,000,000	200,000,000	720,000,000
Current inflation	-0.37%	5.49%	1.82%	-5.34%	21%
Private token allocation	15%	48%	17%	50%	42%
Staking APR	4.8%	6.54%	4.6%	2.68%	8.47%

Note: Maximum supply is the total supply of the asset that could ever exist; n/a means the native asset does not have a maximum limit.

Sources: [Messari.io](https://messari.io); [Dune.com](https://dune.com); staking APRs are from the platforms' websites.

³⁷Active addresses refer to users that interact with a protocol during a predefined time interval through either conducting transactions (sending or receiving) or such events as engaging in economic activities, such as lending. See <https://www.coingecko.com/en/glossary/daily-active-addresses>.

³⁸R. Stephens, "What Is Tokenomics and Why Is It Important?," CoinDesk (11 November 2022). www.coindesk.com/learn/what-is-tokenomics-and-why-is-it-important/.

³⁹In many cases, the founding team building the smart contract platform may raise venture capital (VC) to fund projects, in which case the investor or VC firm is typically allocated a certain share of the native asset in exchange for capital (similar to startups offering equity to raise capital). The investor or firm is allowed to sell the native asset at a future date depending on the vesting schedule.

⁴⁰During the vesting period, holders of tokens sold in the initial coin offering stage, founding partners, and backers are prevented from selling their tokens. The vesting schedule determines the release and sale of these tokens at intervals throughout a given period, thus preventing any dumping of the tokens and a crash in price. See CoinMarketCap's "Crypto Glossary": <https://coinmarketcap.com/alexandria/glossary>.

price of the respective cryptoasset will appreciate in the long term. Among the five smart contract platforms we considered in this report, Cardano, Avalanche, and BNB Chain are the only ones that have a maximum supply of tokens.

Inflation refers to the increasing supply of the cryptoasset in circulation. If supply exceeds demand, the cryptoasset will decrease in value over time. However, issuing new coins is desirable because it ensures security for the network. When validators stake their assets to validate transactions on the network, new coins are issued to them as a reward for staking their assets. To counteract the growing supply and to stabilize the price, some platforms use a token "burning" mechanism, permanently removing them from circulation and thus reducing token supply, which can lead to the cryptoasset becoming deflationary. For example, BNB Chain uses a quarterly auto-burn, which removes BNB from supply, with a long-term goal of limiting the coins in circulation to 100 million BNB. Generally, a new platform will have high inflation at the early stages to secure the network, but note that decreasing inflation should be an indicator of a decreasing supply in the future.

Token allocation (or "distribution") refers to how the token's supply will be distributed among stakeholders, such as venture capital firms, the founding team, and retail investors. These tokens are typically vested over several years but vary significantly on the basis of what each founding team of the platform negotiates with the VC firm. The founding team of the platform tends to plan the distribution of tokens over time to decrease the impact of the increase in supply on the native asset's price. If tokens are allocated

disproportionately toward the VC firm, this allocation may in the future lead to a fall in the value of the token when the VC firm decides to exit its position and sell the asset for gains.

Insider distribution can also provide an insight into how centralized the platform is. As shown, Ethereum and Cardano have the lowest insider holdings, 15% and 17%, respectively. In contrast, Solana, BNB Chain, and Avalanche have given close to 50% of their supply to insiders.

Lastly, we look at how these platforms can handle security and their scalability. If a platform has an increasing number of users and decentralized applications, the network should be able to handle that scale and maintain lower fees. Only if the network is scalable would there be a chance for network effects to take place.

As shown in **Exhibit 10**, Solana has the highest capacity for transactions per second, whereas Ethereum has the lowest. The transactions per second rate for ETH is 11.16 and is near its capacity limit, or max TPS (as of the date of this analysis). Comparatively, the average TPS for the other four platforms ranges from 0.5% to 13% of their capacity. Periods of high activity lead to data congestion, increasing transaction fees, and delays in the processing of decentralized applications.

A solution to the scalability issue is the creation of so-called Layer 2 solutions. "Layer 2 refers to a set of off-chain solutions (separate blockchains) built on top of" Layer 1 platforms (our examples) "that reduce bottlenecks with scaling and data."⁴² As an analogy, the credit card company Visa groups transactions



Exhibit 10. Scalability Metrics for Smart Contract Platforms, as of 12 April 2023

	Ethereum	Solana	Cardano	BNB Chain	Avalanche
Transactions per second (TPS)	11.16	3,960	1.84	41.9	23.53
Max TPS	15	44,838	250	300	4,500
Average transaction fee	\$4.79	\$0.0001	\$0.066	\$0.19	\$1.05

Source: Blockchain explorer⁴¹ tool websites for each smart contract platform.

⁴¹A blockchain explorer allows users access to information related to the blockchain, including all the transactions that have occurred on the blockchain, the fees for conducting transactions, and the status of their transaction. Examples include Etherscan.io for Ethereum and SnowTrace.io for Avalanche.

⁴²See M. Marcobello, "What Are Layer 2s and Why Are They Important?," CoinDesk (29 September 2023). www.coindesk.com/learn/what-are-layer-2s-and-why-are-they-important/.

into batches to be settled by banks at regular intervals; we can consider Visa to be Layer 2 and the banking system to be Layer 1.⁴²

Layer 2 solutions not only help handle platform congestion but also lower fees as they bundle multiple transactions into one. However, a growing number of Layer 2 solutions split liquidity (volume of transactions) from the Layer 1 platform. Another issue relates to the revenue of blockchain platforms. Layer 2 platforms pay a security fee for publishing their data on the Layer 1 blockchain. If more activity moves to Layer 2 solutions and those blockchains require their own tokens for transactions, it will reduce the staking yield on the Layer 1 platform and reduce the amount of native tokens staked on that platform. This situation would reduce revenue and may increase the amount of tokens in circulation (e.g., in the case of Ethereum, less ETH would be "locked up" in staking), leading to a reduction in price and security of the network.⁴³ Thus, there might be a trade-off between growth and revenue as Layer 2 solutions are implemented.

In summary, such factors as demand metrics, tokenomics, and scalability can assist in valuing smart contract platforms as a network or an economy. If we consider smart contract platforms as an economy and the native asset as its "official" currency, on-chain metrics allow us to measure the demand and supply, as well as the security of the economy, and to subsequently value the native asset relative to its competitors.

Example: Relative Valuation Framework Comparing Solana and Cardano

In this example, we provide an outline of how two competing smart contract platforms perform based on various on-chain metrics, which are used to support a relative valuation analysis. Because Ethereum has a first-mover advantage compared with other platforms, it has higher network activity and outperforms other platforms in several aspects; thus, we focus our relative valuation analysis on two more closely comparable platforms—Cardano and Solana.

As **Exhibit 11** illustrates, Solana leads Cardano in terms of total value locked, with \$310.29 million, compared with Cardano's \$152.26 million. The higher value invested and locked into Solana's ecosystem may be an attractive factor for users and investors. Solana also generates significantly higher fee

revenue compared with Cardano, indicating higher activity on Solana. Solana lags Cardano on active developers, however, which may point to potentially greater innovation and enhanced functionality in the future on Cardano.

The tokenomics for Cardano stand out. Notably, it has a lower current inflation rate (1.82%) than Solana (5.49%). Lower inflation can be favorable for investors because it reduces the potential dilution of existing holders, leading to a potential price appreciation over time. Furthermore, the private token allocation for Solana is 48%, which is significantly higher than that for Cardano. This percentage represents the number of tokens distributed to private investors or contributors during the early stages of the project. Cardano's lower private token allocation indicates a more decentralized distribution of tokens and lower concentration risk, reducing the likelihood of insider transactions significantly affecting the token's price. However, Cardano offers a lower staking yield than Solana.

In terms of scalability, the maximum transactions per seconds that Solana can potentially handle is much higher than that for Cardano (and with lower transaction fees). However, capacity utilization (current transactions per second) is significantly below the maximum TPS for both platforms, indicating that if activity increases in the future because of higher demand, both Solana and Cardano have ample capacity to accommodate the increase in transactions without slowing down the network, and users should not face higher fees due to network congestion.

Overall, we observe that Solana tends to outperform Cardano on demand and scalability metrics. However, the tokenomics of Solana may be an area of concern. If we analyze tokenomics in greater depth—referring to the vesting schedule of the smart contract platform—we may find further insights regarding the risks associated with the private token allocation. For example, if the vesting schedule is well planned out over a relatively long time horizon, it may reduce the impact of a large number of tokens entering the market in a short period of time as insiders sell their allocations, reducing the impact on the token price (and thus the degree of risk associated with the tokenomics).

We can further expand the analysis by calculating relative valuation metrics, such as the market capitalization to TVL and price-to-fees ratios.

⁴³See D. Duong, "Could L2s Eat Ethereum's Lunch?," Coinbase (8 August 2022). www.coinbase.com/institutional/research-insights/research/monthly-outlook/could-l2s-eat-ethereums-lunch-august-2022.

Exhibit 11. Relative Valuation Analysis of Solana and Cardano Based on On-Chain Metrics, as of 19 September 2023

	Solana	Cardano
<i>Demand-side metrics</i>		
Total value locked	\$310.29 million	\$152.26 million
Fees	\$14.97 million	\$1.54 million
Active addresses	84,790	116,000
Core developers	69	173
<i>Tokenomics</i>		
Maximum supply	n/a	45,000,000,000
Circulating supply	412,877,337	35,124,664,414
Current inflation	5.49%	1.82%
Private token allocation	48%	17%
Staking APR	6.54%	4.6%
<i>Scalability</i>		
TPS	4,362	1.84
Max. TPS	44,838	250
Average transaction fee	\$0.0001	\$0.066
<i>Metrics</i>		
Market capitalization	\$8.24 billion	\$8.93 billion
Market cap to TVL ratio	26.5×	58.64×
Price-to-fees ratio	505.03×	5,295.57×

Note: n/a means no maximum limit.

Sources: Multiple sources, including TokenTerminal.com, Messari.io, Dune.com, DefiLlama.com, Solscan.io, and Cardanoscan.io.

