Grove City College

Economic Impacts of Blockchain Technology

Anthony Rozmajzl

Economics 420A

Dr. Herbener

1 February 2018

The progress of human history can be told from the perspective of infrastructure inversion. This is a phrase used by Andreas Antonopoulos to describe the general features of major technological innovations and how new technologies disrupt existing markets, create conflict, but eventually make their way into everyday life. Antonopoulos, in just a few brief pages, summarizes a few of the major infrastructure inversions throughout history. As an example, he reminds us how disruptive the advent of the automobile was to the longstanding institution of horse-based transportation. Initial public opinion of automobiles was poor. People found them obnoxiously noisy, were skeptical of how far cars could travel before needing refueled, and did not trust their maneuverability on wet, muddy roads. Horses, on the other hand, could travel far before needing to eat, maneuvered well through the mud, and were relatively quiet. Evaluated alongside the current infrastructure, automobiles did not fare well. They had been invented and implemented on top of an infrastructure built for horses, thus, their initial popularity suffered. Eventually, however, we started paving roads. And as that new infrastructure became more prevalent, an incredible thing happened. Not only could the existing technology (horses) use the newly-paved roads, but they greatly increased the efficiency of automobiles as well. What is more telling, this new infrastructure opened up brand new markets for transportation. Paved roads allowed for the invention of motorcycles, skateboards, Segways, and other new technologies. This is the pattern of infrastructure inversion. As Antonopoulos explains, “You start with the new technology existing on top of an old infrastructure and then, it flips. You build infrastructure and then the old

infrastructure rides on top, on the infrastructure designed for the new technology."[1] Moreover, the new infrastructure allows unique technologies to be built on top of it, technologies that are often unpredictable but yield great benefit to society. The pattern of infrastructure inversion was present in other technological advancements throughout history, manifesting when electricity disrupted the natural gas industry and, more significantly, when communications were shifted from voice to data, that is, when service providers' backbones switched to dedicated data lines instead of only voice lines, helping to usher in the era of big data.[2] However, Antonopoulos, along with others, believes another type of infrastructure inversion is on the way with technologies like Bitcoin; not with the digital currency per se, but with the technology that undergirds it, namely, the blockchain.

Although the blockchain is a relatively new technology,[3] a lot of buzz and a fair amount of hype has been generated about the scope of the blockchain's real-word applications. Martha Bennet, principal analyst for Forrester Research[4], is of this opinion.

> Following blockchain technology feels a little like living in two parallel universes: One is the world of press and vendor hype, fueled in equal measure by commercial self-interest and a genuine desire for innovation, and which remains firmly in the phase of irrational exuberance. The other is the world of enterprise business and technology professionals actually

[1] Antonopoulos: Internet of Money (Page Number, Section 6.1.1)
[2] Ibid. (Page Number: Section 6.1.6)
[3] Blockchain technology first appeared alongside Bitcoin when Bitcoin was released in 2009.
[4] Forrester is one of the foremost companies in providing advice on existing and potential impacts of new technologies. They conduct annual surveys of over 675,000 consumers and business leaders (Forrester.com).

> working on blockchain projects; this world is firmly anchored in the phase of rational assessment, and everyone's agreed that large-scale, widespread deployment of blockchain-based (or indeed blockchain-inspired) networks isn't imminent.[5]

In other words, there is the world of hype and the world of those who realize that the widespread adoption of blockchain technology will need to occur very gradually. The latter also realizes that weaving blockchain technology into traditional business models will take time, for "non-technical as much as technical reasons."[6] As will be discussed later, these non-technical obstacles deal almost entirely with how government regulation could affect blockchain implementation.

Bennet's synopsis of public opinion towards blockchain technology is not to be taken lightly. She offers a harsh, but needed analysis of the current situation and her contributions raise the crucially important question of where the true economic impact of this technology lies. On one end of the spectrum, you have the blockchain speculators who believe that the blockchain has the ability to topple governments and wholly replace established monetary systems. On the other end are those who think the technology adds no value to our current infrastructure. Both of these opinions are faulty. It is publicly known that important companies like Amazon[7] and BP are already investing in

---

[5] Martha Bennett, "Predictions 2018: The Blockchain Revolution Will Have to Wait a Little Longer," Https://go.forrester.com/blogs/predictions-2018-the-blockchain-revolution-will-have-to-wait-a-little-longer/ (web log), November 9, 2017, , accessed November 28, 2017, https://go.forrester.com/blogs/predictions-2018-the-blockchain-revolution-will-have-to-wait-a-little-longer/.

