THE SIZE OF THE CRYPTO-ECONOMY: CALCULATING MARKET SHARES OF CRYPTOASSETS, EXCHANGES AND MINING POOLS

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Cryptoassets and related actors such as crypto-exchanges and mining pools are now fully integrated into mainstream economic activity. A necessary corollary is that they have attracted heightened regulatory and investor scrutiny. While some rules and obligations apply uniformly across all economic actors in a given sector, many others, such as antitrust laws and some financial regulations as well as investor decisions are informed by actors' relative economic size—meaning that those with larger market shares can become more attractive regulatory or investing targets. It is therefore a foundational issue to properly measure the economic footprint of economic actors in the crypto-economy, for otherwise regulatory oversight and investor decisions risk being misled. This has proven a remarkably difficult exercise for multiple reasons including unfamiliarity with the underlying technology and role of involved actors, lack of understanding of the applicable metrics' economic significance, and the unreliability of self-reported statistics, partly enabled by lack of regulation. Acknowledging the centrality of cryptoasset size in a number of regulatory and policy-making areas, and the fact that previous attempts have been incomplete, simplistic, or even plainly wrong, this paper presents the first systematic examination of the economic footprint of cryptoassets and their constituent actors—mining pools and crypto-exchanges. We aim to achieve a number of objectives: to introduce, identify and organize all relevant and meaningful metrics of crypto-economic actors market share calculation; to develop associations between metrics, and to explain their meaning, application, and limitations so that it becomes obvious in which context metrics can be useful or not, and what the potential caveats are; and to present rich, curated, and vetted data to illustrate metrics and their use in measuring the shares of crypto-economic actors in their respective markets. The result is a comprehensive guidance into the size of the crypto-economy.

I. INTRODUCTION

Over the past few years cryptoassets have transitioned from fringe experimental projects to tools of the mainstream economy. Cryptoassets (e.g. cryptocurrencies, tokenized securities, crypto-derivatives etc) are digital instruments of economic value that are developed on blockchain networks, verified by validators (e.g. miners), and usually traded over crypto-exchanges. The popularization and adoption of cryptoassets has been controversial with great resistance still surrounding their utility, reliability and safety.[1] That said, with an increasing number of applications in banking, finance, legal, logistics, and other sectors,[2] it would not be wise to ignore the trend. Indeed, regulators and law and policy makers are showing heightened activity in devising appropriate rules for the blockchain and crypto-economy.[3]

While some rules and obligations apply uniformly across all firms in their respective sector, many are contingent on the relative size of the regulated subjects, meaning that smaller actors may incur different regulatory treatment compared to larger actors. Antitrust law is the prime example, with most rules being triggered only after a showing of market power, whose main (but not exclusive) determinant is the relative size of the challenged firm in a defined market (or a defined "ecosystem" if more modern analysis geared toward digital markets is chosen).[4] Emerging antitrust litigation in the cryptoasset industry involving both monopolization[5] and anticompetitive agreements[6] will require an assessment of defendants' relative size, whether in a defined market or in the broader ecosystem, to determine whether they possess the necessary power to effectively engage in monopolization or in anticompetitive agreements that affect the industry beyond the thresholds set by the law. Regulators are also carefully monitoring the space; notably, the European Commission last year launched an investigation into the potential for anticompetitive conduct by Facebook's Libra enabled by the sheer magnitude of the Libra cryptocurrency project. Related concerns on the systemic importance of Libra for the operation of markets, stemming from its potentially monopoly-level market share and its relationship with investors, users and governments, have been voiced around the world by numerous authorities and law-makers too.

Financial regulation also includes sets of rules that are targeted to institutions, which, due to their size, are deemed to be systemically important and which therefore incur additional oversight or obligations. Examples of size-dependent oversight or obligations include monitoring by the Financial Stability Board,[7] regulations proposed for adoption by the Dodd-Frank Act's Financial Stability Oversight Council against banks and nonbank financial companies,[8] and the Senior Managers and Certification Regime,[9] all of which are concerned with financial institutions whose large economic size—however defined—poses a

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[1] Matt Higginson, Marie-Claude Nadeau & Kausik Rajgopal, *Blockchain Development and the Occam Problem*, MCKINSEY INSIGHTS (January 2019).

[2] For a summary of adoption cases *see* ConsenSys, *Enterprise Ethereum: Blockchain Use Cases and Applications by Industry*, MEDIUM (November 14, 2018).

[3] For a list of the large body of emerging regulatory activity *see* The Law Library Of Congress, Regulation Of Cryptocurrency Around The World (2018), https://www.loc.gov/law/help/cryptocurrency/cryptocurrency-world-survey.pdf.

[4] The rebuttable correlation between market shares and market power dates back to United States v. Aluminum Co. of America, 148 F.2d 416, 424 (1945). For "ecosystem" analysis *see infra* Part II.

[5] United American Corp. v. Bitmain, Inc. et al, Docket No 1:2018cv25106 (December 6, 2018).

[6] Leibowitz et al v. iFinex Inc. et al, Docket No 1:19-cv-09236 (October 6, 2019).

[7] Financial Stability Board, Policy Measures to Address Systemically Important Financial Institutions (2011), http://www.fsb.org/wp-content/uploads/Policy-Measures-to-Address-Systemically-Important-Financial-Institutions.pdf.

[8] Codified in Dodd–Frank Wall Street Reform and Consumer Protection Act, H.R. 4173, § 101.

[9] Financial Conduct Authority (FCA), Senior Managers and Certification Regime, https://www.fca.org.uk/firms/senior-managers-certification-regime.

potential risk to financial stability. Investor decisions are also informed by economic size; for example, as assets with large capital base are commonly seen as more liquid and exchanges with large volume as offering greater tradability.[10]

Evidently, economic size forms a key determinant of regulation, litigation, and law and policy making, and it is therefore imperative to measure it accurately. This has proven remarkably difficult in the case of cryptoassets and their constituent actors. There have certainly been attempts in that direction—some highly influential, like for example calculating market shares of cryptocurrencies by market capitalization—but existing efforts are incomplete, simplistic, or misleading.[11] The reasons that make market share calculation of cryptoassets challenging are multifaceted. Part of the difficulty stems from the lack of understanding of the technologies involved, but also of the economic significance of the applicable metrics. As with every new technology there is a steep learning curve in terms of the roles performed by each actor in a given market, and of the measurements that most accurately reflect the portion of economic activity for which actors account in their respective markets.

Moreover, it would be wrong to assume that a single metric is always the most accurate or reliable for any and all aspects of the economic size one wishes to measure. Depending on the purpose and particular circumstances of each case, different proxies for size may be more instructive than others. This has long been recognized, at least by antitrust courts and authorities, which rely on numerous proxies to obtain a more comprehensive assessment of firms' market shares. However, when the available proxies all point in the same direction, it is not clear which one is the determinative one and why. This is a point of complexity in the crypto-economy, because, as it will become apparent in the analysis below, the available proxies can yield diverging results—e.g. a cryptoasset may boast a high number of transactions but have low market capitalization.[12] For this reason, a mapping of available proxies rather than a single go-to proxy and an explanation of what they represent and how to measure them is more advisable.

What further complicates the assessment of crypto-economic actors' relative size, importance and strength, even if the correct proxies are identified, is that the data may be unavailable or—worse—unreliable or manipulated. This is particularly true in crypto-markets largely due to lack of sufficient regulation and oversight, which allows the relevant actors to report unchecked or fabricated data.[13] The greatest danger is that investigators and investors may not even suspect that the available data is unreliable, and therefore scholarly warnings in that direction should be welcome.

Acknowledging the centrality of economic size measurements in a number of regulatory and policy-making areas, and the multifarious and often hidden difficulties they entail, this paper presents the first systematic analysis of how to measure market shares in the crypto-economy and in particular of the most common elements and actors, namely cryptoassets, miners and crypto-exchanges. The analysis herein will allow antitrust authorities, courts and litigants to establish the necessary degree of market power or size thresholds, which in turn are required in claims of monopolization, anticompetitive agreements and merger control. It will further allow regulatory authorities and antitrust authorities to rank threats in their respective regulatory domain by formulating sounder views on the magnitude of the economic activity and size of crypto-economy actors. It can also, lastly, inform investor decisions by providing insights into key measurements of the relative market strength of cryptoassets and their constituent actors.

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[10] *See* Hermann Elendner et al., *The Cross-Section of Crypto-Currencies as Financial Assets*, *in* HANDBOOK OF BLOCKCHAIN, DIGITAL FINANCE, AND INCLUSION, VOLUME 1 145–173 (David Lee Kuo Chuen & Robert Deng eds., 2018) where the authors discuss size metrics such as market capitalization, volume etc as influential determinants of cryptoasset investing.

[11] *See infra* Parts III and IV.

[12] *See infra* Part II.

[13] Deceptive trade practices in the crypto-economy have invited law enforcement actions. *See* Caleb Silver, *NY Attorney General Launches Inquiry into Cryptocurrency Exchanges*, INVESTOPEDIA (April 17, 2018).

To deliver these results we proceed in the following steps: we introduce, identify and organize all relevant and meaningful proxies of market share calculation of cryptoassets, mining pools and crypto-exchanges. Some of the proxies we discuss below are new (e.g. realized market capitalization), while others have been known, but their use particularly in measuring cryptoasset relative size had escaped attention. Secondly, we develop associations between proxies, and we explain their meaning, application, and limitations so that it becomes obvious in which context proxies can be useful or not, and what the potential caveats are. Thirdly, we present rich, curated, and vetted data to provide metrics and their use in measuring the shares of crypto-economic actors in their respective markets. While the data we use is publicly accessible, we draw correlations useful to the measurement of cryptoasset economic footprint that have been missed in the past. We do not mean to conclude that there is a single appropriate proxy for size; rather we accept that each proxy reflects a different aspect of economic activity and that relying on more than one proxy provides a more complete picture. Through these functions collectively, the article provides regulatory authorities, lawmakers, but also investors and scholars, with a comprehensive vade mecum on estimating the size of the crypto-economy's most central actors, as one of the most foundational determinants in their regulatory treatment.

The article is structured as follows: Part II explains the function and challenges of market share calculation, highlighting the significance, fluidity, and challenges of the inquiry. We then turn to the core of our inquiry, namely the roadmap on how to conduct proper calculation, which we organize in inter-asset calculation (Part III) and intra-asset calculation (Part IV). Inter-asset calculation is concerned with the measurement of market shares of cryptoassets relative to other cryptoassets, whereas intra-asset calculation refers to the measurement of market shares of the actors that make up cryptoasset networks, i.e. mining pools and crypto-exchanges. Together, inter-asset and intra-asset calculations provide a comprehensive guidance into the size of the crypto-economy.

II. THE FUNCTION AND COMPLICATIONS OF MARKET SHARE CALCULATION

Market share is an indication of firms' relative economic size; it reflects the portion of economic activity for which a firm accounts in the relevant market.[14] Traditionally, size has played an important role in antitrust proceedings, as it formed the primary proxy for market power,[15] which in turn is a standard requirement for almost every type of antitrust proceeding, including monopolization claims (abuse of dominance), anticompetitive restraint claims (agreements) and mergers (concentrations). The idea is that commanding a large share of a defined market makes an actor's activities more impactful in that market and allows the actor to more easily disregard the pressure coming from competitors and consumers—the essence of market power.

As of recent, the relevance of market shares has come under fire not only because it may not necessarily be as instructive a proxy for market power as initially thought,[16] but because the concept of relevant market, which is a necessary predicate of calculating market shares, has been criticized as unhelpful,[17] and particularly in digital markets, to which blockchain markets are akin. Despite these reservations, the calculation of market shares is still a useful exercise for numerous reasons, and all the more so in blockchain markets. It is true that market shares do not present the full picture of market power, since new entry, multihoming, product differentiation, brand loyalty, and industry structure and

[14] JONATHAN JACOBSON, ANTITRUST LAW DEVELOPMENTS 341 (6th ed. 2007).
[15] *See supra* note 4.
[16] *See* Daniel A. Crane, *Market Power without Market Definition*, 90 NOTRE DAME L. REV. 31 (2014).
[17] *See* Louis Kaplow, *Why (Ever) Define Markets?*, 124 HARV. L. REV. 437 (2010).

characteristics also affect market power. However, in all their simplicity, market shares are a prima facie indication, which can be particularly useful in young industries, where deep expertise to appreciate the rest of the factors may be lacking.[18] Moreover, while as snapshot information market shares may have limited value, historical market shares can be highly reliable because their evolution is partly the result of all other factors at play combined.[19] For instance, Bitfinex, a popular exchange, has maintained a market share of around 30 per cent from 2014 through 2019 while other competitor exchanges saw their market shares fluctuate by as much as 50 per cent in a matter of months (see, e.g., Bitstamp, which commanded almost 50 per cent in mid-2014 only to drop to 25 per cent by the end of the year).[20] Such persistence could be indicative of respective market power.

It is also true, that the value of market share calculation, is largely limited by the increasingly contested value and validity of market definition, since market shares are calculated within a defined market. A growing consensus is forming around the idea that market definition and relevant markets are a somewhat outdated concept in antitrust law since they fail to capture the full roster of competitive forces and pressure that firms create and are subject to; instead, looking for the effects of anticompetitive conduct directly[21] or looking more broadly into firms' ecosystems or value chains seems to gain traction.[22] These considerations hold particularly true for digital markets due to the interconnectedness among digital products and services, which cut across what may traditionally be seen as distinct markets.[23] Blockchain markets are likely to be susceptible to such effects, as they are beginning to exhibit the kind of malleability and interconnectedness that makes digital markets easier to construe as ecosystems rather than as traditional vertical value chains.[24] By means of an example, exchanges, which serve as wallets, transaction platforms and issue their own cryptoassets, seem to be in the early stages of developing an ecosystem around them, as they architect the type of transactions that are available on their platforms and also expand themselves into different markets that can otherwise be seen as distinct (e.g. exchange market, cryptoasset market etc).