The price-to-fees ratio (P/F) is calculated as the market capitalization divided by annualized total transaction fees (including protocol revenue and supply-side fees). P/F indicates how the market is valuing the fees generated by a smart contract platform:

$$P/F = \frac{\text{Market capitalization}}{\text{Annualized fees}}$$

Total value locked represents the dollar value of funds that are currently being staked on all decentralized applications on a smart contract platform. An increasing TVL indicates more capital being locked into the platform, which is beneficial for users and

generates more activity. The market cap to TVL ratio is calculated as

$$\text{Market cap to TVL ratio} = \frac{\text{Market capitalization}}{\text{Total value locked}}$$

We can calculate the price of Solana based on Cardano's market cap to TVL ratio using the values in Exhibit 11. The calculation for the value of Solana at Cardano's current multiple (as of the date of analysis) is as follows:

$$\text{Cardano market cap to TVL ratio} = \frac{\text{Price} \times \text{Number of SOL tokens}}{\text{Total value locked in SOL}}$$

$$58.64 = (\text{Price} \times 412.877)/310.29.$$

$$\begin{aligned} \text{SOL price at Cardano multiple} \\ = (58.64 \times 310.29)/412.877 = \$44.07. \end{aligned}$$

The market price of Solana—\$19.27, as of 19 September 2023—is below its value based on the comparable TVL multiple of Cardano. Although Cardano has a lower TVL than Solana, its market capitalization to TVL ratio is much higher than that of Solana. This result is an indicator that Cardano is overvalued because Solana has a much lower ratio but a higher total value locked in its ecosystem.

More generally, we can extend the comparable analysis to either of the ratios, using the same formula:

$$V = \frac{(m_c \times d)}{s},$$

where

V = Value (estimated price of the respective token)

m_c = Market multiple of competitor (e.g., market cap/net assets, price-to-sales ratio (P/S), P/F, market cap to TVL ratio, as applicable)

d = Denominator (e.g., net assets, sales, fees, TVL, as applicable)

s = outstanding supply of tokens

Finally, comparing V with the current market price of the given token enables an evaluation of whether the smart contract platform is under- or overvalued relative to its peers.

In the case of Solana and Cardano, P/F indicates the valuation of both platforms relative to the fees they collect. Cardano has a P/F 10 times that of Solana, which indicates that Cardano is overvalued compared with its peer because it collects about a tenth of the fee revenue for a similar market capitalization.

Finally, performing a relative valuation should not be limited to on-chain metrics and network activity but should be conducted in conjunction with an analysis of the smart contract platform's founding team; its white paper; a review of the latest developments,

such as the introduction of new features to address existing platform issues; and the announcement of partnerships, which can increase the platform's use cases and activity. Such qualitative information provides important context for current performance.

Metcalfe's Law: Cryptoassets as a Network

Metcalfe's law states that the value of a network (V) is proportional to the square of the number of nodes (n^2), or members, in the network. As more people join a network, they add more value to the network in a nonlinear way. An increasing number of users increases the number of possible connections and hence the value of the network.

There are different derivations for the equation, with some models using different variants of the power function and others equating value to the product of n^2 and "A" (a nonconstant proportionality factor or "affinity" value). A is a function of network capacity and is assumed to decline as n grows large. That is, as the network grows, comparable to the law of diminishing returns, more users will add positive but diminishing value, accounting for the fact that there are practical constraints to growth, such as network capacity.

For comparability, Zhang, Liu, and Xu⁴⁴ used Facebook and Tencent to analyze Metcalfe's law and found these companies fit the model and their costs are proportional to the squares of their network sizes.

Numerous analyses have been conducted on the applicability of Metcalfe's law to cryptoassets. An early example is a study from 2017 by Alabi,⁴⁵ who analyzed Bitcoin, Ethereum, and Dash and found them to be modeled fairly well by Metcalfe's law.⁴⁶

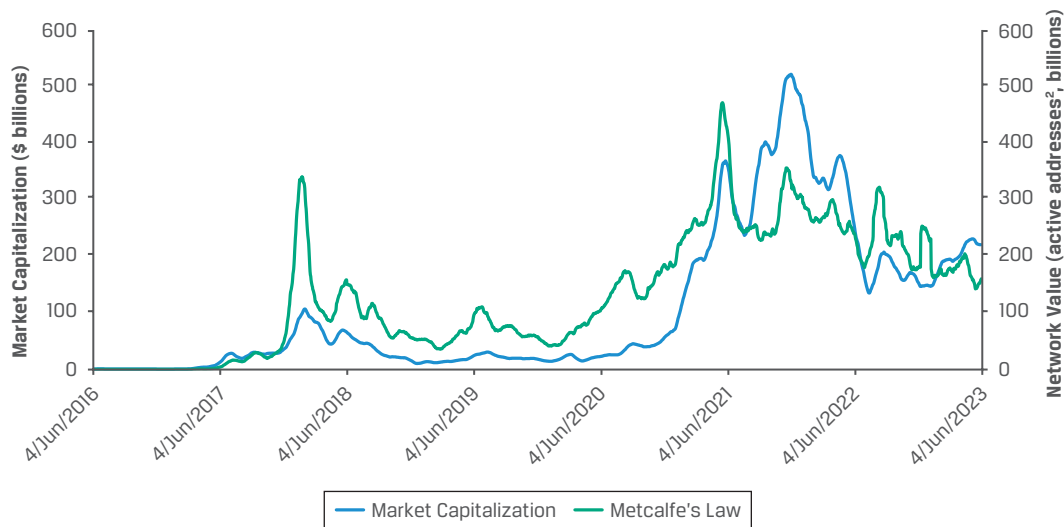
Exhibit 12 shows the value of Ethereum according to Metcalfe's law. We use daily active addresses, defined as the number of unique addresses that were active in the network as either a sender or a receiver, as a proxy for the number of users (n). The exhibit illustrates the 30-day moving average of the network value of Ethereum according to Metcalfe's law and compares it against the 30-day moving average of market capitalization of Ethereum between June 2016 and June 2023.

⁴⁴X.-Z. Zhang, J.-J. Liu, and Z.-W. Xu, "Tencent and Facebook Data Validate Metcalfe's Law," *Journal of Computer Science and Technology* 30 (2015): 246–51. <https://link.springer.com/article/10.1007/s11390-015-1518-1>.

⁴⁵Ken Alabi, "Digital Blockchain Networks Appear to Be Following Metcalfe's Law," *Electronic Commerce Research and Applications* 24 (July–August 2017): 23–29. www.sciencedirect.com/science/article/pii/S1567422317300480.

⁴⁶Timothy Peterson, "Metcalfe's Law as a Model for Bitcoin's Value," *Alternative Investment Analyst Review* 7 (Q2 2018): 9–18. <http://dx.doi.org/10.2139/ssrn.3078248>.

Exhibit 12. Metcalfe's Law for Ethereum: 30-Day Moving-Average Market Capitalization vs. 30-Day Moving-Average Network Value



Note: $V = n^2$, assuming $A = 1$ (authors' calculations).

Source: Market capitalization and active address data are from Glassnode (<https://studio.glassnode.com>).

Exhibit 12 shows that the market capitalization of Ethereum has been below its network value for most of the period studied, with the exception of 2021. Ethereum's market capitalization reached its peak in December 2021, before falling back below its network value.

Despite the apparent correlation between market capitalization and network value according to Metcalfe's law, there is some disagreement among stakeholders regarding the appropriate power value to use in the equation. Second, there are drawbacks regarding the use of active addresses as a proxy for the number of users. For example, an institution transacting a large quantity of a cryptoasset and a retail investor buying a smaller amount of the same cryptoasset would be considered equal, assuming both make a transaction using one address each. This equivalency ignores the size and frequency of transactions that would likely differ between retail and institutional investors.

3.2. Decentralized Applications

Decentralized applications are applications with their own native tokens that are "developed to provide a specific service or product to blockchain users. These applications can run on top of general-purpose smart contract platforms or run on their own application-specific blockchain."⁴⁷ For our analysis, we focus on decentralized finance (DeFi),⁴⁸ a sector of decentralized applications that focuses on financial products and services. The DeFi ecosystem includes a broad range of financial products that are designed to be open source, decentralized, and noncustodial⁴⁹ and can facilitate peer-to-peer transactions.

DeFi aims to transform the traditional financial industry with a host of potential benefits that it brings through its design, including lower costs, higher speeds, and self-execution. These products include lending and borrowing protocols, derivative and

⁴⁷For more information, see, for example, MSCI, "Datonomy Methodology: Guiding Principles and Methodology for Datonomy" (November 2022).

⁴⁸DeFi refers to the provision of financial products, services, arrangements, and activities that use distributed ledger technology in an effort to disintermediate and decentralize legacy ecosystems by eliminating the need for some traditional financial intermediaries and centralized institutions. See OECD, "Why Decentralised Finance (DeFi) Matters and the Policy Implications" (2022). www.oecd.org/daf/fin/financial-markets/Why-Decentralised-Finance-DeFi-Matters-and-the-Policy-Implications.pdf.

⁴⁹Noncustodial means the funds or assets are not held in custody or possessed by a platform or a third party at any point during a transaction or a service period; rather, the user owns and controls the keys to their cryptoassets usually through a software or hardware wallet. See the CoinMarketCap Glossary (<https://coinmarketcap.com/academy/glossary/non-custodial>).

synthetic financial instruments, trading protocols, automated market makers, aggregators,⁵⁰ and settlement protocols for various cryptoassets.

Exhibit 13 presents examples of decentralized applications pertaining to financial services for cryptoassets and brief descriptions of each. We discuss the applicable methods of valuation for decentralized applications, illustrated via examples for decentralized exchanges. Although we present examples only for decentralized exchanges, the methods we discuss are generally applicable across decentralized applications. However, a caveat is that the data available to conduct detailed analyses are limited for other sectors of decentralized finance; they are still in a nascent stage of development compared with decentralized exchanges.

Trading and Prediction Markets

Prediction markets are marketplaces where users can place bets based on unknown future outcomes. Examples include betting on future cryptoasset prices, political events (such as determining election winners), sporting events, entertainment, and economic events (e.g., Federal Reserve interest rate decisions). Compared with traditional betting companies, the main difference with decentralized prediction markets is the use of smart contracts that

allows for automatically recording transactions, as well as settlement and disbursement of funds when an event ends.

Asset Management

Asset management protocols function similarly to traditional asset management firms but use smart contracts for execution and implementation of such processes as portfolio rebalancing, liquidation, and settlement. Similar to traditional asset management, there are various types of funds and strategies in decentralized finance. An example of a decentralized asset management protocol is an index fund. The protocol allows for investors to invest in tokens in weights that are representative of a specific crypto index, providing investors with broad exposure to a basket of cryptoassets.