[6] Ibid.

[7] "AWS Blockchain Partners," Amazon Web Services, Inc., accessed January 31, 2018, https://aws.amazon.com/partners/blockchain/.

blockchain research and development.[8] Moreover, IBM predicts that 66 percent of banks will have scaled and implemented blockchain technology for commercial use by 2021.[9] So, the claim that blockchain offers no value to society is clearly faulty. In reality, the true economic impact of the blockchain lies in between these two extremes. It is not going to eradicate the very institution that stands to profit from its regulation; and the idea that blockchain technology offers no value to the economy is refuted when tested against current research trends. As research indicates, the practical economic impact of the blockchain lies in the efficient transfers of assets using new models of trust and smart contracts.

Before diving into how the blockchain accomplishes this, a sufficient explanation of the technology is in order. It is far too easy to become lost in the technical jargon used to describe the blockchain, so I will attempt to offer an introductory description that is suitable for this discussion. At its most basic level, the blockchain is a distributed ledger technology. This is perhaps the most common definition found in the scholarly literature. In its essence, the blockchain offers a way of creating a "robust, secure, transparent, distributed ledger."[10]

The blockchain, as one may easily guess, is comprised of blocks. A block, as defined by Andreas Antonopoulos, is ". . . a container data structure that aggregates transactions for inclusion in the public ledger, the blockchain. The block is made of a

[8]Andrew Ward, "BP Experiments with Blockchain for Oil and Gas Trading," Financial Times, October 2, 2017, Accessed December 01, 2017, https://www.ft.com/content/100622d0-a680-11e7-93c5-648314d2c72c.
[9] Lucinda Shen, "Blockchain Could Start Making Some Real Waves the Banking Industry Next Year," Fortune, September 8, 2016, Accessed November 28, 2017, http://fortune.com/2016/09/28/blockchain-banks-2017/.
[10] Sinclair Davidson, Primavera De Filippi, and Jason Potts, "Economics of Blockchain," SSRN, March 9, 2016, Accessed November 30, 2017, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2744751. 1.

header, containing metadata, followed by a long list of transactions that make up the bulk of its size."[11] As these blocks are stacked on top of one another, that is, as more transactions are processed across blockchain-based cryptocurrencies like Bitcoin or Ethereum, the blockchain begins to grow, which makes it robust. The reason for this is that each block contains two important identifiers: its own hash, which identifies the current block, and a previous hash header, which identifies the preceding block. The preceding block is known as the "parent block" and the current block is known as the "child block." Because each block's identity is dependent on not only its own hash but the preceding hash as well, any malicious attempt to modify past blocks will require a change in all subsequent blocks. Recalculating large numbers of blocks would require a heavy amount of computational power, essentially rendering the blockchain's deep history unchangeable.[12] By way of analogy, think of the blockchain as geological formation. On the top layers are your dust and soil which can change as new weather comes along. But the deeper you go, the more secure and robust become the layers of geological formation; it is going to take a lot of effort and energy to reach down that far and make any changes.[13]

Vitalik Buterin, co-founder of Ethereum, the second most popular cryptocurrency behind Bitcoin, offers a non-technical definition of what the blockchain actually does, a definition that does a better job at explaining the impact it can have on the economy,

[11] Andreas M. Antonopoulos, Mastering Bitcoin: Unlocking Digital Cryptocurrencies (Sebastopol, CA: OReilly, 2015). 162.
[12] Ibid.
[13] Ibid.

> A blockchain is a magic computer that anyone can upload programs to and leave the programs to self-execute, where the current and all previous states of every program are always publicly visible, and which carries a very strong cryptoeconomically-secured guarantee that programs running on the chain will continue to execute in exactly the way that the blockchain protocol specifies.[14]

This definition highlights the robustness and distributed nature of the blockchain without entangling the reader in technical jargon. It also describes the blockchain as an open-source technology that is transparent to all users. This elementary description of the blockchain should suffice, but there is a large amount of technical literature available for a more detailed understanding of the blockchain.[15]As blockchain technology becomes more commercially prevalent, it is not difficult to see how it will affect conventional trust models, a topic which will be discussed later.