Such features may advocate for a shift toward ecosystem, rather than market, analysis. This, however, does not critically undermine the utility of market shares, since, to the extent that the boundaries of the ecosystem will still need to be defined, much like the need to define the boundaries of the relevant market, market shares (or more precisely "ecosystem shares") can still prove informative within those set boundaries. They will still provide an incomplete picture of the competitive forces at play, but they will also still serve as a prima facie indication of market power, especially when looked at with historical depth. Moreover, the utility of market shares remains unabated in other contexts. For example, market shares matter more in merger control, because the assessment of mergers is done on a forward-looking basis, i.e. whether the proposed merger will result in substantial lessening of competition, and it is relatively uncomplicated to add up the market shares of the merging companies to come up with the

[18] Richard S. Markovits, *The Economics of Antitrust Law: A Comment on the Other Contributions to This Symposium*, 61 ANTITRUST BULL. 198, 202 et seq. (2016).

[19] They can, of course, be the result of other factors that are internal to the firm, such as constant innovation.

[20] *See* Bitcoinity, Exchanges List, *available at* https://data.bitcoinity.org/markets/exchanges/USD/5y#rank_desc.

[21] On the comparison of direct and indirect measurements of market power *see* Crane, *supra* note 16; Gregory J. Werden, *Why (Ever) Define Markets: An Answer to Professor Kaplow*, 78 ANTITRUST L.J. 729 (2012).

[22] James Moore, *Business Ecosystems and the View from the Firm*, 51 ANTITRUST BULLETIN 31 (2006); Daniel A Crane, *Ecosystem Competition and the Antitrust Laws*, 98 NEBRASKA LAW REVIEW 412 (2019); Jose van Dijck, David Nieborg & Thomas Poell, *Reframing Platform Power*, 8 INTERNET POLICY REVIEW 1 (2019).

[23] Konstantinos Stylianou, *Exclusion in Digital Markets*, 24 MICH. TECH. L. REV. 181, 198 et seq. (2018).

[24] Ioannis Lianos, *Blockchain Competition – Gaining Competitive Advantage in the Digital Economy: Competition Law Implications*, *in* REGULATING BLOCKCHAIN: TECHNO-SOCIAL AND LEGAL CHALLENGES 329 (Ioannis Lianos et al. eds., 2019).

combined future market share.[25] However, the rest of the factors that contribute to market power do not necessarily lend themselves to such straightforward analysis. For instance, it may be impossible to accurately predict brand loyalty of the resulting merged company, or the indirect externalities of the combined platforms sides. Furthermore, market shares are used in the blackletter of the law to estimate thresholds, as for example in VBER. While VBER is set to expire in 2022, antitrust law is unlikely to completely dispense with the concept of market shares. Lastly, and taking an expansive approach of the utility of market shares beyond the strict confines of competition law, size calculations become relevant in other areas too. For example, in financial regulation certain obligations, such as the Senior Managers and Certification Regime (SMCR),[26] apply only to firms over a certain size, and while cryptoasset firms are currently not subject to SMCR, it is only a matter of time that regulatory authorities will seek to extend appropriate regulations to them as well.[27] Size also becomes relevant as a consideration of market and investor decisions. For example, as a matter of behavioral finance, investors may be more inclined to invest in cryptoassets with larger market capitalization (e.g. of the cryptocurrencies, Bitcoin), either because they see them as safer or more liquid or providing better returns.[28]

For these reasons it is safe to say that market share calculation retains its relevance. The main difficulty now becomes the actual methodology of the calculation. The difficulty is particularly pronounced when the industry at hand is nascent and the economic footprint of firms is not well understood, let alone measured. The challenge does not only lie in identifying relevant and observable metrics that can serve as common denominators across firms in a given market, but also in knowing which of them should be more influential in every particular situation.[29] While guidance from past cases can be useful, it is often patchy, and cryptoasset markets are unique even among financial markets, in which courts and authorities have experience. This makes a scoping exercise of appropriate metrics necessary to understand not only what metrics are relevant, but also how they apply in particular markets.

As a general matter, it is commonly said that sales is "the primary index of market power."[30] Yet, it is not immediately obvious how one should calculate sales—whether by revenue, by units or by other indexes, and how these are reflected in different types of markets.[31] Moreover, sales—however measured—are not always the best metric, because they may not reflect the true economic strength of firms under the particular circumstances of the industry in question. For example, in oligopolistic markets characterized by a high degree of vertical integration, where sales across the value chain do not take place in an open market context, since both the prices and amounts of the transfers can be manipulated, sales may not necessarily reflect an accurate picture of the market positions of the various companies.[32] In such cases, production capacity rather than sales can be a better indicator.[33] Then again, when a resource is pre-

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[25] Werden, *supra* note 21 at 735 et seq.

[26] *See supra* note 9.

[27] *See, e.g.*, FCA's plans and activity on distributed ledger technologies *in* Feedback Statement FS17/4: Distributed ledger technology on consultation Discussion Paper DP17/3, https://www.fca.org.uk/publication/feedback/fs17-04.pdf.

[28] On behavioral finance *see* ANDREI SCHLEIFER, INEFFICIENT MARKETS: AN INTRODUCTION TO BEHAVIORAL FINANCE (2000); Robert A. Nagy & Robert W. Obenberger, *Factors Influencing Individual Investor Behavior*, 50 FINANCIAL ANALYSTS JOURNAL 63 (1994).

[29] Gregory J Werden, *Assigning Market Shares*, 70 ANTITRUST L.J. 67, 67 (2002).

[30] Brown Show Co. v. United States, 370 U.S. 294, 322 n 38 (1962). *See also* Geneva Pharms. Tech. Corp. v. Barr Labs., 386 F.3d 485, 500 (2004) ("Although market share is not functionally equivalent to monopoly power, it is nevertheless highly relevant to the determination of monopoly power.").

[31] JACOBSON, *supra* note 14 at 341–343.

[32] *See, e.g.*, United States v. Amax, Inc., 402 F. Supp. 956, 961 (1975).

[33] *Id.*

produced and pre-committed to future long-term customers, as is the case in some energy markets, current production capacity may be misleading, and uncommitted capacity may be a more accurate predictor of future economic strength in the market.[34]

Furthermore, when one zooms into a specific industry, these broad categories of metrics fork into numerous variations and more can be added too.[35] For example, in the financial sector, which encompasses cryptoassets, among the relevant metrics have been: total assets, deposits, and loans in the retail banking market;[36] transaction value and transaction volume in the stock exchange market;[37] number of cards and volume of card transactions in the credit/debit card market;[38] and "league table" rankings in the investment banking market.[39]

Moreover, even when the relevant metrics have been identified, it is not at all clear which one should be the most decisive. This may not be a problem when all metrics point to similar outcomes, but if there are significant discrepancies, the right choice becomes decisive. For instance, in *United States v. Amax* where the court could choose between sales and capacity as the appropriate measure of market positioning, the difference was significant since "[i]f sales were used it would reduce by almost half the market share which the Government, using … capacity as the measure, alleges Amax would control…"[40] (the court chose capacity in the end).

But, unhelpfully, in financial markets the various metrics seem to all point in the same direction and are used interchangeably, thereby concealing which metric is the most influential.[41] For example, in the *DB/NYSE* merger the European Commission (hereinafter Commission) relied on the metrics of value and volume in the equity trading, bond trading, and future contracts markets, finding mostly aligned figures, except for European bond trading carried out on regulated markets, where the merging parties would achieve a combined share of 0-5% in value terms, but 20-30% in volume terms, which the Commission explained on the basis that the parties mostly attract small trades.[42] However, because of the low combined market share under either metric, the Commission did not have to decide which metric should be more determinative. In a different context (anticompetitive agreements), in *Visa International* the Commission again cumulatively used various metrics without separately discussing each one's merits. It noted that "[o]n the national markets for cards … Visa holds, in terms of number of cards in circulation, a market share varying between 4% and 69%, [and in] terms of volume and value of Visa card transactions

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[34] *See, e.g.*, United States v. General Dynamics Corp., 415 U.S. 486, 501 (1974).

[35] For examples of industry-specific metrics *see* ALISON JONES & BRENDA SUFRIN, EU COMPETITION LAW 337 (5th ed. 2014). Also, in some markets multiple metrics become relevant all at the same time in varying degrees. For instance, in the market for online voice communication software (e.g. Skype, Messenger etc) relevant metrics can include total users, active users, call volume, call duration, traffic volume, total revenue, or revenue from user subscriptions, all of which reflect a tranche of the full picture. *See* Case No COMP/M.6281 - Microsoft/ Skype.

[36] *See, e.g.*, United States v. Phillipsburg National Bank & Trust, 399 U.S. 350 (1970); United States v. Philadelphia National Bank, 374 U.S. 321 (1963).

[37] *See, e.g.*, Commission Decision of 1 February 2012 Case No COMP/M.6166 — Deutsche Boerse / NYSE Euronext.

[38] *See, e.g.*, Commission Decision of 9 August 2001 Case No COMP/29.373 — Visa International, para 51. *See also* Commission Decision of 3 October 2007 Case No COMP/D1/37860 — Morgan Stanley/Visa International, paras 80-93.

[39] *See, e.g.*, Commission Decision of 19 December 1997 Case No IV/M. 1068 — Credit Suisse First Boston/ Barclays, para 9.

[40] Amax, *supra* note 32 at 961.

[41] And that is even putting aside the common problem of redacted decisions where market shares are not made publicly available and so it is impossible to determine the extent to which they are used.

[42] DB/NYSE, *supra* note 37 para 115.

Visa's market share varies respectively from 2% to 95% and 2% to 93%."[43] The conclusion was that, based on Visa's position in the market, its network indeed had an appreciable effect on competition, but we do not know whether the conclusion would have been the same if any one of the metrics considered suggested a markedly different market position. Similarly, in *Mastercard* the Commission considered the number of cards and transaction volumes as relevant metrics, but even though the two metrics diverged significantly, the Commission opined that the available data on transaction volumes were unreliable and did not end up using it, passing up an opportunity to discuss their relative value.[44]

One last complication relates to the choice of metrics depending on the nature and purpose of the investigation. As far as antitrust law is concerned, in merger cases, where the assessment is forward looking, courts and authorities have tended to rely on metrics that reveal firms' future economic strength, whereas in anticompetitive agreements or monopolization cases the emphasis is on metrics that reveal firms' market shares at the time of the anticompetitive conduct. This is reasonable because the goal of merger control is to prevent a future anticompetitive outcome, whereas the purpose of antitrust enforcement in cases of anticompetitive agreements or monopolization is to attest past or ongoing anticompetitive conduct and put an end to it if it persists. As far as regulation is concerned, the relevant metrics are those that reflect firms' market shares at the time the regulatory assessment is made. For example, for the purposes of SMCR, the relevant time is the time firms seek or should seek compliance with the SMCR regime.

Considering the heterogeneity of the available metrics as documented above, it would not be wise to conclude that any one metric is superior to the others for use in the cryptoassets market or any market for that matter. In fact, as will become obvious below, novel markets may be characterized by unique metrics, and these have to be taken into account as well. The only meaningful approach therefore is to list the relevant metrics in the cryptoassets market, and analyze what they mean and what they show about the economic strength of the cryptoasset market actors. Then, it is up to investigators and researchers to choose the appropriate metrics for their particular purposes.

III. INTER-ASSET CALCULATION

Inter-asset calculation of cryptoasset market shares determines the economic significance and competitive positioning of cryptoassets relative to each other. This finds various applications, from guiding decisions of investors and financial services businesses who try to assess liquidity and network effects to determine which cryptoasset to support; to informing decisions of entrepreneurs deciding which blockchain to build on top of and may care about the size of the network and its economic traffic; to helping regulators and authorities assess which cryptoassets are worthy of attention and regulation. Determining the relative strength and prevalence of cryptoassets is a significant challenge. Cryptoassets are in many cases collaborative, grassroots projects, lacking a single authority which could provide relevant and accurate data and disclosures—as compared with, for instance, a public corporation, which issues quarterly reports or has to file 10-K forms to the SEC. And while public ledger data can be accessed directly, which allows observation of the necessary indexes, systematic comparative methods have yet to be developed as the industry is still in its infancy. This exposes investors, researchers and regulators to the discretion of the data services making comparisons, which are often disputed or obscure.

[43] Visa International, *supra* note 38 para 51.

[44] Commission Decision of 19 December 2007 Joined Cases COMP/34.579 — MasterCard, COMP/36.518 — EuroCommerce and COMP/38.580 — Commercial Cards, paras 105-117.

The most popular inter-asset comparative method is by *market capitalization*, which reflects cryptoassets' economic footprint as a function of their market price multiplied by the circulating supply. It was popularized by industry-leading website CoinMarketCap, a cryptoasset rankings and a data service, which in 2018 was at one point one of the 100 most-visited websites on the Internet.[45] Due to its market-leading status, methodologies employed by CoinMarketCap are influential in the cryptoasset industry. However, informative as it may be at first glance, market capitalization is problematic both because it treats all cryptoassets as homogeneous, and because, given the considerable discrepancies among cryptoassets in terms of float and liquidity, it glosses over numerous influential aspects of their size, use and health.

To respond to these weaknesses, we first disaggregate below different cryptoassets and cluster them into like-kind groups, and then propose a number of alternative metrics of cryptoasset economic strength, which can be used to compare cryptoassets with greater nuance and accuracy.

A. Disaggregating Cryptoassets

Cryptoassets are digital instruments of economic value that are developed and traded on distributed ledger technology (DLT) and most commonly on blockchain.[46] The function of cryptoassets resembles that of common financial instruments, like currencies, stocks and derivatives. Blockchain equivalents would include cryptocurrencies, tokenized equity and crypto-derivatives. While cryptoassets share many characteristics, the cosmetic and structural similarities between them should not be mistaken for inherent teleological similarity sufficient to render the industry as a whole a stable, single asset class. The market is highly diverse, and includes tokens intended as straightforward currencies, (pseudo) or actual tokenized equity, scarce representations of some commodity (e.g. storage and computing power), access keys for a given application or service, or representations of some external asset like gold.[47] Since these are all diverse functions, it is worth devising a taxonomy to disaggregate these assets.