Credit/Lending

Credit and lending protocols allow users to take out loans of cryptoassets or lend their cryptoassets to earn returns. Similar to banks, users either pay interest as a borrower or receive interest as a lender; however, execution is conducted using smart contracts when certain conditions are met. Users can use other cryptoassets as collateral, and the amount that can be borrowed depends on the total

Exhibit 13. Decentralized Finance Applications by Category

Category	Example DeFi Applications	Uses
Trading/prediction markets	Polymarket, Augur	Trading/betting based on future events using cryptoassets (e.g., elections, sporting events)
Asset management	TokenSets, Index Coop, Amun Index Tokens, Cryptex Finance	Cryptoasset investment products based on thematic indexes, leveraged products, and yield products
Credit/lending	MakerDAO, Aave, Compound	Supplying cryptoassets (earning interest for providing liquidity) and borrowing cryptoassets (paying interest) via liquidity pools
Insurance	Nexus Mutual, Etherisc	Insurance for validators, stablecoin depeg protection, travel delay protection, crop insurance, and so on
Derivatives/synthetic assets	Syntheticx, dYdX	Trading perpetual contracts for cryptoassets
Decentralized exchanges	Uniswap, SushiSwap, Balancer, Curve, Orca	Trading cryptoassets without a centralized intermediary

⁵⁰A DeFi aggregator brings together trades across various decentralized finance platforms into one location, saving users time and increasing efficiency for cryptocurrency trades⁵¹; see the CoinMarketCap Glossary (<https://coinmarketcap.com/academy/glossary/defi-aggregator>).

deposited amount and the safety of the collateral. Lending protocols also have a feature known as flash loans, which are uncollateralized loans that have to be repaid as part of the same transaction of the initial loan. These transactions are completed in seconds and are generally used by traders who arbitrage when two markets are pricing a cryptoasset differently.

Insurance

Insurance protocols can be used to build insurance products allowing users to obtain financial cover against different types of crypto-native risks. A few examples of crypto-native insurance products are ETH staking cover for validators (protection against penalties and missed rewards), custody cover (protection against custodial hacks), and USDC depeg cover (protection against instability in the USDC stablecoin, or departure from its dollar peg). There are also real-world insurance products, such as travel delay protection and crop protection, that are automatically triggered—for example, if the government announces a drought or a flood.

Derivatives/Synthetic Assets

Derivatives/synthetic asset applications allow for trading in perpetual swap contracts of digital assets, as well as commodities and currencies, using stablecoins. They are decentralized exchanges but are focused specifically on derivatives and can be based on an order-book matching model or an automated market maker model.

3.2.1. Decentralized Exchanges

Decentralized exchanges (DEXs) are one of the most popular sectors of DeFi. They enable the exchange of cryptoassets using smart contracts. Traditional exchanges work using a limit order book mechanism, in which price discovery is based on the matching of buy and sell orders placed by market participants (multilateral trading); using market making, which occurs via an intermediary—the market maker or dealer—that stands between buyers and sellers (bilateral trading); or using a combination of both. Decentralized exchanges facilitate trades by using automated market making (using an algorithm to determine the prices at which buyers and sellers can trade) via the use of smart contracts.

Decentralized exchanges have "liquidity pools," which are funds that are used to execute the trades

that take place on the platform. Users deposit their cryptoassets in the liquidity pool in exchange for interest payments, and the smart contract algorithmically determines the price of cryptoassets that can be traded. Thus, a user does not have to wait for an opposite party to agree on a price to make a trade; rather, the price is predetermined, and the trade can be executed automatically at that price from within the liquidity pool.

Key differences between traditional exchanges and decentralized exchanges include custody of funds and assets (in the case of decentralized exchanges, assets remain in the custody of the user) and lower customer identification requirements (decentralized exchanges typically have no regulatory KYC, or know-your-customer, requirements). Revenue for decentralized exchanges is measured using transaction fees, which may be split between protocol revenue and supply-side fees (which we explain in the subsequent examples).

Exhibit 14 provides a summary of three of the largest decentralized exchanges by total value locked.

We take the example of Uniswap to further understand the revenue breakdown. Uniswap allows users to directly trade/swap cryptoassets built on the Ethereum smart contract platform without converting to fiat currency. Swapping makes it more convenient to exchange cryptoassets and reduces transaction fees relative to selling an asset, converting it to fiat currency and then converting the fiat currency back to another asset.

Uniswap charges a 0.3% transaction fee for each trade on the platform. Generally, fees are divided between two parties: users who have staked the native asset and liquidity providers. Fees paid to the former are referred to as protocol revenue, and fees paid to liquidity providers are referred to as supply-side fees. As of the time of writing, Uniswap pays out all of its transaction fees to liquidity providers and does not take any protocol revenue. Transaction fees for Uniswap totaled \$788.71 million for 2022.⁵¹ In comparison, Curve had total transaction fees of \$90.85 million in 2022, shared equally between liquidity providers and protocol revenue, while total transaction fees on Balancer amounted to \$38 million, with 50% going to liquidity providers and 50% to protocol revenue.

The protocol revenue is again split between a treasury, which is used for reinvestment in future growth of the platform, and a part that is paid out

⁵¹See <https://tokenterminal.com/terminal/financial-statements>.

Exhibit 14. Descriptive Data on the Three Largest Decentralized Exchanges

DEX Platform	Launch Year	Smart Contract Platform	Description	Fee Structure
Uniswap (UNI)	2018	Ethereum	Trading and swapping cryptoassets. Liquidity providers deposit funds and receive transaction fees from traders.	Three levels: 0.05%, 0.3%, and 1%. No protocol fees, possibly 0.05% in the future.
Curve (CRV)	2020	Ethereum		Variable between 0.04% and 0.4% on all pools, of which 50% goes to liquidity providers and 50% goes to veCRV holders. ^a
Balancer (BAL)	2018	Ethereum		Decided by the liquidity provider, ranges between 0.01% and 1%. Liquidity providers receive 50% of trade fees. Protocol takes 50% of trade fees.

^aThe term "veCRV" stands for vote escrowed CRV and refers to CRV that is staked on Curve DAO. Staked CRV allows the user to vote on governance and receive the trading fees.

Sources: Governance and FAQ pages of each decentralized application: Uniswap, <https://docs.uniswap.org/concepts/protocol/fees>; Curve, <https://classic.curve.fi/rootfaq>; Balancer, <https://docs.balancer.fi/concepts/governance/protocol-fees.html>.

to long-term token holders (those who have staked the native asset), similar to a dividend. Continuing the analogy with traditional finance, supply-side fees (payments to liquidity providers) can be considered similar to operational expenses. Decentralized applications may keep more funds in their treasury to finance future projects and create improvements to their existing product (i.e., conserve cash to fund growth) or pay out more of the revenue to long-term token holders (i.e., offer higher staking yield, akin to a dividend).

We can evaluate DEXs through relative valuation metrics and intrinsic valuation. However, the DEXs we analyze have key differences that affect the valuation methods used. We provide three examples: Uniswap, Curve, and Balancer.

Uniswap

Uniswap uses a constant-product formula, $x*y = k$, where users provide liquidity by depositing two assets (x and y , such as ether and USDC) in amounts such that their product equals a given value (k) that must be maintained. More specifically, x and y represent the pool balance of each token, and k is the

constant that should be maintained; to withdraw some amount of token x , a proportional amount of token y has to be deposited to maintain the constant k (before fees). Liquidity pool providers receive liquidity tokens in exchange for depositing assets x and y . Traders can pay a fee to use the liquidity, and the fee is split proportionally between the liquidity providers (Uniswap has only supply-side fees).

Curve

Curve is an automated market maker (AMM) that provides liquidity pools consisting of stablecoins and wrapped⁵² versions of assets. In contrast to Uniswap and Balancer, Curve is focused on stablecoins. The model used by Uniswap would not be ideal when trading stablecoins because of its higher fees and slippage (difference between the expected price of an order and the price at order execution). Curve uses efficient algorithms to counter such problems as slippage. Curve also allows for the creation of liquidity pools containing an equal dollar amount of three cryptoassets, compared with the limit of two in Uniswap. Curve has both supply-side revenue and protocol revenue, with 50% of transaction fees going to each.

⁵²Wrapped tokens represent "locked collateral [e.g., wBTC] of the original asset (i.e., BTC) on a separate blockchain." They increase interoperability between different blockchains. See J. Gilbert, "Wrapped Crypto Tokens and Why They're Critical to Markets," Blockworks (13 June 2022). <https://blockworks.co/news/wrapped-crypto-tokens-and-why-theyre-critical-to-markets>.

Balancer

Balancer allows the creation of weighted pools of up to eight cryptoassets at any proportion. Users are allowed to create their own pool or add assets to existing pools. Similar to Curve, Balancer has both supply-side revenue and protocol revenue, with 50% of transaction fees going to each.

3.2.2. Valuation Models: DeFi

Valuation of DeFi tokens presents significant challenges, given that DeFi is still in a nascent and evolving stage. One benefit of the structure of DeFi applications is that they have characteristics similar to those of traditional finance business models and may use a business model that generates revenue on a structural basis. This feature enables adapting traditional finance valuation models to DeFi, either in a relative value context or to estimate an intrinsic value. Furthermore, DeFi apps can also be compared with their traditional finance (TradFi) counterparts because revenue is a metric that is consistent across protocols and across DeFi and TradFi.

Most categories of decentralized applications generate revenue through fees applied on the service they provide. For example, decentralized exchanges charge trading fees, lending protocols charge interest, and insurance protocols charge premiums. These items equate to transaction fees of the specific protocol, which, in turn, can be decomposed into revenue and supply-side fees. The valuation models we present for decentralized exchanges are applicable across all categories of decentralized applications.

First, we assess the metrics used for a comparable analysis of decentralized applications or DeFi protocols⁵³—terms we use interchangeably—in the same category. Second, we highlight the most widely used metrics and analyze relative valuation among DeFi protocols. To evaluate intrinsic valuation, we assess the discounted cash flow model, which has been adapted to DeFi according to its own characteristics.

Comparable Analysis

Comparable analysis, like traditional finance, looks at the fundamentals of a DeFi protocol in a given product category by calculating relevant metrics to identify undervalued or overvalued assets on a relative valuation basis. In the section titled "Valuing Blockchain Platforms as a Network," the market cap

to TVL ratio and the price-to-fees ratio were used to analyze smart contract platforms, and we can similarly use those metrics and others to evaluate decentralized applications. Several multiples already in use in DeFi can be used to conduct a comparable analysis among similar protocols. In the following, we list the multiples and ratios that are typically used.