Moving away from definitions, we begin to take a closer look at where much of the hype over the blockchain is being directed. One of the more prominent realms of blockchain hype is the market for cryptocurrencies, which are just one of the many applications of blockchain technology. Lawrence H. White, writing for the Cato Institute, provides us with a measure of the growth in the cryptocurrency market. Tracking data from CoinMarketCap.com, White noted that in May of 2013 Bitcoin's market cap was $1.2 billion. Only 13 altcoins—cryptocurrencies other than Bitcoin—were listed and had

---

[14] Vitalik Buterin, "Visions Part 1: The Value of Blockchain Technology," Ethereum Blog (web log), April 13, 2015, Accessed October 26, 2017, https://blog.ethereum.org/2015/04/13/visions-part-1-the-value-of-blockchain-technology/.
[15] For a more detailed description and in-depth understanding of the computer science behind the blockchain, a very good place to start is chapter 7 of Andreas Antonopoulos' *Mastering Bitcoin.*

a total market cap that was only 6 percent of Bitcoin's. Thus Bitcoin captured approximately 94 percent of the cryptocurrency market. Fast-forward 2 years and Bitcoin's market share had dropped to roughly 87 percent.[16] From the time White had written the article until November 29, 2017, Bitcoin's market share has dropped to roughly 56 percent, giving altcoins 44 percent of the cryptocurrency market. Additionally, the number of altcoins with measurable market caps has exploded to 1,500.[17]

Another telling metric to grasp the size of the cryptocurrency market is current trading volume. According to Bitfinex, one of the largest online cryptocurrency trading platforms, the twenty-four hour trading volumes for Bitcoin, Ethereum, and Litecoin, the three most popular cryptocurrencies, are $1.12 billion, $323 million, and $702 million respectively. Taken together, these three cryptocurrencies constitute roughly 74 percent of all trading volume. Compared to just one year ago, the same twenty-four hour trading volumes for these cryptocurrencies stood at $63 million, $7 million, and $1.4 million, respectively.[18] There is no question that the cryptocurrency market has ballooned in recent years.

But perhaps the most surprising development is the continued rise in the value of Bitcoin, currently valued at roughly $11,000 per unit. New record prices have generated significant buzz around Bitcoin and cryptocurrencies in general. Furthermore, retail use

---

[16] Lawrence H. White, "The Market for Cryptocurrencies," Cato Journal 35, no. 2 (December 14, 2014): , accessed October 12, 2017, doi:10.2139/ssrn.2538290. 354.
[17] "Cryptocurrency Market Capitalizations," CoinMarketCap, Accessed November 27, 2017, https://coinmarketcap.com/.
[18] Ibid.

of Bitcoin, although small, is growing. In December of 2014, Microsoft joined other large online retailers like Overstock, Dell, Expedia, Tiger Direct, and Newegg as a company that accepts Bitcoin for its products. Moreover, payment processing firms Bitpay, Coinbase, and others are enabling brick and mortar stores to accept Bitcoin payments through Bitcoin wallet smartphone applications.

Hearing about growth trends and commercial usage increases can make it seem as though blockchain-based cryptocurrencies like Bitcoin are on the verge of replacing our current financial system. There are those out there who believe Bitcoin and other cryptocurrencies, if they become popular enough, will replace the dollar and restructure our entire monetary system. The hype surrounding this claim should be focused specifically on Bitcoin because it is the most common medium of exchange within the cryptocurrency market and already denominates a number of altcoins.

Economically speaking, Bitcoin's finite supply poses a challenge to its becoming money. In the market for loans, we need to consider the problem of deflation with a money whose quantity cannot be increased in a growing economy. Suppose, for example, a country with a fixed amount of cryptocurrency had enough economic growth to cause 5 percent price deflation, but time preferences were such that the rate of interest was only 2 percent. Given a fixed-quantity cyptocurrency, economic growth would stagnate as people would find it more beneficial to simply hold the digital currency for a 5 percent annual return as opposed to the 2 percent annual interest they would receive from lending. In this scenario, economic growth becomes infeasible. With a fixed-quantity currency, if the rate of price deflation exceeds the rate of people's time preferences,

lenders would have to switch to another currency to achieve economic growth. Contrary to popular belief, Bitcoin, at least for the time being, *is* an inflationary currency. As of June, 2017, Bitcoin has an inflation rate of roughly 4 percent.[19]