Several notable disaggregations have been attempted. Burniske and White in an early influential white paper offered a by function disaggregation of the industry aiming to raise awareness around the heterogeneity of the features and purpose of cryptoassets, and arguing that assets should be placed into distinct conceptual buckets for analytical purposes.[48] They distinguished three categories: cryptocurrencies (such as Bitcoin and Litecoin), crypto-commodities (access rights to some digitally native scarce commodity like storage or computation) and tokens (access rights to some finished digital good or service, like a social media platform or a prediction market). This disaggregation can be augmented by adding tokenized equity, which represents a digitized version on a blockchain of what

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[45] *See* Alexa rank *available at* https://www.alexa.com/siteinfo/coinmarketcap.com.

[46] The vast majority of cryptoassets is developed and traded on blockchain networks, although there exist cryptoassets that rely on DLT but not on blockchain. A notable example is IOTA, whose distributed ledger does not consist of transactions grouped into a chain of sequential blocks as in a blockchain, but as a stream of individual transactions entangled together. See Serguei Popov, 'The Tangle' (*Descryptions*, 30 April 2018) <http://www.descryptions.com/Iota.pdf> accessed 12 June 2019. *See also* the relevant point on the overlap of cryptoassets with cryptocurrencies *in* MICHEL RAUCHS ET AL., *Second Global Cryptoasset Benchmarking Study* 17 (2018).

[47] *See* Paolo Tasca & Claudio J. Tessone, *Taxonomy of Blockchain Technologies. Principles of Identification and Classification*, ARXIV:1708.04872 [CS], 6–8 (2017).

[48] CHRIS BURNISKE & ADAM WHITE, *Bitcoin: Ringing the Bell for a New Asset Class* (2017).

would normally be considered real-world equity.[49] Tokenized equity is beginning to account for a recent but growing share of the market.[50]

Greer's general asset taxonomy can also be adapted for use into the cryptoasset market.[51] Greer divides assets into capital assets (which are valued on the basis of their cash flows), consumable/ transformable assets, and store-of-value assets which are non-cash-generating vehicles for parking and storing wealth. This can be roughly adapted to the cryptoasset industry: to the extent that they are used as hard-to-tamper-with wealth storage mechanisms, Bitcoin and similar such assets have no intrinsic cash flows and can be assigned to the store-of-value category. Representations of equity like the BNB token (whose value derives from periodic buybacks performed by the cryptocurrency exchange Binance) fall under the capital asset category. And tokens like Sia or Storj, which (in theory) entitle users to a digital service, are commodity-like in that the tokens represent the consumable/transformable asset of storage. Regulators such as UK's FCA, Switzerland's FINMA, and EU's ESMA have embraced a similar taxonomy, dividing cryptoassets into exchange tokens (e.g. Bitcoin), security tokens, and utility tokens.[52]

Greer's and similar taxonomies show their limitations in ascriptions of tokens such as 0x and MKR, which are intended to be used for governance in the sense of distributing decision-making authority over some shared open-source protocol. Similarly, the common distinction made in the industry between tokens intended to store value versus tokens intended for transactional usage partly breaks down in practice. All popular cryptoassets used for transacting must have some users who hold the tokens for a nonzero period, otherwise they cannot maintain a positive exchange rate (if not pegged to some other currency like the dollar). Questions also arise over the status of so-called utility tokens, whose value derives from their exclusive use in a tokenized ecosystem—a decentralized application or set of applications. These tokens are tantamount to transferable API keys that grant users access to a bundle of services. The value proposition of these tokens has yet to be proven, and their precise position in the asset taxonomy is still poorly understood, but many dozens in the category have nonzero trading values.

Considering these weaknesses, one can move away from a by function classification and instead adopt a classification based on where the relevant information for the cryptoasset to perform its function resides. This classification is becoming more relevant as the notion of *tokenization* of conventional assets gains momentum (in this context, tokenization is the conversion of a conventional asset into cryptoasset form). Conceptually, there is almost nothing in common between a security token representing a tokenized real estate project, and a cryptocurrency like Bitcoin or Litecoin, aside from the fact that they both use proof of work (PoW) blockchains for clearance and settlement.[53] Rauchs et al.'s DLT Conceptual Framework distinguishes assets along this dimension.[54] The authors distinguish cryptoassets by the provenance of information within the ledger: endogenous references derive entirely from internal data (Bitcoin's ledger, for instance, simply tracks addresses posted to the blockchain and values held within those addresses), while exogenous entries refer to external data, which must be validated by third parties.

Distinguishing among different classes of cryptoassets enables meaningful like-for-like comparisons, mirroring traditional asset classes (where, for example, capital assets are held as wholly distinct from

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[49] Carol R. Goforth, *Securities Treatment of Tokenized Offerings under U.S. Law*, 46 PEPPERDINE LAW REVIEW (forthcoming) (2018).

[50] *See, e.g.*, the tZero prospectus filed with SEC *available at* https://www.sec.gov/Archives/edgar/data/1130713/000110465918013731/a18-7242_1ex99d1.htm.

[51] Robert J. Greer, *What Is an Asset Class, Anyway?*, 23 THE JOURNAL OF PORTFOLIO MANAGEMENT 86–91 (1997).

[52] FCA Feedback Statement, *supra* note 27. *See also* FINMA, Guidelines for Enquiries Regarding the Regulatory Framework for Initial Coin Offering (16 February 2018); ESMA, Own Initiative Report on Initial Coin Offerings and Crypto-Assets, ESMA22-106-1338 (19 October 2018).

[53] For example, a security token can subsist on Ethereum using one of its token standards.

[54] MICHEL RAUCHS ET AL., *Distributed Ledger Technology Systems: A Conceptual Framework* (2018).

currencies and foreign exchange), and allows more accurate representation of relative sizes. It is true that the rise of single-purpose, novel, or hybrid transactional and representation token models introduces significant complexities to this task, but a clear conceptual divide between tokens intended as direct equity or pseudo-equity, and cryptoassets created to facilitate general value transfer on a permissionless, peer-to-peer basis remains. Meaningful comparisons should be made within peer groups, rather than across a universal sample of cryptoassets.

B. Market Capitalization and Its Discontents

When it comes to assessing the relative size, importance and strength of cryptoassets, by far the most popular measure employed is *market capitalization*, taken as the market price multiplied by the circulating supply. For instance, if a cryptocurrency has issued one billion tokens and at a given time the price of each token is £10, the market capitalization at that time is £10 billion. This figure expresses an asset's market share vis-a-vis its value. While divergent market prices are an occasional problem due to fragmented liquidity in global markets,[55] the most significant imprecision with market capitalization derives from imperfect measures of supply. These can be attributable either to the unreliability of data sources which can overstate the liquidity of these assets, or to uncertainty over market-relevant supply. In properly calculating market capitalization one needs to ensure that only the relevant supply is counted. This section lists the slices of supply that should be excluded from nominal market capitalization either as unreliable (fake) or as irrelevant.

Unreliability is a symptom of the very nature of cryptoassets. Since cryptoassets and their trading venues are not regulated, and settlement occurs directly on the blockchain, there is no equivalent of institutions like the Depository Trust & Clearing Corporation to account for all the outstanding units, nor an authoritative and trusted methodology of self-reporting. Instead, within the broader market for cryptoassets, third parties who directly issue units of supply must be relied on to provide accurate data, or data has be collected, filtered, and analyzed from public blockchains. The poor integrity of available data makes ranking sites, which are often relied on to compare cryptoassets' relative size, also be unreliable. Since exchanges are globally distributed and vary significantly in quality and listing criteria, newly-created tokens tend to have little difficulty getting listed on a trading venue. Once they have exchange volume, they are granted access to the cryptoasset ranking sites. As the majority of cryptoasset exchanges are unregulated, and rely on decentralized networks like Bitcoin and Ethereum for clearance and settlement, they can function independently from the conventional financial system. Even if engaging in orderbook-matching is normally a highly regulated activity, cryptoasset exchanges are not reliant on the typical regulatory and financial constraints that popular securities trading venues are beholden to.

One notorious case was the Bitconnect Ponzi scheme, which promised users daily return in exchange for a capital lockup.[56] While Bitconnect was a straightforward Ponzi, the popular rankings site CoinMarketCap included data from Bitconnect's own proprietary (allegedly fraudulent[57]) exchange in trading volume, allowing the scheme to advertise meaningful liquidity and a market cap in the billions, which enticed traders.[58] Bitconnect is one of the more illustrative cases demonstrating how exchange data

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[55] *See, e.g.*, Bitcoin's Kimchi premium, Kyungji Cho, *Bitcoin's "Kimchi Premium" Has Vanished*, BUSINESSWEEK (February 2, 2018).

[56] Fitz Tepper, *Bitconnect, Which Has Been Accused of Running a Ponzi Scheme, Shuts Down*, TECHCRUNCH (January 16, 2018).

[57] Olga Kharif & Christie Smythe, *BitConnect's 'Crypto-Wonderland' Hit with Investor Lawsuit*, BLOOMBERG (January 25, 2018).

[58] Nick Chong, *Bitconnect Finally Gets Delisted from All Crypto Exchanges — "Officially Dead,"* ETHEREUM WORLD NEWS (September 12, 2018).

originating on unregulated exchanges which is then aggregated on popular coin rankings sites has very low integrity. However, these inputs form the basis for measures like market capitalization, which then powers inter-asset comparisons.

Data unreliability is a pervasive problem, which will hopefully subside as the industry gets increasingly regulated or is disciplined under the forces of competition. Uncertainty over market-relevant supply, on the other hand, requires a different approach. The issues there relate to unpredictable supply and variable issuance rates, lost or inactive coins, and supply inheritance, whose causes are lack of understanding of the function of cryptoassets or of the meaning of the relevant metrics. By illuminating these parameters, investors, regulators, and users can gain a significantly improved insight into cryptoassets' (relative) economic footprint. We address these in more detail in sequence below.

1. Supply Arbitrariness

Supply arbitrariness refers to situations where the total supply of a cryptoasset may be known in advance, but the time of release remains unknown and often at the discretion of a single entity. Without a precise supply figure, the calculation of market capitalization becomes a challenge beset in disagreement.

A famous example of a single entity maintaining discretion over the supply of a cryptoasset is XRP, the token created and sold by Ripple Labs. Around 100 billion XRP were created at inception in January 2013, but since then only 41 billion have entered circulation (through distribution events called "airdrops" and direct sales by Ripple Labs). Ripple Labs controls the remaining 59 billion XRP and can issue them at their discretion. Ripple claims to have escrowed 55 billion XRP on their ledger,[59] with that supply being progressively released until 2023, but since Ripple Labs maintains de facto control over the ledger and consensus system, that commitment is not as credible as a PoW system where issuance is codified for perpetuity at inception. The case of Stellar, an offshoot of Ripple, is equally instructive. The Stellar Development Foundation is tasked with the distribution of the native currency (Lumens or XLM), which it has done with predictable arbitrariness. Since 2014, the Stellar Foundation has issued just over 8.6 billion XLM out of its allotted 95 billion.[60] The considerable discretion that the Stellar Foundation retains over the distribution of the XLM supply means that there is little predictability in future issuance.

Moreover, in cases like those of Stellar and Ripple where the entirety of supply was created at inception, and then issued progressively (and with little predictability) over the subsequent years, the question of how to definitively calculate supply complicates matters. If it is assumed that investors are aware that only nine percent of all XLM tokens have been distributed, then they may be valuing the asset on the basis of fully diluted supply, which suggests that the ultimate supply should be contemplated, rather than the current circulating figures. Despite this, it is common to adjust cryptoassets based on actual circulating supply (free float),[61] and eliminate from supply coins held in the treasury of the issuing entity, if one exists. However, a tension remains: in cases where issuance is not credibly set according to a rigid schedule (as with XLM), the supply held in the ostensibly out-of-circulation issuer wallets is liable to enter active supply unexpectedly. Investors may therefore seek to incorporate this uncertainty into valuation which again makes the fully diluted supply figure more stable and reliable.

Supply arbitrariness presents an even thornier complication when a forward-looking comparison of different cryptoassets is attempted to assess their relative economic footprint. Normally, the common five-year discounted market cap method could be used, whereby the known or estimated supply increase

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[59] Ripple Escrows 55 Billion XRP for Supply Predictability, RIPPLE, https://ripple.com/insights/ripple-escrows-55-billion-xrp-for-supply-predictability.

[60] Stellar Development Foundation Mandate, STELLAR, https://www.stellar.org/about/mandate.

[61] *See, e.g.*, Bitwise's methodology at Bitwise Crypto Index Methodology, BITWISE INVESTMENTS, https://www.bitwiseinvestments.com/indexes/methodology.

is projected five years into the future and then the resulting expected supply figures are used for comparisons rather than the outstanding supply. Since supply schedules in many cases are programmatic, these projections can be useful. However, in the cryptoasset market it is not uncommon to have divergent issuance schedules, in which case one would have to decide on the appropriate future term. Comparing coins with high rates of new issuance, such as Zcash, where new yearly issuance is currently equivalent to 46% of its supply, to Bitcoin, with a 3.7% annualized issuance rate, is tricky. Evidently, if future issuance rates are incorporated into comparative measures, these discrepancies become salient.

2. Inert Supply

Free float, as commonly applied in the industry, does not however capture inert supply in non-centrally distributed cryptoassets, like Bitcoin or any of its numerous forks.[62] Inert supply reflects assets that are in circulation but are highly illiquid (**Figure 1**). To take inert supply into consideration would overestimate an asset's truly active and liquid supply. Even the most well-dispersed and liquid cryptoasset, Bitcoin, has significant illiquid tranches which only move with extreme rarity or not at all. A large, if unknown, number of units is understood to be permanently out of circulation. In Bitcoin, coins which have not moved since 2010 and can safely be understood to be lost amount to approximately 10.6% of supply. Research firm Chainalysis estimates that 3.6m BTC are either lost and out of circulation or held in wallets controlled by Bitcoin creator Satoshi Nakamoto, who is presumed to have abandoned the project and his/her coins.[63]

[62] A fork in this context refers to a competing offshoot from an established cryptoasset. In the case of Bitcoin, the existing state of the ledger was copied in August 2017 to create a competing blockchain called Bitcoin Cash.