Market cap to net assets ratio: This ratio indicates how changes in a DeFi protocol's net assets affect its underlying value. The multiple arises from two indicators: the protocol's market capitalization and its treasury (net assets owned by the protocol).

$$\text{Market cap to net assets ratio} = \frac{\text{Market capitalization}}{\text{Treasury}}$$

Market capitalization is calculated by multiplying the outstanding supply of a cryptoasset with its price. Treasury refers to an on-chain wallet where the protocol revenue of the decentralized application is collected. The assets in the treasury are used to fund future projects, chosen through a voting process. The founding team and users who have staked the asset of the specific decentralized application are allowed to vote on future proposals and projects. The equity valuation counterpart of the market cap to net assets ratio would be the price-to-book ratio, which shows the premium of a stock's price to its net assets. In this context, the analyst could expand the comparable analysis by looking at the price-to-book ratio of traditional exchanges from developed and emerging markets.

P/S: The price-to-sales ratio is traditionally calculated by dividing a company's share price by its sales per share. It allows investors to compare price multiples of revenue. In decentralized finance, P/S compares a protocol's market capitalization with its total revenue accruing to the protocol (i.e., excluding supply-side fees):

$$P/S = \frac{\text{Market capitalization}}{\text{Annualized revenue}}$$

The price-to-sales ratio may help analysts determine how tokens are priced relative to each other when comparing tokens across similar sectors in DeFi or with their counterparts in TradFi. A comparably high ratio, for example, could indicate that a protocol is overvalued relative to its peers.

P/F: Related to P/S, the price-to-fees ratio is calculated as the market capitalization divided by

⁵³According to CoinMarketCap.com, DeFi protocol refers to any lending, borrowing, and staking services that are controlled by a smart contract. Protocol generally refers to the back end used by developers, whereas application refers to the interface for customers.

annualized total transaction fees (including protocol revenue and supply-side fees):

$$P/F = \frac{\text{Market capitalization}}{\text{Annualized fees}}$$

P/F indicates how the market is valuing the fees generated by a decentralized application. A number of protocols do not generate revenue in their initial stages to support their growth; thus, when comparing protocols in which some may produce revenue and others may not, P/F would be more useful than P/S.

Market cap to TVL ratio: Total value locked represents the dollar value of funds that are currently being staked in a DeFi protocol. An increasing TVL indicates more capital being locked into the protocol, which is beneficial for users. For example, in a lending protocol, more TVL would lead to greater lending capacity. In this case, TVL includes cryptoassets deposited by users that allow them to borrow or lend other cryptoassets and receive interest income.

Total value locked is calculated by taking the total number of tokens staked on the protocol and multiplying it by the price of the token. If a protocol allows staking multiple tokens, then total value locked would be the sum of the amount of each token staked on the protocol multiplied by its respective price. Because TVL is dollar denominated and cryptoassets

are locked in the protocol, changes in cryptoasset prices affect TVL. To counteract the effect of changing prices, the market cap to TVL ratio includes the respective token prices in the calculation of both the numerator and denominator—specifically,

$$\text{Market cap to TVL ratio} = \frac{\text{Market capitalization}}{\text{Total value locked}}$$

To better understand these metrics, we use DeFi applications in the same sector—decentralized exchanges—and calculate the ratios for them to see how they weigh relative to each other. The examples in our analysis are Uniswap, Curve, and Balancer. **Exhibit 15** provides data for the market cap to TVL ratio for these platforms, and **Exhibit 16** compares the market cap to net assets ratio, P/S, and P/F.

Exhibit 15 shows that the market cap/TVL is less than 1 for Curve and Balancer but not for Uniswap. Among the three, Uniswap has the highest market cap to TVL ratio, partly because Uniswap has the highest total value locked among the three protocols. We use the formula used earlier, in the section titled "Valuing Blockchain Platforms as a Network," to calculate the price of a decentralized application based on the ratio of its competitors:

$$V = \frac{(m_c \times d)}{s}$$



Exhibit 15. Metrics of Decentralized Exchanges, as of 19 September 2023

DeFi Application	Price	Outstanding Supply (millions)	Total Value Locked	365-Day Average TVL	Market Capitalization (circulating) ⁵⁴	365-Day Average Market Cap (circulating)	Market Cap to TVL Ratio	Market Cap to TVL Ratio (365-day average)
Curve (CRV)	\$0.45	881.8	\$2.2 billion	\$4.1 billion	\$455.6 million	\$574.5 million	0.20	0.14
Uniswap (UNI)	\$4.29	577.5	\$3.2 billion	\$3.8 billion	\$3.7 billion	\$4.4 billion	1.15	1.15
Balancer (BAL)	\$3.13	52.2	\$705.5 million	\$1 billion	\$136.6 million	\$219.8 million	0.19	0.22

Source: Token Terminal.

⁵⁴Circulating market cap versus fully diluted market cap: Circulating market cap refers to the total market value of a cryptocurrency's circulating supply. It is analogous to free-float capitalization in the stock market. Fully diluted market cap is the market cap if the maximum supply of coins were in circulation. Source: CoinMarketCap Glossary. <https://coinmarketcap.com/academy/glossary/fully-diluted-value-fdv> and <https://coinmarketcap.com/academy/glossary/circulating-supply>.

Exhibit 16. P/S, P/F, and Market Cap to Net Assets Ratio for Decentralized Exchanges, as of 19 September 2023

	Fees (\$ millions, annualized)	Revenue (\$ millions, annualized)	Net Assets (\$ millions, annualized)	P/S	P/F	Market Cap to Net Assets Ratio
Curve	17.25	6.46	61.6	52.68×	22.01×	6.2×
Uniswap	313.28	288.8	1,800	9.74×	11.6×	2×
Balancer	26.6	13.2 ^a	14.72	12.48×	6.24×	11.27×

^aEstimated using weighted-average fees of the top 10 pools on Balancer.

Sources: DefiLlama; The Block; Token Terminal.

where

V = Value (estimated price of the respective token)

m_c = Market multiple of competitor (market cap to net assets ratio, P/S, P/F, market cap to TVL ratio, as applicable)

d = Denominator (net assets, sales, fees, TVL, as applicable)

s = Outstanding supply of tokens

We can calculate the price of the Curve (CRV) token based on Uniswap's and Balancer's market cap/TVL using the values in Exhibit 15. The calculation for Curve at Uniswap's current multiple (as of the date of analysis) would be as follows:

$$\text{UNI market cap to TVL ratio} = \frac{\text{Price} \times \text{Number of CRV tokens}}{\text{Total value locked in CRV}}$$

$$1.15 = (\text{Price} \times 881.8) / 2,200.$$

$$\text{CRV price at UNI multiple} = (1.15 \times 2,200) / 881.8 = \$2.87.$$

Similarly, we can estimate Curve's price at Balancer's market cap to TVL ratio using the same method, which comes to \$0.47.

The market price of CRV (\$0.45, from Exhibit 15) is below its value based on the comparable TVL multiples of Uniswap and Balancer, which would imply that Curve is relatively undervalued on the basis of these metrics alone. However, if we extend the analysis to consider a broader range of multiples, a different conclusion is reached.

To illustrate further, Exhibit 16 presents P/S,⁵⁵ P/F, the market cap to net assets ratio, and associated data for the three DEXs included in this example, and **Exhibit 17** presents the implied valuations of CRV based on these multiples. One initial observation from Exhibit 16 is that Uniswap typically has lower multiples, suggesting that the market prices in less growth per unit of fundamental characteristics. This finding is consistent with the fact that all transaction fees on Uniswap are paid to liquidity providers, implying lower growth opportunities.

Based on the metrics in Exhibit 17 and compared with the CRV market price (as of 19 September 2023) of \$0.45, the Curve DEX appears largely overvalued relative to its competitors.

As the data illustrate, a limitation of relative valuation is that the results depend on the multiple selected for comparison and the chosen peer group, which are matters of professional judgment. As such, these techniques provide only a partial view of valuation and should not be relied on in isolation.

⁵⁵Although Uniswap currently charges only supply-side fees and does not charge a protocol fee, there is an option for Uniswap governance to "turn on" the protocol fee. To calculate revenue and, subsequently, P/S, we assume that Uniswap switches on the protocol fee.

In cases of variable fee data, we estimate revenue by first calculating the weighted-average transaction fee (in percent) from each of the top 10 liquidity pools on the platform and then applying that percentage fee to the total value of transactions in a given year. We can then apply the protocol fee proportion (as specified in the respective white paper accompanying the given protocol) to the estimated total transaction fee to calculate revenue (sales).

Exhibit 17. Implied Price of Curve (CRV) at Comparable Multiples of Uniswap and Balancer

	CRV Price at UNI Multiples	CRV Price at BAL Multiples
P/S	\$0.07	\$0.09
P/F	\$0.23	\$0.12
Market cap to net assets ratio	\$0.14	\$0.79

Further insight into which metrics drive value for the various decentralized applications is provided in a study by Metelski and Sobieraj.⁵⁶ The authors analyze the relationship between the valuation of 30 decentralized finance protocols with such metrics as total value locked, protocol revenue, total revenue (transaction fees), gross merchandise value, and inflation factor. They find that total value locked and transaction fees have a positive impact on the valuations of DeFi protocols. They also find that the TVL variable has the greatest influence on the valuation of DeFi protocols. Intuitively, the more capital that is locked in the protocol, the greater the benefits to participants and the greater the propensity for development activity to take place and positive network effects to accrue. Conversely, the authors find that protocol revenue has a negative association with market capitalization, reasoning that protocol revenue is similar to the dividends that a public company distributes to its shareholders, meaning that the capital is being paid out and not being reinvested into the protocol.

Furthermore, among the protocols analyzed, Metelski and Sobieraj find that total value locked has the strongest relationship with the valuation of asset management protocols and the relatively weakest association with decentralized exchanges because the performance of asset management protocols depends primarily on funds under management.

Credit and Lending Protocols

Here, we present the example of credit and lending protocols to demonstrate how the relative valuation metrics are applicable among various types of decentralized applications.

The differences between the types of decentralized applications come from how they collect transaction

fees. For example, decentralized exchanges charge a transaction fee, whereas lending protocols charge interest and liquidation fees to their users. Lending platforms allow borrowers to take loans of a cryptoasset by depositing other cryptoassets the borrower owns as collateral, paying interest for the loan. Conversely, lenders deposit their funds to be lent out and earn interest on their cryptoassets. The total interest paid by borrowers (fees) is then divided into supply-side fees (share of interest that goes to lenders) and revenue (share of interest that goes to the protocol).