Not only is there a deflationary concern with Bitcoin, there is also the concern of the enormous costs associated with mining Bitcoin as the algorithm for doing so becomes more complex. As this happens, the amount of electricity needed for the computational processing of blocks of transactions increases while the Bitcoin reward decreases. As miners experience diminishing returns to Bitcoin mining over time[20], it is likely that the only way to incentivize miners to continue producing Bitcoin is to raise transaction fees. The extent to which this is done plays a critical role in the value of Bitcoin, which boasts of low transaction fees compared to traditional intermediaries. (Section about transaction fees). These two factors taken together severely limit Bitcoin's potential to become money. It would seem that Bitcoin's diminishing returns and high expected future costs of production are bigger worries than that of its fixed future quantity.

Research indicates that one of the realms for impact of the blockchain on the economy will be the development of new trust models across common transactions. Understanding this becomes easier when you think of the blockchain as a ledger. Any time we need consensus, we look to ledgers because they confirm ownership, that is, they uphold property rights. Moreover, ledgers confirm identity, status, and authority. "At

---

[19] Demelza Hays, "Central Banks Are Driving Many to Cryptocurrencies," Mises Institute, June 16, 2017, Accessed December 12, 2017, https://mises.org/blog/central-banks-are-driving-many-cryptocurrencies.

[20] Bitcoin's rate of inflation will eventually diminish to zero as the algorithm for mining Bitcoin becomes so mathematically complex that the costs associated with mining Bitcoin devalue the mining process altogether.

their most fundamental level, ledgers map social and economic conditions."[21] A thriving economy needs to have trusted intermediaries to maintain accurate ledgers to confirm all these things. Today we have trusted intermediaries like Paypal, banks, and brokerages to handle electronic transactions between unacquainted parties on the Internet. "Such institutions establish trust and security by preserving a centralized ledger to track account holders' balances and, ultimately, vouch for a transaction's authenticity."[22] In other words, it is through these trusted intermediaries that counter-party risk[23] is prevented, that is, the risk of one malicious party taking advantage of another. Unfortunately, research from the public relations company Edelman's 2015 "Trust Barometer" indicates that trust in corporations has fallen to the disappointingly low levels that have not been seen since the 2008 financial crisis.[24] As the global economy becomes larger, markets and corporations will grow in scale and transaction volumes will increase, causing the potential for counter-party risk *and* transactions costs to rise as more people become globally connected. When these things happen, markets become thinner as parties find it less profitable to transact.[25] Thus, there is little doubt that trust is going to become more important as the global economy expands.

---

[21] Cryptoeconomics Team, "The Blockchain Economy: A Beginner's Guide to Institutional Cryptoeconomics," Medium, September 26, 2017, Accessed November 18, 2017, https://medium.com/@cryptoeconomics/the-blockchain-economy-a-beginners-guide-to-institutional-cryptoeconomics-64bf2f2beec4.

[22] Trevor I. Kiviat, "Beyond Bitcoin: Issues in Regulating Blockchain Transactions," Duke Law Journal 65, 3 (December 7, 2015): Accessed November 27, 2017. 577.

[23] Counterparty risk, also known as default risk, is the risk to each party in a contract that the counterparty will not live up to its contractual obligations (Investopedia.com).

[24] Alex Tapscott and Don Tapscott, *Blockchain Revolution: How the Technology behind Bitcoin is Changing Money, Business and the World* (NY: Portfolio/Penguin). 10.

[25] Christian Catalini and Joshua Gans, "Some Simple Economics of the Blockchain," SSRN, November 27, 2016, Accessed November 22, 2017, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2874598.