[63] Jeff John Roberts & Nicolas Rapp, *Nearly 4 Million Bitcoins Lost Forever, New Study Says*, FORTUNE (November 25, 2017).

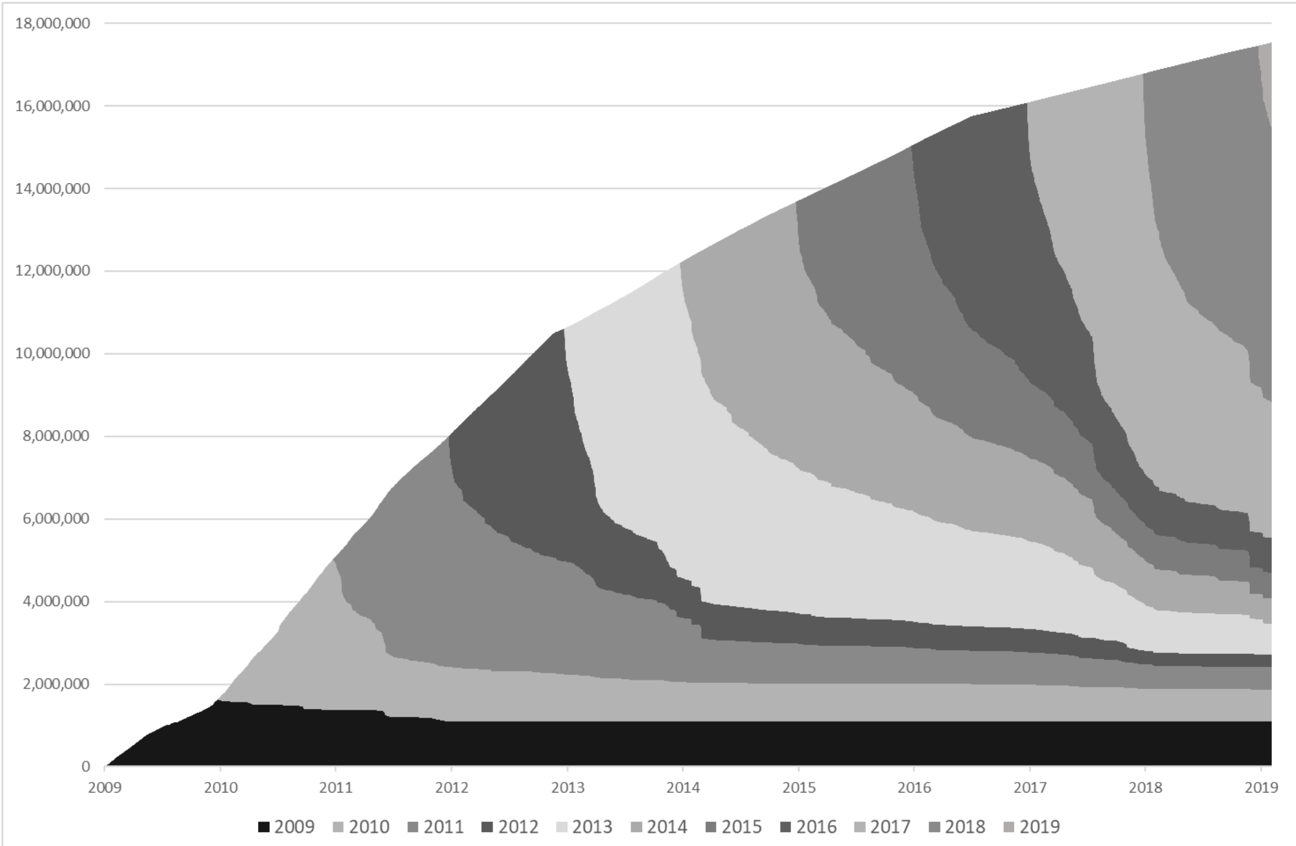

Figure 1*: Bitcoin supply per year of last move. The graph shows that a large quantity of circulating supply has remained dormant over the years, whether out of choice or because owners lost access to it. Source: Coin Metrics*

An unqualified version of market capitalization would incorporate these lost and inert units in market significance of the asset, as if they were potentially spendable. However, unlike equities, where there is recourse if, say, a physical share certificate is lost, in a distributed public key infrastructure like that which underpins cryptoassets, lost cryptographic keys result in a permanent loss of access to the asset. This raises the question of whether these units should be incorporated into supply if they are indeed verifiably lost. The problem is not exclusive to Bitcoin. In November 2017, a bug in a multi-signature contract led to the loss of over 500,000 ether tokens, which have yet to be recovered despite efforts to reassign those tokens to make them spendable.[64] If those efforts were to be abandoned, it would be worth contemplating whether those ~500,000 coins should be subtracted from supply, and by extension, market capitalization. At present, however, popular conceptions of market capitalization do not consider such nuances.

One possible solution to the problem of lost coins and the problem of overestimated supply is to inspect the blockchain directly to ascertain the liveness of supply.

[64] Camila Russo, *Security or Not, Ethereum's Soul Searching Isn't Over*, BLOOMBERG (June 27, 2018).

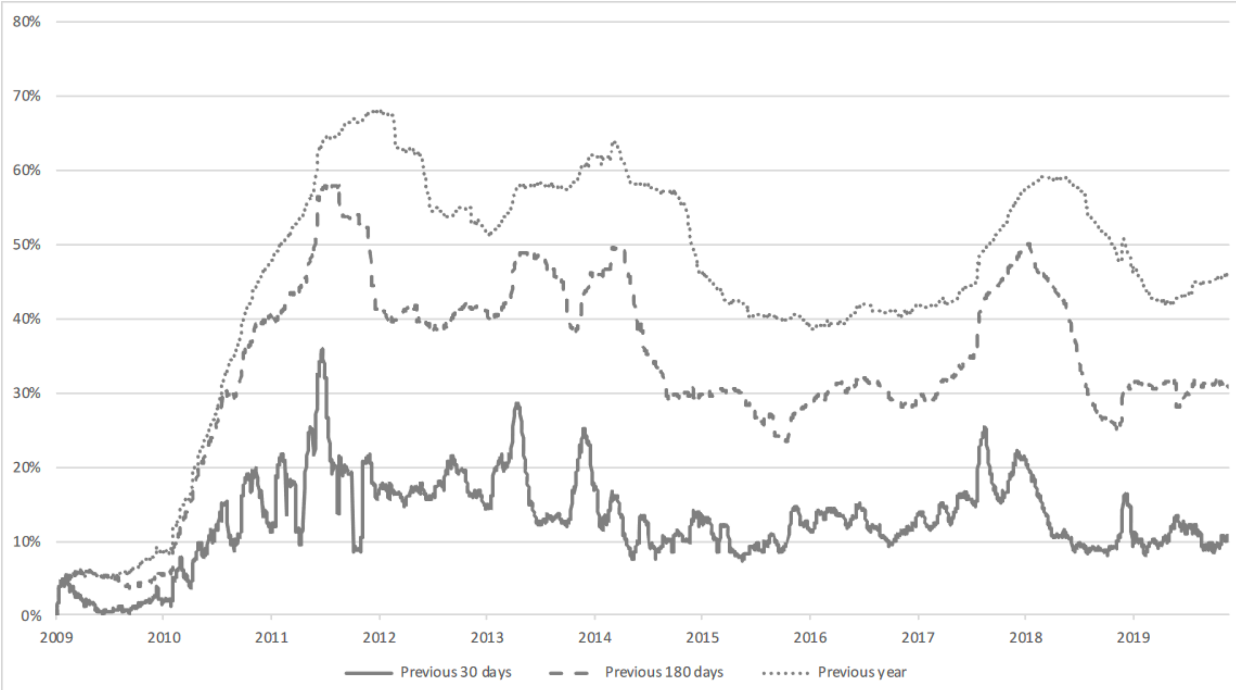

***Figure 2**: Supply activity in Bitcoin. Source Coin Metrics*

Figure 2 shows the fraction of Bitcoin's supply which has moved in the trailing year, six months, or month, evidencing that only a fraction of supply is actually active in the Bitcoin economy. In some sense, indexing Bitcoin's supply to the set of all units ever issued is arbitrary. Its monetary properties are an emergent phenomenon linked to the usage of the asset in commerce and market perceptions; only units which exist and can plausibly circulate (as opposed to units whose keys are lost) can take part in the Bitcoin economy—or any such cryptoasset economy for that matter. Thus, one could plausibly calculate its market significance according to the fraction of supply which actually circulated in some defined period. **Figure 3**, along those lines, demonstrates how different figures look comparing total market capitalization and trailing year active capitalization, indeed by as much as a factor of 2.5x, and this is for Bitcoin which has a reasonable degree of liquidity and churn.

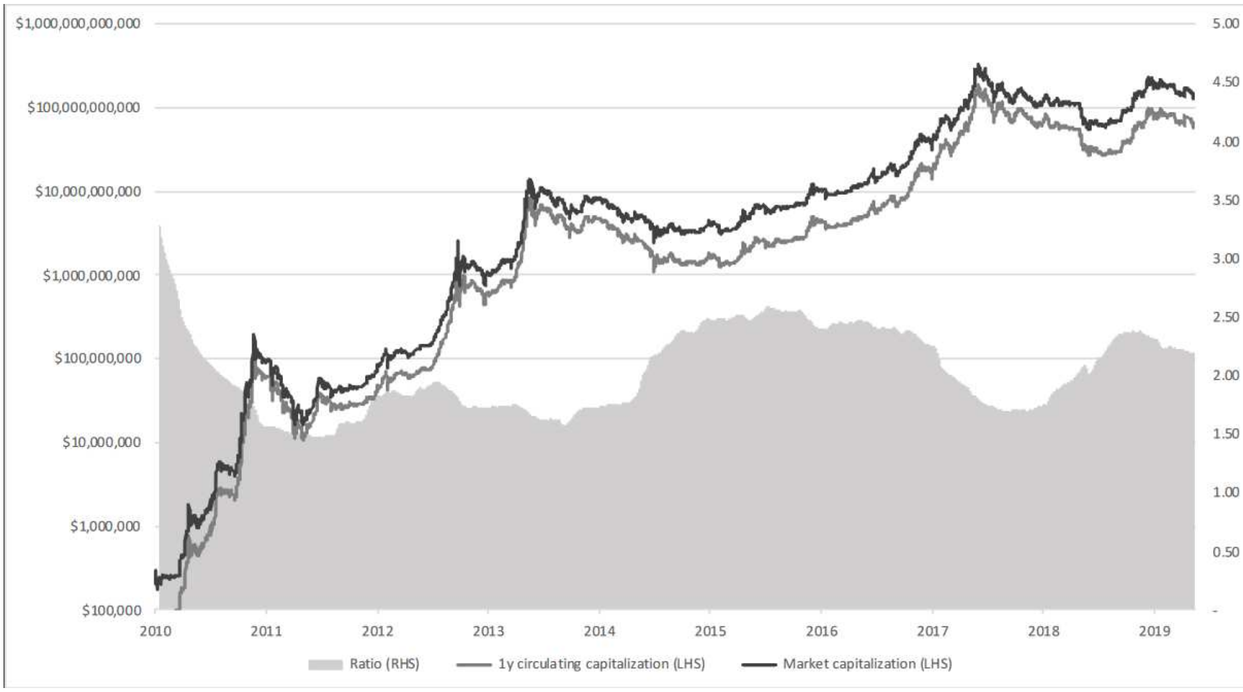

***Figure 3**: Total market capitalization vs trailing year active capitalization differ by as much as 2.5x. Source: Coin Metrics*

An alternative solution to the problem of inactive coins asserting themselves in market capitalization, as well as inactive coins on forked chains as discussed above, is to weight each unit according to the price when they last moved on the ledger itself. While cryptoasset-related economic activity happens on exchanges or in person, final settlement must occur on the blockchain itself. Since blockchain entries (in the most decentralized systems) tend to be costly through fees and the cumbersome management of private keys, it follows that entries on the ledger itself are a reasonable proxy for genuine economic activity. Thus, the notion of *realized capitalization* has become a popular alternative (**Figure 4**).[65] Instead of treating each coin on a distributed ledger as homogenous, it indexes the price of each unit to their market value when they last settled on the ledger. This generates a churn-indexed market cap alternative, and has the elegant property of excluding non-activated coins from forks.

[65] Coinmetrics, Introducing Realized Capitalization (December 14, 2018), https://coinmetrics.io/realized-capitalization.

***Figure 4**: Bitcoin realized capitalization. Coins are weighted by historical movement and the corresponding prices at the time. Source: Coin Metrics*

3. *Supply Inheritance*

Another issue with supply is unique to cryptoassets: the inheriting of supply from a parent fork. Forks are a consequence of the open source and permissionless nature of the industry, and occur when a cryptoasset's development team is split over the future direction of the cryptoasset, in which case two different versions of the cryptoasset will emerge—an original and a fork.[66] When this happens, the dissenting developers take a snapshot of the existing (unified) ledger of account balances while irredeemably altering some parameters such that the two ledgers cannot be reconciled after a split. Naturally, the two ledgers—original and fork—cannot each account for the full original supply at the same time, and yet it is not uncommon to measure them thusly.

Bitcoin's forks are instructive here. In August 2017 a breakaway faction created an alternative version of Bitcoin (BTC) called Bitcoin Cash (BCH). Prior to the fork, owners of Bitcoin were issued pro rata tokens of Bitcoin Cash. Since Bitcoin Cash came to obtain a meaningful economic value, many Bitcoin holders redeemed their Bitcoin Cash coins, either becoming active on the second chain or liquidating their new coins for Bitcoin. Subsequently, Bitcoin Cash itself bifurcated into Bitcoin ABC (this fork retained the original ticker BCH) and Bitcoin SV (BSV). It is important to note that BSV was a fork of the original Bitcoin Cash and thus two degrees of forks removed from Bitcoin. The issue is that both BCH and BSV were assumed to possess the supply of the parent asset: for Bitcoin Cash, Bitcoin, for BSV, Bitcoin

[66] ANDREAS M. ANTONOPOULOS, MASTERING BITCOIN: PROGRAMMING THE OPEN BLOCKCHAIN 274–284 (2nd ed. 2017).