Exhibit 18 shows the respective price multiples based on the revenue, fees, and total value locked for three lending platforms: Aave, MakerDAO, and Compound.

Using the metrics in Exhibit 18, we can calculate the relative valuation of any of the lending platforms with respect to its competitors, analogously to the analysis for decentralized exchanges. For example, the valuation of Aave based on the respective comparable P/F multiple for Compound and MakerDAO would be approximately \$49.53 and \$35.20, respectively. The market price of Aave, \$61.11 (as of 19 September 2023), is overvalued on the basis of the comparable P/F multiples of MakerDAO and Compound.

Relative valuation should take into account the underlying reasons for the differences in multiples across protocols, similar to relative valuation of equities. One limitation, however, is that relative valuation metrics may be susceptible to market sentiment driving multiple expansion. These limitations can be partly overcome by combining relative valuation with intrinsic (fundamental) valuation to form a more holistic view of a given cryptoasset.

⁵⁶Dominik Metelski, and Janusz Sobieraj, "Decentralized Finance (DeFi) Projects: A Study of Key Performance Indicators in Terms of DeFi Protocols' Valuations," *International Journal of Financial Studies* 10 (2022): 108. www.mdpi.com/2227-7072/10/4/108.

Exhibit 18. Comparable Price Multiples of Lending Platforms

	Circulating Supply	Fees (\$ millions)	Revenue (\$ millions)	Net Assets (\$ millions)	P/S (based on circulating supply)	P/F (based on circulating supply)	Total Value Locked	Market Cap to TVL Ratio
Aave	14,547,388	96.08	17.85	82.65	47.8×	8.51×	4.4 billion	0.22
Compound	7,829,249	38.15	5.18	95.37	61.4×	7.50×	1.8 billion	0.17
MakerDAO	977,631	205.83	205.83	164.13	5.33×	5.33×	6.2 billion	0.27

Source: Token Terminal (data based on annualized exhibits as of 31 May 2023).

Intrinsic Valuation

Here, we again turn to discounted cash flow analysis to illustrate how to evaluate the intrinsic value of the DEXs in our example. The DCF analysis is based on the example of Balancer and a five-year projected growth rate. The discount rate we use for this illustration is 30% because we compare DEX protocols with startups, which typically warrant a discount rate ranging from 20% to 70%, depending on stage of development.⁵⁷ Lord⁵⁸ analyzed Curve on the basis of the overall growth outlook of decentralized exchanges and used a terminal exit approach using the price-to-earnings ratios of traditional exchanges. Other analyses, such as that by Xu, Xu, and Lommers,⁵⁹ use a perpetual growth method instead of a terminal exit method for decentralized exchanges. We make the following additional assumptions in our analysis:

- Fees on Balancer range from 0.01% to 1%, with 50% of the transaction fee going to liquidity providers (supply-side fees) and the other 50% going to the protocol in the form of revenue. In Exhibit 16, we estimated the protocol revenue based on the weighted-average fee of the liquidity pools on Balancer. The weighted-average fee percentage on Balancer is 0.0794%,⁶⁰ and therefore, 0.0397% (half the total) is protocol revenue.

- The market share of Balancer has remained between 2.8% and 4.23% since its launch.⁶¹ We assume that it will maintain a constant market share of 4% over a five-year forecast period (2024–2028, inclusive).
- We assume a decreasing growth rate of the total trading volume of decentralized exchanges, considering the bear market of 2022 and a lack of regulatory clarity. We begin with a growth rate of 8.1%, based on the CAGR between 2020 and 2023, and reduce the growth rate by a factor of 2.5 after each year.

We begin with the total trading volume of 2023 for all decentralized exchanges for the analysis. Then, we apply a terminal exit multiple of 22.11× to the 2028 forecasted value, in line with EV/EBITDA multiples of traditional exchanges.⁶² Exhibit 19 shows our calculations and the result based on the assumptions we mention here.

Using our assumptions, we arrive at a value of \$5.32 for Balancer's native token BAL. Its price, as of 19 September 2023, is \$3.28, which implies the platform is undervalued.

Considering the nature of the cryptoasset industry and the short time of existence of decentralized exchanges, one could arrive at a different valuation with different growth rate and discount rate

⁵⁷The discount rate range for startups is sourced from KPMG, "Start-ups and Early Stage Companies" (May 2021). <https://assets.kpmg.com/content/dam/kpmg/kw/pdf/insights/2021/05/valuation-startup-web.pdf>.

⁵⁸F.-X. Lord, "Curve Finance—Valuation Report," Messari (28 December 2021). <https://messari.io/report/curve-finance-valuation-report>.

⁵⁹Teng Andrea Xu, Jiahua Xu, and Kristof Lommers, "DeFi vs TradFi: Valuation Using Multiples and Discounted Cash Flows," Working paper (1 November 2022). <https://arxiv.org/pdf/2210.16846.pdf>.

⁶⁰The weighted average is an estimate based on the largest liquidity pools as of the date of analysis and can change over time as volumes change on the liquidity pools or new pools are introduced.

⁶¹These data are from The Block: www.theblock.co/data/decentralized-finance/dex-non-custodial.

⁶²EV/EBITDA average of publicly listed stock exchanges from developed and emerging markets (author's calculation based on data from Refinitiv).

Exhibit 19. Discounted Cash Flow Model for Balancer

DCF Model, 5-Year Holding Period with Exit Multiple		2023	2024	2025	2026	2027	2028
Volume							
Total DEX volume, \$ millions		756,630.0	1,369,500.3	1,813,218.4	2,048,211.5	2,154,390.8	2,199,064.2
Growth rate			81.00%	32.40%	12.96%	5.18%	2.07%
Balancer market share			4.00%	4.00%	4.00%	4.00%	4.00%
Balancer volume, \$ millions		33,237.0	54,780.0	72,528.7	81,928.5	86,175.6	87,962.6
Fees							
Protocol revenue	0.0397%	13.2	21.7	28.8	32.5	34.2	34.9
Terminal Value	22.11						772.11
PV of cash flows			16.7	17.0	14.8	12.0	217.4
Total PV (\$ millions)	277.9						
Outstanding supply (millions)	52.2						
Price per BAL (\$)	5.32						
Discount rate	30.00%						

Source: Total trading volume of decentralized exchanges is from The Block (www.theblock.co/data/decentralized-finance/dex-non-custodial).

assumptions. For example, if we maintain our growth rate assumptions but increase the discount rate, the implied value converges toward the market price of \$3.28 equaling that value with a discount rate of 45%, before falling below the market price as the discount rate increases toward the upper end of our range (70%).

Our analysis is for illustrative purposes, and the selection of these parameters is subject to the professional judgment of the analyst. Overall, the model illustrates the applicability of analytical methods from traditional finance to DeFi protocols that have measurable cash flows and other market-based characteristics.

3.3. Bitcoin

Bitcoin, created in 2009, has become one of the most popular and widely traded cryptoassets. As of 2 June 2023, it dominates all cryptoassets, with 46% of the total market capitalization of the cryptoasset market. Correspondingly, most of the literature covering the valuation of cryptoassets relates to bitcoin. The valuation methodologies we cover in this section are not exhaustive; rather, they are the methods that are most discussed in the literature and the ones identified as most relevant in our interviews with practitioners.

3.3.1. Total Addressable Market Approach

The total addressable market approach is a method used to value bitcoin against comparable assets that

satisfy the properties of money—namely, a unit of account, a store of value, or a medium of exchange. Such comparable assets include gold, M2 money supply, reserve assets of central banks, gross settlement systems, and remittances. Bitcoin can be compared with these assets assuming that it can fulfill at least one of these traditional monetary properties.

The calculation for the addressable market approach uses a simple formula:

$$\frac{\text{Level of penetration} \times \text{Value of target market}}{\text{Fully diluted supply}}$$

"Value of target market" refers to the size of the market opportunity available for a specific product or service to compete for in an existing industry. For example, global remittances amounted to \$794 billion in 2022. Currently, remittance payments are conducted through money transfer companies, banks, and fintech companies. If bitcoin were to act as a medium of exchange and individuals used it to send remittances, the target market for bitcoin would be \$794 billion. "Level of penetration" refers to how much of the target market bitcoin could potentially capture. "Fully diluted supply" refers to the total amount of the specific cryptoasset that will be in existence. The maximum amount of bitcoin that can be in existence is 21 million, thus making 21 million bitcoin's fully diluted supply.

Using this formula, we conduct a simple analysis of bitcoin's valuation using the total addressable market approach. **Exhibit 20** shows the implied value of bitcoin at various levels of market capture of the aforementioned comparable assets. The values we use for

Exhibit 20. Value of Bitcoin at Different Levels of Addressable Market Penetration

Addressable Market	Value (\$)	Level of Penetration					
		0.50%	1%	5%	10%	20%	30%
US M2	21,149,000,000,000	\$5,035.48	\$10,070.95	\$50,354.76	\$100,709.52	\$201,419.05	\$302,128.57
Gold	13,365,747,545,332.30	\$3,182.32	\$6,364.64	\$31,823.21	\$63,646.42	\$127,292.83	\$190,939.25
US central bank reserves	11,598,000,000,000.00	\$2,761.43	\$5,522.86	\$27,614.29	\$55,228.57	\$110,457.14	\$165,685.71
Global remittances	794,000,000,000	\$189.05	\$378.10	\$1,890.48	\$3,780.95	\$7,561.90	\$11,342.86
Fedwire	1,060,257,294,000	\$252.44	\$504.88	\$2,524.42	\$5,048.84	\$10,097.69	\$15,146.53
Fully diluted supply (number of coins)	21,000,000						

the comparable assets that make up the addressable markets are as follows:

US M2 money supply: \$21.15 trillion⁶³

Gold: \$13.37 trillion⁶⁴

US central bank reserves: \$11.59 trillion⁶⁵

Global remittances: \$794 billion⁶⁶

Fedwire (settlement system provided by Federal Reserve):⁶⁷ \$1,060.257 billion⁶⁸

Exhibit 20 shows an expansive set of potential values for bitcoin at various levels of penetration in each of the addressable markets.

A caveat of this approach is the assumption that bitcoin can take the role of one or more of these markets as an accepted store of value or medium of exchange, an assumption that is yet to be proven. Also, this approach considers bitcoin only relative to comparable traditional assets and does not account

for competition from comparable cryptoassets. Further, the approach is based on current market values of the addressable markets and thus does not account for the potential growth of these markets.