Enter the blockchain, which can also act as a trusted pipeline between unacquainted parties. Fundamentally, "The blockchain is a distributed ledger that does not rely on a trusted central authority to maintain and validate the ledger."[26]The two major cryptocurrencies, Bitcoin and Ethereum, have protocols containing the rules and incentives for "running a decentralized network; securing a shared ledger at the same time."[27] Under this scenario, Christian Catallini and Joshua Gans explain that

> . . . transaction attributes are stored on a blockchain, and the market design of the underlying cryptocurrency defines how and by whom those attributes can be updated, verified and reused at a future date.[28]

That is to say, the underlying design of the cryptocurrency determines how the integrity of transactions on the blockchain ledger is maintained. When these cryptocurrencies have robust underlying protocols, "the blockchain concept allows us to definitively prove what transactions actually happened in the past . . . the system incentivizes stability and this common good to *hold into the future*."[29] Thus, properly-designed cryptocurrencies can create a level of trust akin to that of traditional intermediaries, but without any one organization playing the role of intermediary.

How is this accomplished on the blockchain where a large number of unacquainted third parties are supposed to reach unanimous transactional consensus? This is the underlying question behind what *used* to be an unsolved problem in

---

[26] Cryptoeconomics Team, "The Blockchain Economy: A Beginner's Guide to Institutional Cryptoeconomics,"
[27] Catalini and Gans, "Some Simple Economics of the Blockchain," 4.
[28] Ibid.
[29] Kyle Wang, "Cryptoeconomics: Paving the Future of Blockchain Technology," Hacker Noon, July 21, 2017, Accessed November 25, 2017, https://hackernoon.com/cryptoeconomics-paving-the-future-of-blockchain-technology-13b04dab971.

distributed computing, known as the "Byzantine General's Problem."[30] The problem runs something like this: Imagine the Byzantine army has surrounded a castle in preparation for a siege. Generals spread around the walls of the castle are each commanding different units of the army and suddenly realize that they need to coordinate an attack or a retreat. Without majority commitment, the plan will far apart and the Byzantine army will be crushed. Unbeknownst to all the generals, a few traitorous army men are trying to undermine the army's coordination by sending conflicting messages to different generals.[31] How is it possible to coordinate this type of army? In computer science, "the capability of a system to resist failure from faulty components that prevent other critical components from reaching necessary consensus" is known as Byzantine Fault Tolerance."[32]

The first blockchain-based protocol to solve the Byzantine General's Problem was the proof-of-work (PoW) concept developed by Satoshi Nakamoto, creator of Bitcoin. In the proof-of-work system, "miners" compete to solve complex mathematical algorithms and by doing so are awarded with either Bitcoin or transaction fees for expending computing power to build an "ironclad transaction history," which, as mentioned previously, makes it very expensive for attackers to manipulate anything.[33] Proof-of-work creates a "credible commitment against an attack: the audit trail build by the addition of subsequent blocks becomes more difficult to tamper with over time as more

[30] Antonopoulos, *Mastering Bitcoin*, 4.
[31] Wang, "Cryptoeconomics: Paving the Future of Blockchain Technology"
[32] Ibid.
[33] Ibid.

computing power (and energy) are sunk to support it."[34] This long list of work done by miners discourages malicious tampering as the costs of doing so increase directly with the size of the blockchain.

Because consensus is reached by a majority of miners expending computational power to record transactions, some worry that this will incentivize groups of miners to collude, gather 51 percent of the network's hashing power, and attack the Bitcoin protocol to double-spend transactions or even execute denial of service attacks.[35] As it currently stands, there are four companies that, when pooled together, constitute roughly 60 percent of the hashing power on the Bitcoin blockchain.[36] This is one of the main security concerns with the proof-of-work protocol, but the longevity of Bitcoin and its increasing value should serve as a testament to the blockchain's reliability in compiling trustworthy transaction records.[37]

Ethereum, the second most popular blockchain-based cryptocurrency, operates on the proof-of-work protocol as well, but is planning to switch over to the proof-of-stake (PoS) protocol via the Casper update.[38] "Proof-of-stake requires miners to invest in and hang on to some store of value, i.e., the native token of the blockchain such as Ether in order to vote on the state of the chain. They are no longer miners; they are validators."[39]

---

[34] Catalini and Gans, "Some Simple Economics of the Blockchain," 9.
[35] Antonopoulos, *Mastering Bitcoin*, 213. Antonopoulos offers an example as to how this might occur across common transactions.
[36] "Hashrate Distribution," Blockchain, Accessed December 2, 2017, https://blockchain.info/pools.
[37] Consider the incentives of miners. What incentive would they have for colluding and taking other people's Bitcoin? Part of the value of Bitcoin itself lies in the reliability of miners hashing trustworthy transactions into the blockchain. The moment they act with malicious intent is the moment that Bitcoin's value would plummet, causing significant loss to the malicious attacker.
[38] Oliver Dale, "Beginner's Guide to Ethereum Casper Hardfork: What You Need to Know," Blockonomi, November 07, 2017, Accessed November 29, 2017, https://blockonomi.com/ethereum-casper/.
[39] Alex Tapscott and Don Tapscott, *Realizing the Potential of the Blockchain*, PDF, World Economic Forum, June 28, 2017, 16.