Cash.[67] However, since units on newly-forked chains must be initially moved to become active, simply porting over the supply of the parent chain overestimates the supply of the child chain, since many users choose to ignore their forked coins, leaving them inert. As shown in **Figure 5**, at the time of writing (November 2019), BSV claims a market capitalization of $1.9 billion deriving from a supply of 18.1 million units. However, using exclusively activated units to compute the figure grants it a capitalization of just $962 million and supply of 8.9 million units instead. These adjusted figures should instead be used to calculate the relative size of forks.

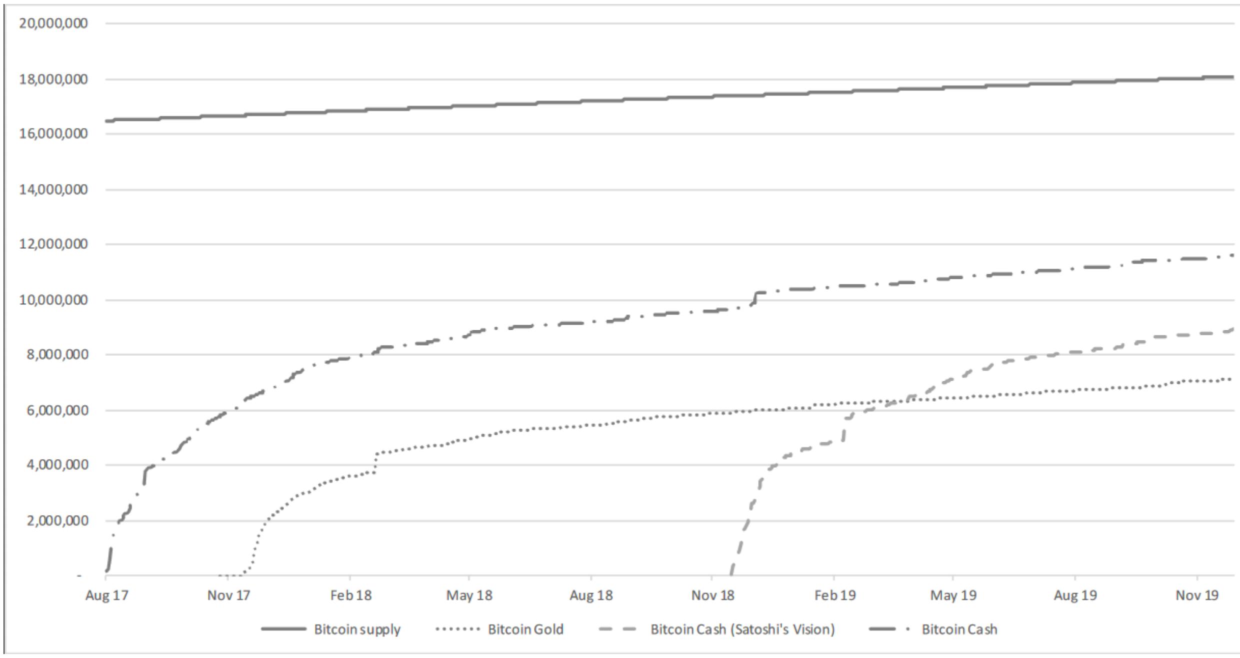

Figure 5*: Bitcoin fork uptake. It is evident that forks do not account for the full original supply of the parent chain. Source: Coin Metrics*

C. Beyond Market Capitalization: Alternative Market Strength Indicators

Unlike market capitalization, which sees cryptoassets as investment or store of value vehicles, and measures their economic footprint as a function of their value, alternative indicators, such as transaction count and volume, treat cryptoasset networks as service providers that enable transactions, and measure their size as a function of the number of transactions that take place on their platforms and the volume they generate.

Transaction count refers to the sum of all economically relevant actions occurring directly on a blockchain in a given timeframe, usually a day (native unit transfers, third party token transfers, contract calls, trades). Similarly to market capitalization, a nominal transaction count measurement can be misleading, meaning that caution should be exercised to obtain accurate figures. Firstly, transaction count can be manipulated especially in permissioned blockchain systems where a closed set of validators can operate behind closed doors, artificially inflating the count.

[67] *See, e.g.*, CoinMarketCap's data on BSV and BCH showing identical supply for both currencies, *available respectively at* https://coinmarketcap.com/currencies/bitcoin-sv and https://coinmarketcap.com/currencies/bitcoin-cash.

Secondly, cryptoasset networks differ widely in terms of how they structure and process transactions, and what each transaction measures in one network may not be the same as in other networks—only similarly positioned cryptoassets should be compared re transaction count.[68] To say that Bitcoin is a smaller or weaker network because it processes fewer transactions per second compared to other networks would not be a fair conclusion.

Thirdly, not all valid transactions are economically relevant in the sense that they represent meaningful transfers of value from one economic actor to another.[69] For example, change transactions may be validly recorded on the blockchain and could be counted towards aggregate transaction value, but they do not really contribute to the meaningful amount that was moved from actor to actor.[70] If I pay with a $20 note for something that costs $15, the economically relevant amount was $15, not $25, $20 from paying and $5 from giving back change. Therefore, change transactions should be filtered out.

Fourthly, common patterns of behavior attributable to cryptoasset exchanges can often result in a single transaction (from an end user to an exchange) being counted several times. The existence of mixers—services that exist to obscure the origin and ownership of cryptoassets—also inflates count significantly, as these involve the repeated churning and mixing of tokens.

More difficult, yet still possible to forge, is aggregate transaction volume, i.e. the volume of transactions happening on the network per given time frame, usually per day, which is obtained by multiplying transaction count by transaction value. Transaction volume represents a more stable basis of comparison between disparate cryptoassets, as it cannot be as easily inflated with many empty transactions: potential spoofers would need to control a significant quantity of tokens in order to inflate transaction value, and as such it is costlier to forge. However, to the extent that transaction count is a factor of volume, volume can also be manipulated, especially by entities which control significant portions of supply (like issuers), by sending themselves wallet balances with high frequency. **Figure 6** does indeed show that the adjusted volume can be significantly lower than the recorded volume of all transactions.

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[68] For instance, Bitcoin is, by design, limited to a maximum capacity of seven transactions per second, Ethereum can process 15, whereas EOS can process millions. By comparison, the Visa network can process 45,000 transactions per second. The large differences in transaction capacity across cryptoassets are explained by the function transactions are called to perform on the cryptoasset networks. For instance, on the EOS network transactions perform numerous functions, from moving value, to enabling distributed apps, to setting up voting processes, to distributing and claiming voting rewards and others.[68]

[69] *See* Coinmetrics, Introducing Our Adjusted Transaction Volume Estimates (June 27, 2018), https://coinmetrics.io/introducing-adjusted-estimates.

[70] ANTONOPOULOS, *supra* note 66 at 20.

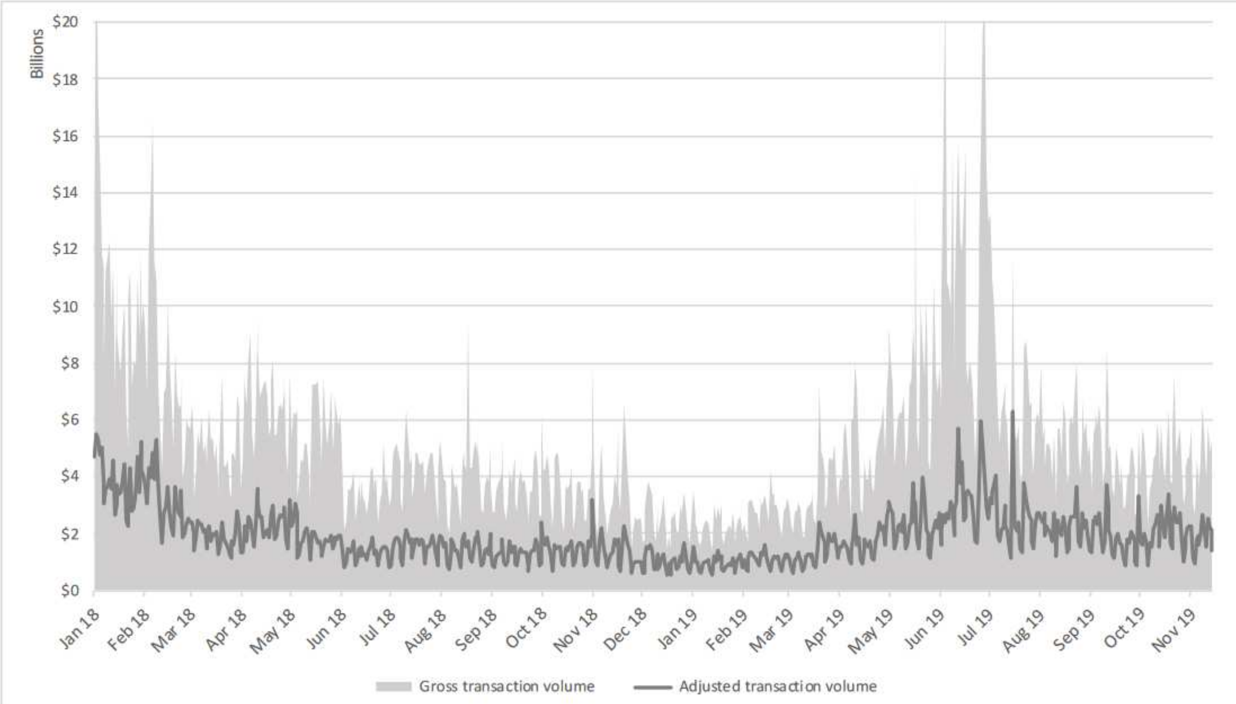

Figure 6*: Total transaction volume (fill area) vs adjusted transaction volume (line) in Bitcoin. Adjusted transaction volume considers only economically relevant transactions. Source: Coin Metrics*

Another potential measure of the economic richness of a cryptoasset system which is hard to forge is simply the aggregate value of transaction fees spent to transact on-chain in a given timeframe, usually a day. Fees are common in most cryptoassets which makes them suitable for cross-sectional comparisons. Their function is to cover (part of) the costs of the nodes which process transactions, payable from users to nodes, and in the process secure the network.[71] Because at any moment a multitude of alternatives exist, many of them low-fee, fees represent unique demand to use a given blockchain, since they are proof of user acknowledgment that their chosen cryptoasset has differentiated and useful traits, whether network effects or settlement assurances or other.

Considering the availability of substitutes, the concentration of fees on a few market leaders indicates sustained demand for those particular ledgers.[72] At present, Bitcoin and Ethereum are the overwhelming market leaders in this domain, collecting an average of $452,000 and $98,000 in daily fees in 2019 thus far (

[71] *Id.* at 213–214.

[72] One should be mindful of the caveat that the fees are set almost always automatically by spenders proposing transactions at a level that corresponds to the network conditions at the time. If the network is artificially manipulated to create congestion, fees will also be inflated. *See* Gur Huberman, Jacob Leshno & Ciamac Moallemi, Monopoly Without a Monopolist: An Economic Analysis of the Bitcoin Payment System, Bank of Finland Research Discussion Paper No. 27/2017 (2017).

Asset	Market cap	Relative share of market cap.	Fees (ytd)	Relative share of fees
Bitcoin	$ 140,035,753,824	72%	$ 150,702,708	81.8%
XRP	$ 23,025,399,335	12%	$ 160,179	0.1%
Ethereum	$ 16,773,980,284	9%	$ 32,807,170	17.8%
Bitcoin Cash	$ 4,064,736,183	2%	$ 57,672	0.0%
Tether	$ 3,802,677,363	2%	$ -	0.0%
Litecoin	$ 3,102,918,694	2%	$ 398,950	0.2%
EOS	$ 2,602,000,000	1%	$ -	0.0%
Bitcoin Cash (Satoshi's	$ 1,988,749,998	1%	$ 42,354	0.0%
Stellar Lumens	$ 1,183,000,000	1%	$ 5,023	0.0%
Tron	$ 1,035,000,000	1%	$ -	0.0%

Table 1). Aside from those two cryptoassets, fees are negligible across the board—the third most fee-heavy chain, Litecoin, is averaging only $1,198. Bitcoin users have shown a considerable willingness to pay fees in the past; for instance, in late 2017, daily fees exceeded $15m for short periods.

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Table 1: Fee rates from the top 10 liquid cryptoassets during 2019 year to date.

One potential confounding factor is the de-prioritization of fees on popular systems such as EOS, Tron, and Ripple. Since the objective of fees in a cryptoasset like Bitcoin is ultimately to subsidize security (when the issuance goes to 0), in cryptoassets with perpetual issuance, or where distributed consensus is not sought, fees can be dispensed with. In the case of EOS, validators are funded from a pool of new issuance totaling 5% per year, which dilutes all of the existing holders of the asset. In Ripple, fees amount to two thousandths of a cent per transaction, making them economically insignificant on the protocol. So, while fees are a good comparative basis for cryptoassets which share a long-term security model, they don't cover alternative models like Ripple and EOS which rely on authority delegated to a select few validators.

IV. INTRA-ASSET CALCULATION

Intra-asset calculation refers to measuring market shares of constituent components of cryptoasset markets, namely actors or mechanisms that enable cryptoassets and underpin their operation. This class includes numerous actors,[73] but we will focus here on the ones that have attracted the most scrutiny and interest: miners (including mining pools) and crypto-exchanges (including wallets).

[73] RAUCHS ET AL., *supra* note 46 at 19–26.