3.3.2. Stock-to-Flow Model

The stock-to-flow model, created by an anonymous author, PlanB, is a tool used to forecast the future price of bitcoin. It is also a highly debated model. The stock-to-flow model attributes bitcoin as a store of value owing to its scarcity arising from its limited supply and decreasing inflation rate (i.e., a decreasing amount of bitcoin enters circulation as the total supply of bitcoin in circulation increases).

The model is based on the ratio between "stock," the current amount of bitcoin in circulation, and "flow," the yearly production (mining of new coins) of bitcoin. It calculates an asset's scarcity—the higher the ratio, the scarcer and theoretically more valuable the

⁶³Board of Governors of the Federal Reserve System, "M2 (WM2NS)," FRED, Federal Reserve Bank of St. Louis (accessed 15 March 2023). <https://fred.stlouisfed.org/series/WM2NS>.

⁶⁴Total above-ground stocks (year-end 2022) = 208,874 tonnes. Spot price = \$1,813.75 per ounce. World Gold Council, "Above-Ground Stocks" (8 February 2023). www.gold.org/goldhub/data/how-much-gold.

⁶⁵Board of Governors of the Federal Reserve System, "U.S. Reserve Assets (Table 3.12)." www.federalreserve.gov/data/intlsumm/current.htm.

⁶⁶KNOMAD, "Remittances Brave Global Headwinds," Migration and Development Brief 37 (November 2022): 12. www.knomad.org/sites/default/files/publication-doc/migration_and_development_brief_37_nov_2022.pdf.

⁶⁷Fedwire is a real-time gross settlement system provided by the Federal Reserve of the United States for depository institutions and other financial institutions to initiate fund transfers. See www.federalreserve.gov/paymentsystems/fedfunds_about.htm.

⁶⁸Federal Reserve Banks, "Fedwire Funds Service—Annual Statistics" (updated 24 January 2023). www.frbservices.org/resources/financial-services/wires/volume-value-stats/annual-stats.html.

asset. Based on the stock-to-flow ratio, a price model can be constructed (incorporating the ratio and other pricing factors) to calculate the value of bitcoin.

There is skepticism among practitioners about the value of the stock-to-flow model. The model is based on the assertion that the market capitalization of a monetary good is derived from its rate of new supply, but there is little research supporting the idea. Over the past 115 years, for example, gold's market capitalization has ranged between \$60 billion and \$9 trillion, indicating significant variation, while the stock-to-flow ratio of gold has remained steady, at a value of approximately 60. Based on 2022 data, for example, the ground stocks of gold were 208,874 tonnes, and 3,303.9 tonnes of gold were mined,⁶⁹ yielding a stock-to-flow ratio of 63.22. This amount, again, is close to the historical stock-to-flow ratio of 60, meaning that the ratio is relatively invariant and thus cannot be used reliably to connect gold's price with its supply.⁷⁰

3.3.3. Metcalfe's Law: Cryptoassets as a Network

In the section "Valuing Blockchain Platforms as a Network," we applied Metcalfe's law to Ethereum.

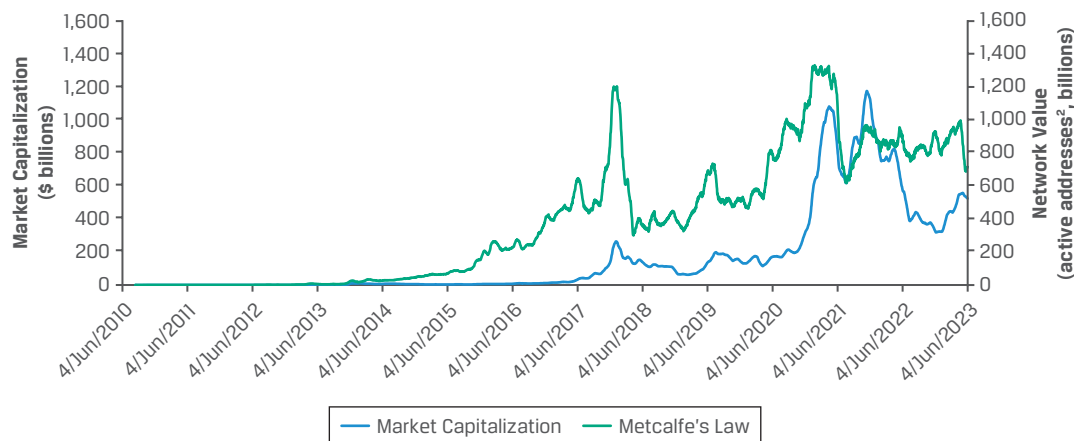
Similarly, we can apply Metcalfe's law to bitcoin by considering the value of bitcoin as the square of its number of users, where we use active addresses as a proxy for the number of users.

Exhibit 21 shows the value of bitcoin according to Metcalfe's law and compares it with the actual market capitalization of bitcoin between 2009 and 2023. Over this time frame, the market cap of bitcoin mostly remained lower than its implied value according to Metcalfe's law.

The correlation between the two variables comes to 0.789 over the period analyzed.

While most literature analyzing bitcoin using Metcalfe's law has found that the relationship holds in the long run, some studies have found that the power value is less than the theoretical value of 2. For example, Pele and Mazurencu-Marinescu-Pele⁷¹ found that a Metcalfe's law model with a power value of 1.69 provides the best fit. The authors also found that because of the bidirectional causality between the price and the network size, there could be positive feedback effects between the two variables, such that an expected increase in price attracts more investors to join the network, leading to exponential price growth and a herding effect among investors.

Exhibit 21. Value of Bitcoin Using 30-Day Moving-Average Value According to Metcalfe's Law vs. 30-Day Moving-Average Bitcoin Market Capitalization



Source: Data from Glassnode.

⁶⁹These data are from the World Gold Council's Goldhub "Data" webpage: www.gold.org/goldhub/data/.

⁷⁰Level39, "Why the Bitcoin Stock-to-Flow Model Is Not Useful," *Bitcoin Magazine* (26 January 2022). <https://bitcoinmagazine.com/markets/why-bitcoin-stock-to-flow-is-not-useful>.

⁷¹Daniel Traian Pele and Miruna Mazurencu-Marinescu-Pele, "Metcalfe's Law and Log-Period Power Laws in the Cryptocurrencies Market," *Economics* 13 (15 May 2019). <https://doi.org/10.5018/economics-ejournal.ja.2019-29>.

Metcalf's law also extends to the development of another ratio, the network value to Metcalfe (NVM) ratio. This ratio is calculated by dividing the value of the cryptoasset's market capitalization by the value of the network value calculated using Metcalfe's law:

$$\text{NVM ratio} = (\text{Market capitalization}) / (\text{Network value}).$$

The NVM ratio is shown in **Exhibit 22**. If the ratio is greater (less) than 1, it means the market is valuing bitcoin more (less) than its network value per Metcalfe's law.

3.3.4. Cost of Production Model

The cost of production model was introduced by Adam Hayes.⁷² It considers bitcoin as a virtual commodity with a competitive market of producers and assumes that the marginal cost of bitcoin production determines the value of bitcoin.

New bitcoins are entered into circulation through mining, which entails solving complex computational problems with the use of extensive computing hardware. The primary cost for mining bitcoin is electricity, measured in dollars per kWh (\$/kWh). In a perfectly competitive market, marginal cost should be equal to the marginal product (new bitcoin) of mining. Theoretically, an individual or a producer would undertake bitcoin mining if the marginal cost is less than or equal to the marginal product.

The marginal cost of mining per day (E_{day}) in dollars is calculated as follows:

$$E_{day} = (\$/kWh \times 24 \times W_{perGH/s}) / (GH/1,000),$$

where \$/kWh is the dollar price of electricity per kilowatt hour (which is multiplied by 24 hours) and $W_{perGH/s}$ (watts per gigahash/second) is the energy efficiency of the hardware. Gigahash (GH) is a measure of the computational power (or "hash power") used by a miner.

The dollar value of the marginal product of mining per day is represented by

$$P \times \text{BTC}_{day} = \theta(\beta\rho/\delta),$$

where

P is the bitcoin price

BTC_{day} is the expected level of daily bitcoin production

β is the block reward

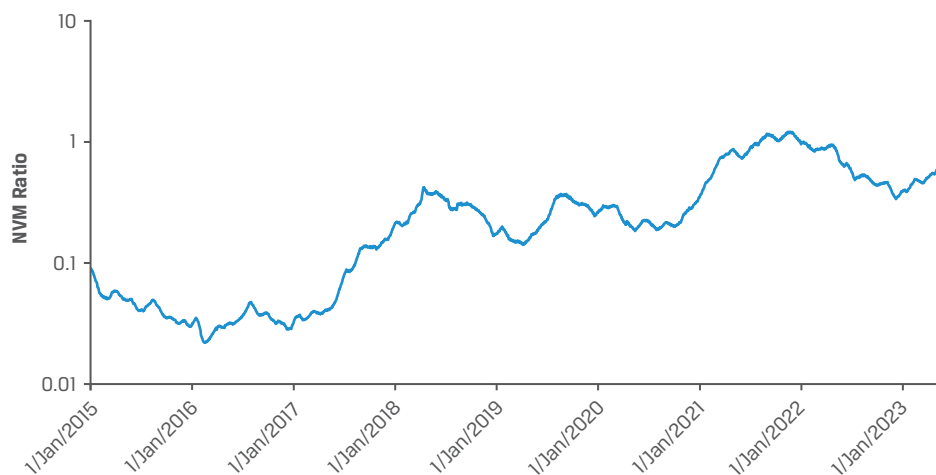
ρ is the hashing power (expressed in GH)

δ is the difficulty (expressed in units of GH/block)

θ is a time constant equal to 0.00002011656761 , calculated as $24\text{hr}_{day} \times 3,600\text{sec}_{hr} / 2^{32}$, where 2^{32} is the normalized probability of a single hash solving a block



Exhibit 22. Bitcoin NVM Ratio, Log Scale: January 2015–January 2023



Source: Glassnode: <https://studio.glassnode.com/metrics?a=BTC&category=&m=addresses.ActiveCount>.

⁷²Adam Hayes, "A Cost of Production Model for Bitcoin" (19 March 2015). Available at <https://ssrn.com/abstract=2580904>.