Ethereum validators deposit a certain amount of Ethereum, essentially voting on what the majority consensus will be.[40] Unlike the proof-of-work protocol which requires significant energy for computing power to be the first validator of blocks of transactions, the creator of a new block under the proof-of-stake protocol is chosen depending on his or her wealth, or stake in perpetuating the blockchain.[41] The incentives to perpetuate a valid ledger are clear—"cause trouble and lose everything"[42] This is the argument used against the possibility of a 51 percent collusion attack from those holding the greatest amount of Ethereum. Those who cause trouble and disrupt transaction aggregation will motivate public distrust in the proof-of-stake protocol and wreck the value of Ethereum, thus losing the value of their own holdings. "If one validator creates an 'invalid' block, his security deposit will be deleted, as well as his privilege to be part of the network consensus.[43] The incentives for maintaining a trustworthy ledger under the proof-of-stake protocol are clear.[44]

The longevity of both Bitcoin and Ethereum, and their rising cryptocurrency values, indicate that their ability to establish trust over a decentralized network of unacquainted actors holds up. In determining where these blockchain technologies can be

---

[40] Wang, "Cryptoeconomics: Paving the Future of Blockchain Technology"
[41] Ameer Rosic, "Proof of Work vs Proof of Stake: Basic Mining Guide," Blockgeeks, July 24, 2017, Accessed November 29, 2017, https://blockgeeks.com/guides/proof-of-work-vs-proof-of-stake/.
[42] Ibid.
[43] Ibid.
[44] Another major reason for switching to the proof-of-stake consensus mechanism is to avoid the increasingly high costs of "mining" blocks under the proof-of-work system, which poses a major threat the scalability of proof-of-work. As of December 1, 2017, Bitcoin's estimated yearly energy consumption is about 31 TWh, 17 TWh more than the entire country of Nigeria. This is enough power to sustain almost half of the Czech Republic for one year. (Digiconomist).

effective in the economy, special focus is given to the applications of blockchain technology which go beyond the formation of cryptocurrencies. As Melanie Swans notes,

> The blockchain can be used for any form of asset registry, inventory, and exchange, including every area of finance, economics, and money; hard assets (physical property); and intangible assets (votes, ideas, reputation, intention, health data, and information). Using blockchain technology this way opens multiple classes of functionality across all segments of businesses involved in money, markets, and financial transactions. Blockchain-encoded property becomes smart property that is transactable via smart contracts.[45]

Most people do not realize that the extent of the blockchain's applications go well beyond cryptocurrency. Swan further notes that "Blockchain tracking could mean that all contributions to a system by all involved parties, no matter how minute, can be assessed and attributed in a seamless, automated way, for later roll-up to the macro-level." [46] The ability to track the details of contributions to a project from start to finish would greatly reduce the risk of fraudulent behavior and increase the authenticity of assets involved in transactions.[47]

Because of the blockchain's capability to register different attributes of tangible and intangible assets, the question of smart contracts as a new business model has been

---

[45] Melanie Swan, *Blockchain: Blueprint for a New Economy* (Sebastopol, CA: OReilly Media, Inc., 2015), 15.
[46] Ibid., 31.
[47] Everledger, started in 2015, is a digital global ledger that tracks and protects items of value on their lifelong journey, giving them an immutable, digital footprint on a transparent record which stakeholders can use to track and protect their assets. They currently use this technology to track the life of diamonds and have recorded over 1 million diamonds into the blockchain through Hyperledger blockchain technology. (https://www.entrepreneur.com/article/283532).