Miners are essential in cryptoassets whose consensus mechanism relies on commitment of resources—whether processing power, storage space, time or other—and where the reward for committing the necessary resources comes in the form of a denomination of a cryptoasset, e.g. Bitcoin. Crypto-exchanges are service providers that allow the trading of cryptoassets—whether with other cryptoassets or with fiat currencies—and they commonly integrate wallet functions, which makes them custodians of users' assets, and which allows users to manage their addresses and transfer funds between them. Crypto-exchanges are not necessary for the operation of cryptoassets but by allowing cryptoasset holders to trade, they significantly increase cryptoasset utility, and have therefore become a crucial part of cryptoasset ecosystems.

A. Miners, Mining Pools and Nodes

Mining technically refers to the process of creating new denominations of cryptoassets (e.g. a Bitcoin).[74] This has come to be seen as synonymous to adding ("finding") new blocks on a blockchain, because in the majority of the most popular cryptocurrencies a denomination of the cryptocurrency is created as reward whenever a new block is added to the respective blockchain. The reward is given in return for users committing the resources necessary to add new blocks. This is an incentive mechanism to help the cryptoasset ecosystem run and grow, but it is not strictly necessary for the process of adding new blocks. In fact, it is mostly required when the resources that need to be committed to validating and adding new blocks are significant, and would not likely be committed but for this reward.[75] Other cryptoassets may provide rewards in the form of fees only (e.g. Cardano).

For our purposes here, of those two functions that miners usually perform (adding blocks and creating new quantity of cryptoassets—mining *stricto sensu*) it is the addition of new blocks to the blockchain that matters the most, because this function is essential in all blockchain-based cryptoassets, whereas the creation of additional quantity of cryptoasset is a corollary feature only of some. In cryptoassets where finding new blocks does not also result in the creation of additional quantity of cryptoassets, the actors that perform this function are usually called nodes, validators, stakeholders, forgers or other. However, because, as mentioned, in many popular cryptocurrencies these two functions are intertwined, the general term miners will be used to refer to those actors too.

Mining can be a resource-intensive process requiring the commitment of scarce resources, such as computational power in proof of work cryptoassets (PoW), or some other (finite) "stake" such as storage space or assets in proof of stake cryptoassets (PoS).[76] For those cryptoassets that rely on scarcity of mining resources, as their blockchain network grows and more resources are committed to the network, the threshold of required resources to add new blocks rises. While theoretically individual miners can be successful at mining blocks, the required amount of resources to make that likely is today prohibitively high, and for that reason miners pool together their resources in so-called *mining pools (or staking pools)*, the purpose of which is to aggregate resources from multiple miners, use them to find new blocks, and then distribute the reward back to participating miners proportionately to the resources they contributed.[77]

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[74] ARVIND NARAYANAN ET AL., BITCOIN AND CRYPTOCURRENCY TECHNOLOGIES: A COMPREHENSIVE INTRODUCTION 39 (2016); Carol R. Goforth, *The Lawyer's Cryptionary: A Resource for Talking to Clients About Crypto-Transactions*, 41 CAMPBELL LAW REVIEW 47, 88 (2019).

[75] NARAYANAN ET AL., *supra* note 74 at 38–42. *See also* Miles Carlsten et al., *On the Instability of Bitcoin Without the Block Reward*, PROCEEDINGS OF THE 2016 ACM SIGSAC CONFERENCE ON COMPUTER AND COMMUNICATIONS SECURITY 154 (2016).

[76] Tasca and Tessone, *supra* note 47 at 18–21.

[77] NARAYANAN ET AL., *supra* note 74 at 124–130.

Mining pools are therefore a symptom of and a business solution to the requirements of the mining process and the expected returns.[78]

It is also relevant to note that even though mining pools appear by name separate and independent, they may be owned by the same company, and some miners may mine for more than one pools. For example, two of the most popular mining pools, BTC.com and Antpool, are owned by the same company, Bitmain, and Bitmain also has a stake in ViaBTC.[79] This creates an issue of attribution in calculating market shares since it must be established which economic entity is behind the mining even if it appears that separate and independent miners do it.

Despite its central function in the cryptoasset market, mining does not seem to have a counterpart in traditional financial markets. Instead it seems to perform partly a manufacturing function and partly a services function. A number of metrics can become relevant in measuring the market share of miners and mining pools, discussed below.

1. Output and Capacity Metrics

Output metrics are those that calculate market shares based on an appropriate standardized unit of production.[80] Capacity metrics are those that calculate market shares based on the rate at which resources can be committed to production output.[81] While productive capacity is not normally a common metric, it has become the metric of reference in cryptoasset mining that relies on PoW algorithms, probably due to Bitcoin's popularity, and it is often conflated with output. None is superior, but it is crucial to clarify what they measure and when they should be relied on.

The relevant capacity-based metric for PoW cryptoassets is *hashrate*. Hashrate expresses the number of hashes per second, where hash is a cryptographic value that miners have to compute in order to find a new block and add it to the blockchain.[82] Finding blocks requires miners to solve a computationally difficult cryptographic problem which involves trying out different hash values until they find the one that fits.[83] Hashrate, therefore, shows the capacity of PoW miners to find new blocks. In PoS cryptoassets, capacity is measured on the basis of the scarce resource they rely on. For example, in Nxt the relevant "stake" is Nxt coins (i.e. the asset itself), whereas in Burstcoin, the relevant stake is storage space.

On the other hand, the actual output of miners/stakeholders in blockchain networks is expressed in the new blocks they add onto the blockchain. The number of added blocks is usually referred to as *block count*. The more blocks a miner adds to a given blockchain, the larger its market share by output measured by block count.

Normally, one would prefer to measure market actors by the quantity they *actually* put out in the market (output), because this is the economic product that is made available for use/consumption, and that for which firms are remunerated by consumers. However, there may be circumstances under which market shares can be assigned on the basis of the *ability* to produce (capacity), rather than the production itself. This is when firms' relative abilities to produce are congruent with their relative abilities to sell,

[78] More accurately it is a symptom of the fact that mining is probabilistic, which implies that give a certain amount of resources invested in mining the miner can expect proportional returns, but the time and variance of when they will get the return is unknown. Miners can reduce the wait time by pooling together resources thereby increasing the probability they will be among the successful miners sooner.

[79] BitMain Initial Public Offering, Hong Kong Stock Exchange (2018), at 2.

[80] Werden, *supra* note 29 at 74.

[81] *Id.* at 83–85.

[82] ANTONOPOULOS, *supra* note 66 at 228 et seq.

[83] More accurately miners have to find a nonce that results in a hash which satisfies the computational problem in the target block. NARAYANAN ET AL., *supra* note 74 at 8–10.

products are homogeneous, and the production capacity is rated.[84] In cryptoassets, for these conditions to be met the ability of miners to find blocks should be congruent with the blocks they find, blocks should be undifferentiated, and mining hardware should come with standardized specifications.

While these conditions are commonly met in PoW cryptoassets, it is not commonly the case with PoS cryptoassets, where the conditions are relaxed. In PoW cryptoassets, hashrate and block count are by and large almost linearly correlated (**Table 2**), because the probability of being the next successful node to add a block to the network is, on average, constant relative to hashing capacity, as the only way to add new blocks is to try out hash values until one fits,[85] and therefore, the more capacity one commands the greater the probability of being successful. But in PoS cryptoassets, forging (i.e. the equivalent term of mining in PoS cryptoassets) is only partially informed by the committed resources. Depending on the implementation, other factors that are independent of the amount of the committed resources also inform the process of the stakeholder selection (e.g. age of stake), and therefore resources do not fully correlate to the probability of output.[86] As more consensus processes are devised and popularized, further removing output from capacity,[87] it bears keeping in mind that, unless there is a reason to prefer capacity, output is a more direct measurement of economic footprint.

Mining pool	**Hashrate (EHash/s)**		**% hashrate of entire network (EHash/s)**		**Block count**		**% block count of entire network**	
	3d	**1w**	**3d (n=53.85)**	**1w (n=53.85)**	**3d**	**1w**	**3d (n=427)**	**1w (n=1055)**
BTC.com	8.93	8.89	16.63	16.51	71	174	16.62	16.49
Antpool	7.80	8.28	14.29	15.37	62	162	14.51	15.35
BTC.TOP	5.54	5.36	10.07	9.96	44	105	10.30	9.95
Slushpool	5.28	5.47	9.84	10.15	42	107	9.83	10.14
F2Pool	4.78	5.36	8.90	9.96	38	105	8.89	9.95

Table 2: *Hashrate and block count shares on the BTC.com mining pool taken on October 4, 2018. There is almost linear correlation between hashrate and block count shares making the two metrics interchangeable for PoW cryptoassets.*

Hashrate and block count are not complete substitutes for each other even under the above conditions. They can still yield discrepancies and are not always interchangeable. They yield discrepancies firstly because finding blocks involves an element of luck (even when randomness is not coded into the consensus algorithm), and therefore the correlation between hashing capacity and added blocks is not complete; and secondly because some of the blocks that will be found as a result of the hashing process will not be validated but instead discarded, and therefore some of the hashing power will ultimately not correspond to any actual output. In that sense, block count can be a more accurate measurement of miners' output, albeit admittedly only by a small margin.

Moreover, they are not always interchangeable because hashrate is appropriate only for cryptoassets that rely on a PoW algorithm, whereas block count is a relevant metric in other cryptoassets as well (e.g.

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[84] Werden, *supra* note 29 at 89.

[85] NARAYANAN ET AL., *supra* note 74 at 43–44. Blocks may differ in size and the transactions they contain may differ in number and value, but on average they can be thought as undifferentiated; and mining hardware commonly comes with specifications of capacity in hashrate.

[86] Zibin Zheng et al., *An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends*, *in* 2017 IEEE INTERNATIONAL CONGRESS ON BIG DATA (BIGDATA CONGRESS) 557–564 (2017).

[87] For an overview of consensus mechanisms *see* Shehar Bano et al., *Consensus in the Age of Blockchains*, ARXIV:1711.03936 [CS] (2017).

those that employ PoS). This is an important point for cross-asset comparisons, especially if a market is defined to include both PoW and PoS cryptoassets. For example, it would provide a meaningful measure of total captured share of the market to say that a stakeholder finds x% of blocks of a PoW cryptoasset and y% of blocks of a PoS cryptoasset, if those two cryptoassets are deemed to be in the same market, but it would be impossible to use hashrate because this measure could not encompass the PoS cryptoasset (**Figure 7**).

That said hashrate can still be used across cryptoassets that rely on PoW, but caution should be exercised to correctly apportion hashrate figures to cryptoassets in case miners mine for more than one cryptoasset. A number of mining pools dynamically apportion their hash power to different cryptoassets (*merged mining*), and so one must ascertain how much of the reported capacity is allocated to each cryptoasset.

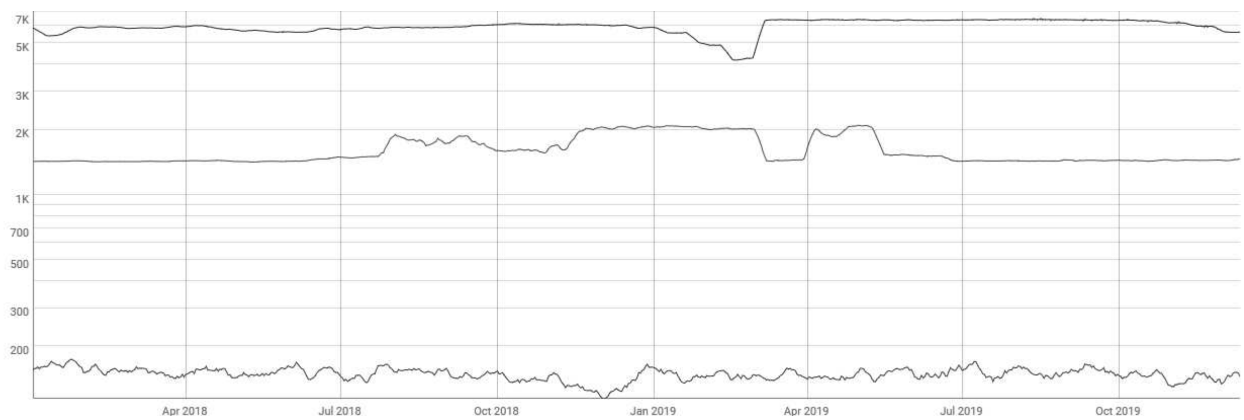

***Figure 7**: Daily block count of Bitcoin (bottom), PIVX (middle), and Ethereum (top). Bitcoin and Ethereum are PoW, whereas PIVX is PoS. Assuming these three cryptocurrencies are in the same market, one could use the number of blocs found by a miner in each cryptoasset network to calculate total market share by block count across the entire market, which would be impossible using hashrate as it is irrelevant in PIVX. Source: Coinmetrics*

2. Revenue and Profits

Market share calculation by revenue is common, as revenue shows the portion of the market captured by unit of currency spent by consumers, and therefore takes into account the price of goods, not just the units sold in the market. Revenue is mostly reliable when the price reflects the qualities and attributes of the good and is not the result of monopoly power, subsidies (e.g. freemium services) or other factors.[88]

In the mining/staking market, revenue can come from two sources: block reward and transaction fees. Cryptoassets are free to choose whether miners will be compensated through block rewards or transaction fees or both.[89] In calculating miners' revenue one should ensure inclusion of all applicable sources.

Block rewards are new denominations of cryptoassets that are awarded by the blockchain network to miners for each block they successfully find, and are common in PoW cryptoassets. When miners find a block they gain the right to include an extra transaction in the block which is equivalent to the denomination specified by the cryptoasset protocol, and which is made payable to the successful miner (although miners can choose someone else as the recipient of the block reward). For example, as of 2018 the Bitcoin block reward is 12.5 BTC, which means that for every block a miner adds to the blockchain, they earn 12.5 BTC as block reward.

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[88] Werden, *supra* note 29 at 76–78.
[89] These parameters are specified in the cryptoassets' protocols and whitepapers.

Transaction fees are fees that are paid by cryptoasset spenders to miners/stakeholders to have a transaction included in a valid block. They are common both in PoW and in PoS cryptoassets and their purpose is to incentivize and reward miners. In most PoS cryptoassets, transaction fees are the only reward, whereas in PoW cryptoassets, they constitute an additional financial incentive toward miners to process transactions as a matter of priority when the network is congested (**Figure 8**).[90] In cryptoassets that issue block rewards, transaction fees tend to constitute a small percentage of the total revenue, but this may not always be the case in the future.[91] For instance, block reward in Bitcoin is halved every 210,000 blocks, which may mean that as time passes miners will turn to transaction fees to compensate.