In a perfectly competitive market, the marginal cost of mining should equal its marginal product. That is,

$$E_{day} = P \times \text{BTC}_{day}$$

such that

$$P = \frac{E_{day}}{\text{BTC}_{day}},$$

which is the price below which a miner would operate at a marginal loss and hypothetically remove themselves from the network.

We illustrate the utility of the equation with an example, assuming the following values:

- \$/kWh: 0.05 (average global electricity price)⁷³
- WperGH/s: 0.028 J/GH⁷⁴ (mining hardware efficiency)⁷⁵
- ρ : 1,000 GH \times 10⁹ (computational power used by a miner)
- δ : 57,119,871,304,635 (difficulty of mining a block, expressed in GH per block)⁷⁶
- β : 6.25 (block reward, amount of bitcoin given when successfully validating a new block)

Mining difficulty is a measure of how difficult and time consuming it is to mine a block. The higher the difficulty, the more computational effort required to mine the block. Bitcoin mining difficulty changes every 2,016 blocks (approximately every two weeks). The block reward has decreased over time; as of 2023, it is 6.25. Approximately every four years, the block reward is cut to half its value. The next "halving" is expected to take place in 2024, when the block reward will decrease to 3.125 BTC. Over time, the block reward will reach virtually zero.

Using the values we listed, we can calculate the marginal cost per day of a 1,000 GH/s mining rig as

$$E_{day} = (0.05 \times 24 \times 0.028) \times (1,000/1,000) = \$0.0336.$$

The marginal product of bitcoin mining expressed in units of BTC is

$$\begin{aligned} \text{BTC}_{day} &= 0.00002011656761 [(6.25 \times 1000 \\ &\quad \times 10^9)/57,119,871,304,635] \\ &= 0.00000220113499366897. \end{aligned}$$

The ratio is thus

$$P^* = E_{day}/\text{BTC}_{day} = \$15,264.85,$$

compared with a market price of bitcoin of \$27,216 as of the close on 19 September 2023.

In his original (2015) example, Hayes⁷⁷ found the marginal cost to be \$2.622/day and the number of bitcoins mined in a day to be 0.010604 BTC/day, which gives a value of 247.27/BTC, close to bitcoin's price of \$255, as of 19 March 2015. In a later (2019) study,⁷⁸ Hayes backtested the cost of production model using regression and vector autoregression models to find that the model holds. He considers the cost of production price as a theoretical value around which the market price of bitcoin may tend to gravitate.

The cost of production model, however, has caveats. According to Kristoufek,⁷⁹ changes in mining costs of bitcoin follow changes in prices—not the other way around—and miners in the dollar-bitcoin market are price takers, not price makers. This view of mining dynamics would counter Hayes's theory that market prices tend to gravitate toward the production price.

While the cost of production model may not fully capture the complex dynamics of bitcoin mining and its relationship with market value, it offers a valuable theoretical framework for analyzing the economics of bitcoin production and understanding the crucial role of electricity costs in the mining process.

3.3.5. Metrics

Such metrics as the network value to transactions (NVT) ratio and market value to realized value (MVRV)

⁷³Average electricity price for bitcoin mining. Note that it is difficult to estimate the average price of electricity paid by Bitcoin miners for multiple reasons, including price variation between and within countries, if consumers are retail or wholesale, and in some cases because consumers at wholesale rates may have power purchase agreements. Source: Cambridge Bitcoin Electricity Consumption Index (CBECI) (no date) ccaf.io. Available at: <https://ccaf.io/cbnsi/cbeci/methodology> (Accessed: 09 November 2023).

⁷⁴J/GH refers to joules per gigahash. 1 WperGH/s = 1 J/GH.

⁷⁵Average of 25 miners, according to ASIC Miner Value's "Miners Efficiency" webpage: www.asicminervalue.com/efficiency/sha-256.

⁷⁶Glassnode.com.

⁷⁷Hayes, "A Cost of Production Model for Bitcoin."

⁷⁸Adam S. Hayes, "Bitcoin Price and Its Marginal Cost of Production: Support for a Fundamental Value," *Applied Economics Letters* 26 (2019): 554–60. www.tandfonline.com/doi/abs/10.1080/13504851.2018.1488040.

⁷⁹L. Kristoufek, "Bitcoin and Its Mining on the Equilibrium Path," *Energy Economics* 85 (January 2020). www.sciencedirect.com/science/article/abs/pii/S0140988319303834.

ratio are derived from on-chain data and are used by some investors as indicators for price movements in bitcoin (trading signals based on historical performance). These metrics are technical indicators, as opposed to measures of intrinsic value; as such, we provide only a brief summary.

Network Value to Transactions Ratio

The NVT ratio describes the relationship between market capitalization (as a proxy for network value, consistent with Metcalfe’s law) and transaction volume and is illustrated in **Exhibit 23**. An NVT ratio higher than the historical mean indicates that investors are pricing bitcoin at a premium, implying that market cap growth is outpacing on-chain transaction volume and value settlement. Conversely, a low NVT ratio means that bitcoin is being priced at a discount, with utilization outpacing market cap growth. The NVT ratio is calculated as

$$\text{NVT ratio} = \frac{\text{Market capitalization}}{\text{Transaction volume}}$$

There are some limitations to the metric,⁸⁰ including difficulty of accurately calculating the number of

users (determining transaction volume) and the limited relevance of on-chain transactions for valuation (which depends on viewing bitcoin as a medium of exchange as opposed to a store of value).

Market Value to Realized Value Ratio

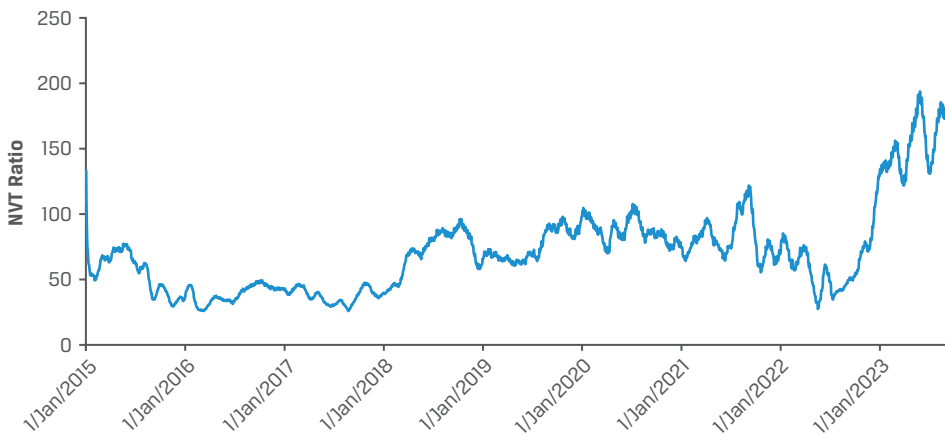
The MVRV ratio is calculated by dividing the market capitalization of bitcoin by realized capitalization.⁸¹ Realized value refers to the value of bitcoin on a cost basis,⁸² and market value is the current market capitalization of the asset. Thus, the realized value is the cost basis of all participants who own bitcoin.

Comparing market value with realized value enables an assessment of investor profitability. If the MVRV ratio is greater than 1, the average cost for all bitcoin is lower than the market capitalization and investors, on average, will be profitable. If the MVRV ratio is lower than 1, the average cost for all bitcoin is higher than the market capitalization and investors, on average, will be incurring losses.

To illustrate, using data as of 19 September 2023 (sourced from coinmetrics.io), we can calculate the MVRV ratio as follows:



Exhibit 23. Bitcoin NVT Ratio, 30-Day Moving Average: January 2015–September 2023



Source: coinmetrics.io.

⁸⁰See, for example, E. Koto, E. Regan, M. Caple, and J. Sotoyo, "Network Value to Transaction Volume (NVT) Analysis," Massachusetts Institute of Technology Blockchain Lab Program (2018).

⁸¹Realized capitalization is measured using the price at the time of creation. It values cryptocurrencies at different parts of the supply and at different prices, whereas market cap uses the (current) closing price. For further detail, see, for example, Coin Metrics, "Introducing Realized Capitalization" (14 December 2018). <https://coinmetrics.io/realized-capitalization/>.

⁸²If someone bought bitcoin at \$22,000 in January 2023, the realized value would be \$22,000 and the market value would be the current price (e.g., approximately \$30,000 as of 17 July 2023).

Market capitalization = 530.4322 billion.

Realized capitalization = 395.4049 billion.

MVRV ratio = Market capitalization/Realized capitalization = 1.3415.

Historical data for the MVRV ratio are presented in **Exhibit 24**.

As Exhibit 24 illustrates, the MVRV ratio has mostly been above 1 during the period; however, it fell below 1 in 2012, between 2015 and 2016, in 2019, in 2020, and during the cryptoasset bear market of 2022–2023. In addition, the ratio reached highs in 2011, 2013, 2017, and 2021.

High MVRV ratio values would likely indicate large unrealized profits and potential for profit taking

and may be construed as the top of bullish cycles. Similarly, low MVRV ratio values may indicate market bottoms. According to Mahmudov and Puell,⁸³ an accumulation phase⁸⁴ would be represented by the MVRV ratio going below the value of 1, and a distribution phase⁸⁵ would be indicated by the value going above 3.7.

There are some caveats with this metric, including the fact that its interpretation depends on the cryptocurrency's own price history and the impact of market volatility on the aforementioned ranges. Use of these metrics should be treated with caution and not relied on solely when analyzing bitcoin or other cryptocurrencies.

Exhibit 24. Bitcoin MVRV Ratio and Bitcoin Price (\$), 2011–2023



Note: BTC price is in log scale, while MVRV ratio is linear scale.

Source: coinmetrics.io.

⁸³M. Mahmudov and D. Puell, "Bitcoin Market-Value-to-Realized-Value (MVRV) Ratio," Medium (1 October 2018). <https://medium.com/@kenoshaking/bitcoin-market-value-to-realized-value-mvr-ratio-3ebc914dbae>.

⁸⁴An accumulation phase is a sideways and range-bound trading period that occurs after a prolonged downtrend.

⁸⁵A distribution phase is a sideways, range-bound trading period that occurs after a prolonged uptrend.

4. CONCLUSION

This report analyzes the various valuation methodologies used to evaluate cryptoassets, focusing on smart contract platforms, decentralized applications, and bitcoin. Current valuation models and approaches carry a number of limitations and require further development; thus, a single model or metric should not be used in isolation to value any given cryptoasset.