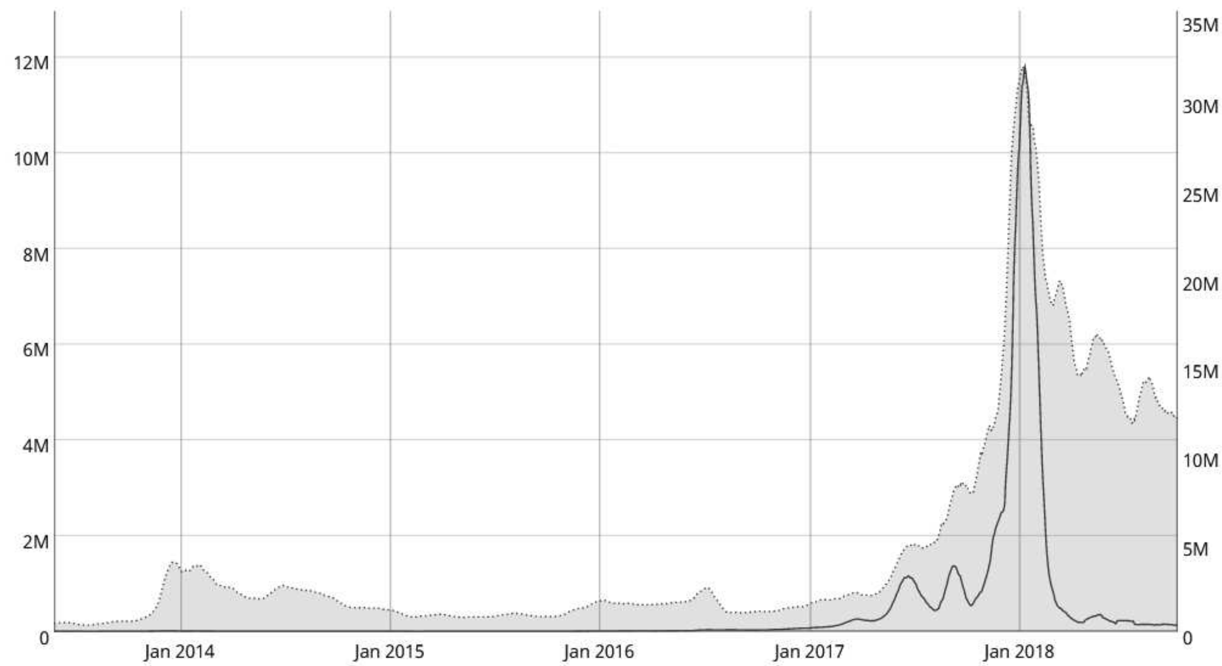

Figure 8: *Transaction fees (line) compared to coin value (fill area) generated in USD in the Bitcoin network. In December 2017 - January 2018 transaction fees amounted to almost 30% of the total reward, a testament to how the network struggled with transaction volume. Source: Coin Metrics*

One will notice that, unlike traditional economic actors, miners' revenue seems to be determined by factors that are outside of their control, since they have no control over either the block reward or the transaction fees. The only way to increase revenue—assuming these are the only two sources—is to find more blocks or to process by priority transactions that come with higher fees. The fact that miners cannot use the pricing mechanism (but only output) to adjust revenue may be saying something about *profits* as a relevant metric of economic footprint. Even though profits are not normally considered a relevant metric, because they relate to internal-to-the-firm factors as well as taxation, they can sometimes be informative. For example, as of 2018 Apple's share in the smartphone market is 19% by unit sales (output), yet its market share by revenue is 51%, and its market share by profits is closer to 90%.[92] This means that even

[90] NARAYANAN ET AL., *supra* note 74 at 97–98.

[91] David Easley, Maureen O'Hara & Soumya Basu, *From Mining to Markets: The Evolution of Bitcoin Transaction Fees*, JOURNAL OF FINANCIAL ECONOMICS (forthcoming) (2018).

[92] Scott Bicheno, *Apple iPhone: 19% of Shipments, 51% of Revenue, 87% of Profit*, TELECOMS (February 15, 2018).

though Apple sells fewer smartphones than its competitors, it captures the majority of consumer spending, of which a large share is mark-up. The difference between revenue and profits may be attributable to innocuous factors, like increased efficiency, but it may also be an indication of the ability to price without regard to consumers or competitors, which in turn is an indication of market power.[93] Therefore, to the extent that market share is one of the proxies of market power, any measurement of market share, including by revenue and profit, that can be evidence of business conduct which shows disregard for consumers or competitors should be taken into account.

In the case of miners, since they have no control over fees (i.e. price), a *prima facie* conclusion would be that profitability hinges on efficiency and cost-reduction rather than mark-up and therefore it provides no evidence of exercise of market power. However, this may not necessarily be true for collective mining pools, which distribute fees back to individual miners based on internal rules that can be shaped to increase profitability of the pool at the expense of profitability of the individual miners. In that case sustained high profits that do not correspond to industry standard revenue-profit ratio or other innocuous explanations may be indicative of market power in the market for individual miners. An example of how this could happen is larger mining pools instituting higher joining fees during the hashing difficulty adjustment window. During this time, larger pools have an advantage over smaller pools because, with the difficulty adjusted upwards, larger pools are more likely to find blocks, and therefore miners may be more willing to (temporarily) switch to them. This is exacerbated in cryptoassets with less frequent block generation, because the laws of probabilities favor larger players.[94] It may therefore be worth looking at profit market shares as well, especially if there is a theory of market power or abuse of power behind the inquiry.

3. Miner Count

As mentioned, because solo mining is today inefficient, it is most common that miners aggregate their resources to create mining pools (or, less commonly, staking pools in PoS cryptoassets. The term miner and mining pool will be used to cover all types of pooling together of resources).[95] In a mining pool arrangement miners offer their resources (hashing power in PoW cryptoassets; stake in PoS cryptoassets), and the mining pool offers the service of coordinating and managing the miners.[96] In this market one possible metric of mining pools' market share is by miner count, i.e. the number of miners that commit their resources to one or more mining pools. In its most general sense, miner count represents the total number of miners belonging to each mining pool, but more precise counting may choose to include only active miners (e.g. miners that have contributed to the mining pool within a given timeframe) or only miners that contribute over a certain threshold of mining capacity or apply other criteria as appropriate.[97]

Because miners can mine for multiple cryptoassets and multiple pools at the same time, a case of multihoming emerges, which affects the total miner count by which the miner count of a given pool should be divided. For example, in a market of 4 individual miners and 2 pools in which all 4 miners participate in both pools, the total individual miner count should be 8, not 4, and the market share of each

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[93] *See* Case 85/76 Hoffmann-La Roche & Co AG v. Commission, [1979] ECR 461, para 38; Case 2/76 United Brands v. Commission [1978] ECR 207, para 65.

[94] Adem Efe Gencer et al., *Decentralization in Bitcoin and Ethereum Networks*, ARXIV:1801.03998 [CS], 12–13 (2018).

[95] Katalyse, *Staking Pools — How They Work*, MEDIUM (March 8, 2018). Other examples of pooling include Tezos delegation and the hybrid Decred PoW/PoS pooling system.

[96] *See supra* note 77.

[97] We have seen similar classifications of users (active users, unique users, total users) in past cases, *see e.g.* Case No COMP/M.6281 - Microsoft/ Skype.

pool will be 50%, even though each pool has signed up the total population of individual miners. Otherwise, we would end up with the paradox of two monopolists in the same market (both pools having 100% of the total miner count in the same market).

The value of miner count as a metric may not be immediately apparent, since the goal of mining pools (and therefore their main metric of success) is to aggregate as many resources as possible, regardless of the number of individuals contributing the resources. In that sense, a mining pool of a hundred miners and 10 Thash/s of total capacity is a "bigger" player than a mining pool of a thousand miners and 1 Thash/s of total capacity (see **Figure 9**). But miner count can become relevant in a number of contexts. For example, a merger between a mining pool with large capacity and few miners, and a mining pool with small capacity but many miners would create a mining pool with large capacity and many miners. This may be problematic, and yet it would not be captured in an assessment of the market share of the merging mining pools if we looked only at one metric (either capacity or miner count).

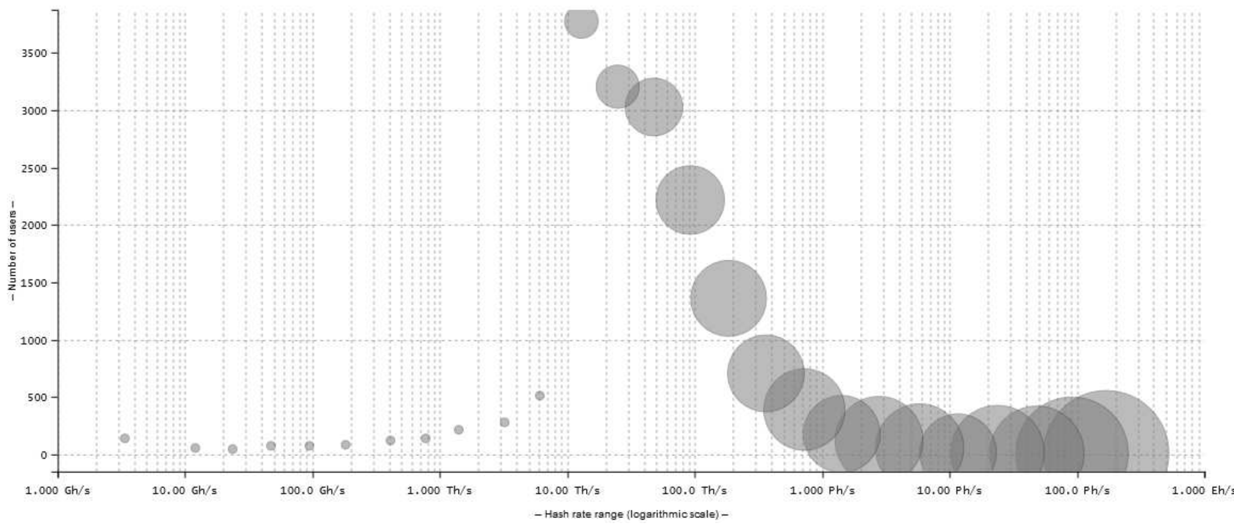

Figure 9: *Distribution of individual miners by hashing power in the popular Slushpool mining pool (November 2019). The graph shows thousands of miners across all clusters of capacity. Source: Slushpool*

Moreover, miner count shows how many economic actors in a market are involved and/or affected, regardless of their size or importance. For some policy areas the number of individual independent actors in a market matters. For example, it can be linked to concentration rates. In the hypothetical example in **Table 3**, if we only look at the industry's capacity concentration rate based on number of mining pools the HHI is 3350 (high), whereas if we look at it based on individual miners it falls to 1395 (low). Whether it is more appropriate to calculate concentration rates based on mining pools or individual miners depends on the purpose of each particular investigation, but it is worth noting that mining pools are not self-contained black boxes, but are rather comprised on individual potentially independent actors.

Mining pool	**Mining pool capacity**	**No of miners in mining pool**	**Miner capacity (assuming equal distribution)**
A	50 Ghash/s	2	25 Ghash/s
B	20 Ghash/s	4	5 Ghash/s
C	15 Ghash/s	10	1.5 Ghash/s
D	15 Ghash/s	10	1.5 Ghash/s

	HHI on pool basis		HHI on miner basis
	3350		1395

Table 3: *Concentration rates measured by mining pool and by individual miners (capacity held constant). Not realistic scenario; for illustration purposes only.*

B. Crypto-exchanges

Crypto-exchanges are entities that primarily enable trading between cryptocurrencies or between cryptocurrencies and fiat currencies, and in the future between other financial instruments as well.[98] They also commonly incorporate a wallet function and thereby facilitate the transfer of crypto-assets between users. While the operation of crypto-exchanges resembles that of traditional exchanges, there are key differences that warrant caution as to how to properly perform market share analysis on crypto-exchanges.

Unlike traditional exchanges, which normally trade stocks or commodities, crypto-exchanges mostly trade currency pairs. This is peculiar, because fiat currencies are traded on a centralized global foreign exchange market, whereas cryptocurrency pairs and cryptocurrency-to-fiat currency pairs are traded on any number of crypto-exchanges, each with its own exchange rate.[99] Moreover, trading on traditional exchanges is performed by authorized intermediaries, whereas crypto-exchanges directly interface with end users. Lastly, exchanges are heavily regulated, whereas crypto-exchanges still operate largely unregulated, despite recent activity in that direction.[100] Taken together, these differences both affect the relevance of applicable metrics, but also cast into doubt the reliability of some metrics, which may affect their influence on market share calculation.

Exchanges are characterized by a number of metrics. Before we discuss the ones suitable for market share calculation in the exchange market it is worth mentioning two common and influential metrics, which, however, do not appear as relevant in the crypto-exchange market. One is *market capitalization*. Exchange market capitalization is the total number of issued shares of listed companies multiplied by their respective prices at a given time.[101] For the vast majority of crypto-exchanges, there is no equivalent metric, since they do not list stocks or equivalent financial instruments. To say that the equivalent could be the aggregate market capitalization of their listed cryptocurrencies also does not seem right, because unlike stocks, cryptocurrencies are traded on multiple crypto-exchanges and are therefore not associated with a single one, they can be created on demand, and there are no rules on which exchange they can be listed on. Therefore, the aggregate market capitalization of listed cryptocurrencies is not indicative of any useful financial measure of crypto-exchanges. The second one is the *number of listed companies*. Exchanges are sometimes ranked by the number of companies whose shares are traded on their platform, the idea being that the more the listed companies, the greater the economic importance of the exchange, everything else equal.[102] The equivalent in crypto-exchanges could be the number of listed currency

[98] NARAYANAN ET AL., *supra* note 74 at 88–89; Xin Li & Chong Alex Wang, *The Technology and Economic Determinants of Cryptocurrency Exchange Rates: The Case of Bitcoin*, 95 DECISION SUPPORT SYSTEMS 49–60, 50–51 (2017). Crypto derivatives exchanges are beginning to emerge, See, e.g., Christine Kim, *Markets Tech Firm to Launch Crypto Derivatives Exchange*, COINDESK (August 6, 2018). A popular exchange that allows derivatives trading in BitMEX.

[99] On the determinants of exchange rates see Li and Wang, *supra* note 98.

[100] *See, e.g.*, SEC, Statement on Potentially Unlawful Online Platforms for Trading Digital Assets (March 7, 2018).

[101] World Federation of Exchanges, Statistics, Definitions, and Examples (September 2013) 2.

[102] *Id.* at 4.

trading pairs (e.g. BTC-ETH), but this also does not correspond to any meaningful measurement, since trading pairs can be created on demand, and since they relate more to the scope of offered services, rather than the market size of a crypto-exchange.

Instead, for the purposes of market share calculation the following metrics are more useful.

1. Trading Volume

In exchange markets trading volume is a common and influential metric.[103] It represents the total value of the assets traded on an exchange at a given time. The volume of share trading, for example, is the total number of shares traded multiplied by their respective matching prices.[104] Volume is relevant in market share calculation because the role of the exchange market is to enable the trading of assets, and volume shows what part of the total traded (exchanged) asset value is taking place on a given exchange. The equivalent in crypto-exchanges would be the aggregate value of all currency pair trades on a crypto-exchange at a given time, usually converted to US dollars as the common numeraire. Most crypto-exchanges advertise their traded volume, and most crypto-exchange rankings use volume as the only or the main parameter to rank exchanges by market share.[105]

While volume makes sense as a metric, extreme caution is required in the context of crypto-exchanges. Crypto-exchanges are not regulated, meaning that the reported volumes can be misleading, and the listed transactions manipulated.[106] They can be misleading because crypto-exchange trading activity is most commonly not recorded on the blockchain, where anyone can see and validate transactions, it is only recorded on the crypto-exchange that facilitates the transaction, and therefore depends on the veracity of the crypto-exchange.[107] For example, when a user wants to trade BTC for ETH on a crypto-exchange, the crypto-exchange updates the user's wallet with the new balances and records the transaction internally. The aggregate volume it reports is self-calculated and can be false. The incentive to lie is obvious: large trading volumes appeal to users, and the more users trade on an exchange the more liquid it becomes and the stronger the snowball effect.

As **Table 4** demonstrates, the reported crypto-exchange volumes can differ dramatically across crypto-exchange ranking services, especially for crypto-exchanges which are suspect of manipulating the volume of transactions that takes place on their platform (of those shown in **Table 4**, ZB.COM and Coinsuper have been flagged as suspect (highlighted in grey), and are indeed the ones that exhibit greater discrepancies across measurements).

Crypto-exchange	**Volume reported by crypto-exchange ranking services (in BTC)**			
	CoinMarketCap	**CoinMarketCap Adjusted[108]**	**CoinGecko**	**Coinhills**

[103] *See, e.g.*, Deutsche Boerse / NYSE Euronext (n 37).

[104] World Federation of Exchanges (n 101) 5.

[105] *See, e.g.*, CoinMarketCap, 24 Hour Volume Rankings (Exchange), https://coinmarketcap.com/exchanges/volume/24-hour/.

[106] Oscar Williams-Grut, *The Justice Department is Investigating Crypto Market manipulation — Here's Why It's Such a Big Problem*, BUSINESS INSIDER (May 24, 2018); John Medley, *Fake Volume on Exchanges Giving Crypto a Bad Name*, CRYPTOGLOBE (August 9, 2018); Marco Paez, *Over $6 Billion in Daily Trading Volume Faked Across Top 100 Exchanges*, BITCOINIST (August 25, 2018).

[107] NARAYANAN ET AL., *supra* note 74 at 87.

[108] CoinMarketCap defines adjusted volume as "volume from spot markets excluding markets with no fees and transaction mining." The adjusted index is meant to filter out transactions CoinMarketCap deems suspicious.

Binance	115,377	115,377	117,045	115,890
Bitfinex	26,229	26,229	22,674	23,379
Coinbase Pro	9,421	9,421	9,488	-
ZB.COM	79,520	54,608	150,471	105,987
Coinsuper	28,695	10,942	28,990	29,197

Table 4: *Crypto-exchange trading volume (in BTC) over 24h taken on October 13, 2018. The discrepancies among the various crypto-exchange ranking services are notable especially for exchanges that have been flagged as suspect.*

Common techniques of manipulation include wash trading, where an investor simultaneously sells and buys the same financial instruments to create artificial activity on an exchange,[109] and "painting the tape," where investors buy and sell among themselves to create the appearance of substantial trading activity.[110] Both practices are prohibited on traditional regulated exchanges, but only minimally regulated on crypto-exchanges, thusly allowing fake volume reports. Various investigations have concluded that self-reported exchange volumes can be inflated by as much as 4,400 times the real estimated value.[111] To determine the credibility of self-reported volume data, investigations look at factors such as the ratio of visitors to declared volume relative to other exchanges (larger volume per user ratios can be suspect),[112] the patterns of trading volume (regular patterns can be suspect),[113] the effect of a transaction on the price of the traded currencies (big impact can be suspect),[114] the intra-exchange velocity (higher relative velocity can be suspect),[115] the level of activity and community engagement (low activity and engagement relative to claimed volume can be suspect),[116] and others.

Given the state of the crypto-exchange market, there are a number of methods that investigators can employ to improve the reliability of volume metrics. One approach is to attempt to filter out suspect results. This approach requires intricate familiarity with the crypto-exchange market and perhaps arbitrary decisions, but nothing out of the ordinary in the frame of a market investigation. A different way would be to calculate the average figures from all available sources under the presumption that any tainted inputs will equally affect the market share of all actors. To enhance this average, investigators can choose to ignore high and low extreme values, similarly to statistical analysis methods. Lastly, investigators can choose to rely on meta-rankings, which take into account a number of factors, such as reputation and activity tracking, to devise their own calculation of market shares.[117]

2. Trade Count

Another common metric that applies to many financial intermediaries, including exchanges, is the number of trades (:transactions) that are performed on their platform at a given time (only one side of the

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[109] Hacken, *Investigation on Fake Trade Volume of Top Crypto Exchanges: BigONE*, MEDIUM (August 10, 2018).

[110] Will Kenton, *Painting the Tape*, INVESTOPEDIA (January 14, 2018).

[111] Blockchain Transparency Institute, Initial Rankings Report (2018), https://www.blockchaintransparency.org/reports.

[112] Hacken, *supra* note 109.

[113] *Id.*

[114] Sylvain Ribes, *Chasing Fake Volume: A Crypto-plague*, MEDIUM (March 10, 2018).

[115] Louis Baudoin, *Further Hints of Fake Volume on Major Cryptocurrency Exchanges*, LINKEDIN (September 14, 2018).

[116] Crypto Exchange Ranks, https://cryptoexchangeranks.com.

[117] Crypto Exchange Ranks, https://cryptoexchangeranks.com/ (last visited Dec 23, 2018).

transaction is counted). In the context of crypto-exchanges this metric represents the total number of trades between cryptocurrencies and between cryptocurrencies and fiat currencies.

The number of trades as a metric for market share calculation shows how widely or frequently an exchange is used, regardless of the size of the transactions that take place on its platform, and in that sense, trade count is indicative of an exchange's market popularity. While normally not the most influential measure, trade count can provide insights into the nature/character of an exchange, which in turn can inform industrial and economic policy. For example, an exchange that exhibits low transactional volume but high trade count is likely to be one that is preferred by smaller retail investors. This piece of information can be relevant in M&A policy, where authorities have an interest to protect the market not only from concentration in terms of numbers, but from the exit (through M&A) of firms that have unique features or uniquely serve a certain part of the market (in this example small retail investors).[118]

Trade count suffers the same weakness as trading volume, namely that in the unregulated environment of crypto-exchanges transactions can be easily fabricated and the numbers reported by crypto-exchanges can be misleading. Reports of crypto-exchanges employing bots that place buy-sell orders to artificially inflate the number of transactions are proliferating making trade count an unreliable metric.[119]

3. Trader Count

One less common metric of exchange activity is the number of trading participants, which represents the individuals who trade on an exchange through direct access to the trading platform.[120] Traditionally, this metric has not been indicative of an exchange's economic significance because it only measured the number of intermediaries that enable trading on the exchange, rather than end customers (investors) and therefore the exchange's economic footprint on the market. Limited exceptions, whereby private investors can directly trade on an exchange,[121] do not significantly change the utility of the metric.

However, the trading participant metric has greater value in the context of crypto-exchanges, because on crypto-exchanges users participate directly rather than through brokers. In that sense, trading participant count shows the installed base of a crypto-exchange platform. It is not uncommon to use the number of users as an important metric in online platform markets as it is indicative of market adoption, especially if users are considered a homogeneous pool.[122] The question is how to measure traders on crypto-exchanges.

A straightforward answer would be to rely on the self-reported figures provided by the crypto-exchanges themselves. For instance, Coinbase reports over 20 million users, while other major crypto-exchanges, such as Kraken and Cex.io, report 4 million and 1 million users respectively.[123] However, not

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[118] An example of how firms' unique characteristics other than mere market size are taken into account in M&A can be found in the abandoned AT&T / T-Mobile merger, where the US DoJ expressed reluctance to allow AT&T to absorb T-Mobile, because T-Mobile was known as a small but disruptive player in the market. *See* US DoJ v. AT&T and Deutsche Telecom, Case 1:11-cv-01560 (August 31, 2011), at 12 et seq.

[119] Timothi Tam Coinfi, *How Bots Are Manipulating Cryptocurrency Prices*, VENTUREBEAT (December 14, 2017).

[120] Tokens24, Crypto Exchanges: Insights Report (2018), https://www.tokens24.com/exclusive/crypto-exchanges-insights-report-2018.

[121] London Stock Exchange, Direct Market Access, https://www.londonstockexchange.com/prices-and-markets/stocks/tools-and-services/direct-market-access/direct-market-access.htm

[122] For example, when Github was recently acquired by Microsoft, Github's market positioning was measured by the number of users (programmers) on its platform. *See* Microsoft News Center, Microsoft to Acquire GitHub for $7.5 Billion (June 4, 2018).

[123] *See respectively* https://www.coinbase.com/about; https://www.kraken.com; https://cex.io/about.

all crypto-exchanges report their user statistics, and even when they do, reliability concerns of the sort described previously remain.

Alternatively, and considering that blockchain transactions in permissionless blockchains are public, one would want to be able to infer the number of crypto-exchange users through blockchain transactions. This presents a number of difficulties. Firstly, it is most common that crypto-exchanges process transactions internally and then settle and post aggregate transactions on the blockchain, from which it is hard, if not impossible, to disentangle the individual transactions—and by extension the users behind them—that took place on the crypto-exchanges' platforms.[124]

Secondly, the parameter that would be measurable in publicly posted transactions is the public key (address) with which transactions are signed. However, there is no one-to-one mapping between users as persons, user accounts, wallets, and keys. A user can have multiple accounts, each account may hold multiple wallets, and each wallet may hold multiple keys, or conversely, a number of users may be sharing an account, a wallet, or a key. As a result, it is impossible to calculate with accuracy the actual economic actors on any given crypto-exchange (a problem that in fairness is common on all online platforms).

Thirdly, a meaningful use of relative sizes would require knowing the total size of the market, i.e. the total number of users, as well. While it is easier to calculate the total number of blockchain users, since no association with specific exchanges is needed, the mapping problem persists and not all of the addresses are economically relevant, meaning that they are used for transactions between two individuals and not simply as intermediate facilitators. As Chainalysis explains there are "about 460 million [Bitcoin addresses] as of December 2018. … [Of these,] 172 million are economically relevant—they are controlled by people or services who currently own bitcoin. Of these, only 27 million actually hold bitcoin."[125] Other estimates place the total number of addresses at around 35 million.[126] Services that attempt to work through these difficulties exist,[127] but their results are limited by what they can observe and extrapolate from there.[128]

V. Conclusion

While until recently the legal cases and regulatory scrutiny around cryptoassets mostly related to criminal activity, it is now increasingly common that antitrust, financial regulation and broader industrial policy become more involved. In these areas of law and policy-making the size of the involved actors plays a defining role as larger actors are conventionally thought to have more market power and generally be more impactful in their respective markets. Already a body of research around how market power can manifest itself in blockchain markets is emerging and is bound to inform regulatory priorities.[129] But much like in any nascent market, it takes time for courts, authorities and policy-makers to familiarize themselves with the market dynamics and to decipher how power builds up. Proxies, such as market shares, assist in this investigation and form an indispensable part, along with other factors, of understanding the market positioning of the involved actors. In that direction, this article has documented,

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[124] Ivan da Silva Sendin, *On Detecting Cold Storage Transactions on Bitcoin's Blockchain* 155–166 (2018).
[125] Mapping the Universe of Bitcoin's 460 Million Addresses, CHAINALYSIS (December 19, 2018).
[126] RAUCHS ET AL., *supra* note 46.
[127] *See, e.g.*, Wallet Explorer, http://www.walletexplorer.com.
[128] For example, Wallet Explorer uses a common technique to better associate addresses (public keys) with wallets, by combining different addresses under the same wallet if they are spent in the same transaction. But on limitations *see* Sendin, *supra* note 124.
[129]

systematized, and quantified the relevant proxies for measuring the size of cryptoassets, validators (miners and stakers) and crypto-exchanges. This exercise has traditionally presented many challenges on account of multiple reasons, including the fact that the cryptoasset universe presents novel concepts, issues, and inter-relations, the lack of regulatory oversight which taints measurements, and the tendency to over-simplify. By providing a systematic examination of how to properly conduct market share calculation this article serves as an authoritative vade mecum to regulatory authorities, courts, researchers and investors.