The cryptoasset ecosystem is currently in its earliest stage, and as such, there is a lack of historical data to build a comprehensive modeling framework or backtest the robustness of a given model.

With regard to intrinsic valuation analyses adapted from traditional finance (such as the discounted cash flow model) and applied to decentralized applications or smart contract platforms, the lack of historical data, DCF models' potential sensitivity to their assumptions, and rapid developments in cryptoassets pose further challenges in deciding on a proper range of assumptions to use in DCF valuations. Further, cryptoasset-specific models, such as the models presented for bitcoin, present several caveats, including potential misinterpretation of variables and focusing on certain characteristics to construct the models, thus limiting their use in providing a theoretical understanding of the underlying dynamics of the cryptoasset.

Despite the limitations of the valuation models addressed in this report, these models offer insights into the functionality and mechanics of the respective assets. An approach that uses these models as part of a thorough research and analysis process, incorporating independent professional judgment regarding the applicability of the different variables and assumptions, provides a more effective basis for making investment decisions.

Moreover, disagreement over existing models should be welcomed and embraced. Such counter-analysis and critique can lead to the development of improved valuation approaches, and the introduction of new concepts and more robust datasets will improve our understanding and modeling capabilities over time.

Overall, although these models have strengths and drawbacks, they can improve our collective comprehension of cryptoassets and facilitate a more complete understanding of their valuation drivers.

The process by which valuation models and methodologies become widely accepted market practices can take many years or decades. Research and empirical analysis facilitate the discovery and validation of models. This paper contributes to this dynamic.

APPENDIX 1. GLOSSARY

Active Addresses: A crypto address refers to "a unique string of characters that represents a wallet that can send and receive cryptocurrency. Every address is unique and denotes the location of a wallet on the blockchain." An address is considered "active" as soon as it becomes a direct participant in a successful transaction—either as a sender or receiver. Active addresses are the sum count of unique addresses that were active in the network (either as a destination or source of ledger change).

Source: CoinMarketCap Glossary (2023). <https://coinmarketcap.com/alexandria/glossary/address>.

Automated Market Maker: "An automated market maker (AMM) is a type of decentralized exchange (DEX) protocol that allows users to buy and sell digital assets without the need for a third-party intermediary."

Source: CoinMarketCap Glossary (2022). <https://coinmarketcap.com/alexandria/glossary/automated-market-maker-amm>.

Blockchain: "The blockchain is a distributed ledger that is updated in groups of transactions called blocks. Blocks are then chained sequentially via the use of cryptography to form the blockchain."

Source: Bank for International Settlements, "Cryptocurrencies: Looking beyond the Hype" (June 2018). www.bis.org/publ/arpdf/ar2018e5.htm.

Cryptoassets: "A cryptoasset is any digital asset that uses cryptographic technologies to maintain its operation as a currency or decentralized application."

Source: CoinMarketCap Glossary (2022). <https://coinmarketcap.com/alexandria/glossary/cryptoasset>.

Decentralized Exchange: Decentralized exchanges "often facilitate the exchange of crypto-assets through smart contracts rather than through centralized trading platforms, which require traders to deposit their crypto-assets with the trading platform operator."

Source: IOSCO, "IOSCO Decentralized Finance Report" (March 2022). www.iosco.org/library/pubdocs/pdf/IOSCOPD699.pdf.

Decentralized Finance: "DeFi commonly refers to the provision of financial products, services, arrangements, and activities that use distributed ledger

technology . . . in an effort to disintermediate and decentralize legacy ecosystems by eliminating the need for some traditional financial intermediaries and centralized institutions."

Source: IOSCO, "IOSCO Decentralized Finance Report" (March 2022). www.iosco.org/library/pubdocs/pdf/IOSCOPD699.pdf.

Layer 1 Blockchain: "Layer 1 blockchains are the most basic form of blockchain and the foundation for all other blockchain layers. They are often referred to as the 'core' or 'foundation' of the blockchain network, as they provide the infrastructure for all other applications and protocols that are built on top of the network. They are the only layer directly responsible for maintaining the distributed ledger, validating transactions, and securing the network from malicious actors."

Source: CoinMarketCap Glossary (2023). <https://coinmarketcap.com/alexandria/glossary/layer-1-blockchain>.

Prediction Market: "Prediction markets are exchanges where individuals trade what are sometimes called 'event contracts,'" which "specify some future event with different possible outcomes." Examples include political events, contest results, and sporting events.

Source: Adam Ozimek, "The Regulation and Value of Prediction Markets," Mercatus Center, George Mason University (March 2014). www.mercatus.org/research/working-papers/regulation-and-value-prediction-markets.

Stablecoin: "A stablecoin is a digital asset designed to maintain a stable value by linking its value to another asset or a basket of reserve assets."

Source: Congressional Research Service, "Digital Assets and SEC Regulation" (June 2021). <https://sgp.fas.org/crs/misc/R46208.pdf>.

Staking: "Staking is locking up crypto assets to earn a return on your principal and help secure the blockchain. The blockchains that support the staking process run on the proof-of-stake consensus mechanism. Nodes with staked cryptocurrency validate new blocks and receive a yield on their investment."

Source: CoinMarketCap Glossary (2023). <https://coinmarketcap.com/alexandria/glossary/staking>.

Synthetic Assets: "Synthetic assets are decentralized finance (DeFi) analogues of derivatives in the traditional finance world—financial arrangements which derive value from and are directly pegged to fluctuations in the value of an underlying asset."

Source: Abrar Rahman, Victor Shi, Matthew Ding, and Elliot Choi, "Systematization of Knowledge: Synthetic Assets, Derivatives, and On-Chain Portfolio Management," arXiv (20 September 2022). <https://arxiv.org/abs/2209.09958>.

Token: "A representation of a particular asset that typically relies on a blockchain or other types of distributed ledgers."

Source: Garth Baughman, Francesca Carapella, Jacob Gerszten, and David Mills, "The Stable in Stablecoins," FEDS Notes, Board of Governors of the Federal Reserve System (16 December 2022). www.federalreserve.gov/econres/notes/feds-notes/the-stable-in-stablecoins-20221216.html.

APPENDIX 2. ESTIMATING DISCOUNTED CASH FLOW MODEL PARAMETERS USING THE CAPITAL ASSET PRICING MODEL

Using small-cap software firms as a proxy, we calculated the discount rate for Ethereum using the capital asset pricing model to estimate the average discount rate for 35 small-cap technology firms. **Exhibit 25** presents the names of the firms, their market capitalizations, and their beta values. We calculated an average beta for all 35 firms of 1.407.

We used the Damodaran Online dataset, accessible via the CFA Institute Research Foundation

Investment Data Alliance, to obtain the risk-free rate and the equity risk premium. Using the most current data, we obtained values of 3.88% and 5.94% for the respective variables.

Discount rate: $r = r_f + \beta \times \text{ERP}$.

$r = 3.88\% + 1.407 \times 5.94\%$.

$r = 12.24\%$.



Exhibit 25. Market Capitalization, EV/EBITDA, and Beta Values for 35 Small-Cap Firms

Identifier	Company Name	Market Cap (\$)	EV/EBITDA	Beta
EGHT.OQ	8x8 Inc.	289,069,168.33	13.85	1.30
ATEN.N	A10 Networks Inc.	804,099,380.70	17.71	0.98
ACIW.OQ	ACI Worldwide Inc.	2,239,237,993.42	10.62	1.03
ADEA.OQ	Adeia Inc.	910,606,391.11	6.20	1.72
AVID.O	Avid Technology Inc.	1,184,722,617.70	20.89	1.13
BLKB.OQ	Blackbaud Inc.	3,724,598,106.32	26.63	1.07
BOX.N	Box Inc.	3,647,230,996.56	33.80	0.94
CRNC.OQ	Cerence Inc.	728,418,350.52	12.48	2.53
CVLT.OQ	Commvault Systems Inc.	2,955,839,414.81	35.35	0.62
CCSI.OQ	Consensus Cloud Solutions Inc.	478,050,997.59	10.56	0.86
CTS.TO	Convergent Technology Solutions	402,362,186.40	9.64	1.80
APPS.OQ	Digital Turbine Inc.	558,875,309.52	12.11	2.61
DV.N	DoubleVerify Holdings Inc.	4,653,808,932.20	35.94	1.52
ESMT.N	EngageSmart Inc.	3,445,951,933.17	73.82	1.26
ENV.N	Investnet Inc.	2,290,435,602.00	33.20	1.26
EVBG.OQ	Everbridge Inc.	839,670,378.80	40.95	0.80
EVCN.OQ	EverCommerce Inc.	1,908,168,406.23	22.86	1.16
GWRE.N	Guidewire Software Inc.	7,356,540,237.60	12.36	1.14

(continued)

Exhibit 25. Market Capitalization, EV/EBITDA, and Beta Values
for 35 Small-Cap Firms (*continued*)

Identifier	Company Name	Market Cap (\$)	EV/EBITDA	Beta
HLIT.O	Harmonic Inc.	1,122,507,239.37	23.06	0.93
HCP.OQ	HashiCorp Inc.	4,160,830,900.40	49.70	2.57
INFA.N	Informatica Inc.	6,099,825,915.30	24.44	1.47
INST.N	Instructure Holdings Inc.	3,835,913,073.84	27.24	0.91
IDCC.OQ	InterDigital Inc.	2,154,026,820.72	3.80	1.20
MLNK.N	MeridianLink Inc.	1,406,735,665.92	16.94	0.99
MITK.OQ	Mitek Systems Inc.	481,425,912.00	14.94	0.94
NCR.N	NCR Corp.	3,683,126,000.00	7.28	1.63
PRFT.O	Perficient Inc.	2,046,071,555.46	15.35	1.49
PWSC.N	PowerSchool Holdings Inc.	4,486,540,032.80	38.27	1.22
RIOT.OQ	Riot Platforms Inc.	1,704,813,645.20	14.50	4.24
SMTC.O	SemTech Corp.	1,502,964,588.52	17.58	1.64
SWI	SolarWinds Corp.	1,541,950,048.08	15.02	1.00
TASK.O	TaskUs Inc.	774,576,503.75	12.42	2.20
TDC.N	Teradata Corp.	4,451,544,000.00	13.80	0.98
VRNT.OQ	Verint Systems Inc.	1,359,334,357.20	21.51	1.04
VERX.OQ	Vertex Inc.	3,570,953,545.92	38.34	1.06
		Average	22.4	1.407

Source: Refinitiv.

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