gaining more traction. According to Chris Berg, Sinclair Davidson, and Jason Potts, "Contracts are at the center of institutional cryptoeconomics. It is here that blockchains have the most revolutionary implications."[48] They further note that having smart contracts on the blockchain "allows for contractual agreements to be automatically, autonomously and securely executed."[49] It is the secure, public ledger of the blockchain which acts as an enforcement mechanism to execute the terms of a specified contract.[50] These three authors are not alone in their conviction that smart contracts have serious potential to form new models of business organization. Dylan Bargar claims "Perhaps one of the most obvious and easily applicable uses of the blockchain concerns smart contracts."[51] Additionally, Jerry Cuomo, vice president for technologies at IBM, believes smart contracts can be used "all across the chain from financial services to healthcare to insurance."[52] The specific applications to the financial sector will be discussed later on.

Smart contracts facilitate the transfer of money, property, shares, or anything of value in a transparent, conflict-free manner without the services of a middleman.[53] Smart contracts, at their core, are pieces of code that simultaneously define and execute the terms of a commercial agreement. Because blockchains transactions are programmable and self-enforcing, two or more parties could use smart contracts to define an agreement and avoid the costs of monitoring and enforcement.[54] This fact is significant for reducing

---

[48] Cryptoeconomics Team, "The Blockchain Economy: A Beginner's Guide to Institutional Cryptoeconomics."
[49] Ibid.
[50] Kiviat, "Beyond Bitcoin: Issues in Regulating Blockchain Transactions," 605.
[51] Bargar, Dylan, "The Economics of the Blockchain: A Study of its Engineering and Transaction Services Marketplace" (2016). *All Theses*. Paper 2417.
[52] Ameer Rosic, "Proof of Work vs Proof of Stake: Basic Mining Guide."
[53] Ibid.
[54] Kiviat, "Beyond Bitcoin: Issues in Regulating Blockchain Transactions," 606.

the amount of counter-party risk involved in transactions. With smart contracts being executed by objectively specified code, the incentive to default on one's contractual obligations or exploit the terms of the agreement is practically eliminated. Again, it is not difficult to see how smart contracts could change our traditional conceptions about trust and transactions. Normally, two or more parties to a contract rely on the incumbency of well-established intermediaries for the reduction of counterparty risk, but blockchain technology is here to offer an alternative to that well-established business model. According to Accenture research, investment banks alone could save up to $12 billion per year with smart contracts.[55] Additionally, Gartner research estimates that by 2022, "ratified, unbundled[56] smart contracts will be in use by more than 25 percent of global organizations."[57]

One of the ways to look at smart contracts is as a series of conditional (if-then) statements. For example, a smart contract between parties X and Y may be defined in the following manner*: If the S&P 500 drops by more than 2 percent tomorrow, pay Y 1 Bitcoin*. Or, as another example, we can understand smart contracts like vending machines. When you put money into a vending machine and enter the code for a snack or drink, an irrevocable process is set in motion which cannot be interrupted. In a sense, the terms of the "contract" are implanted in the hardware and software of the vending

[55] Roger Aitken, "Smart Contracts On The Blockchain: Can Businesses Reap The Benefits?" Forbes, November 21, 2017, Accessed November 29, 2017, https://www.forbes.com/sites/rogeraitken/2017/11/21/smart-contracts-on-the-blockchain-can-businesses-reap-the-benefits/#5e7f50c31074.
[56] Unbundled here means that the contracts are strictly defined and have narrow impact (Panetta)
[57] Kasey Panetta, "Why Blockchain's Smart Contracts Aren't Ready for the Business World," Smarter With Gartner, June 26, 2017, Accessed December 1, 2017, https://www.gartner.com/smarterwithgartner/why-blockchains-smart-contracts-arent-ready-for-the-business-world/.

machine.[58] More broadly speaking, consider the market for futures trading. Futures agreements speculate over objectively verifiable conditions regarding the future and are highly standardized, ensuring that contracts are priced well and traded with ease.[59] If we consider smart contracts within these areas, the terms of the agreement would easily be self-enforceable and self-monitoring through "a combination of scripting, multi-sig, and oracles, systems set up to monitor off-blockchain information and data that is essential to the execution of the smart contract's terms."[60] Because future markets deal with objective, verifiable conditions, it would be easy to monitor the information necessary to validate the terms of a smart contract.

As far as the potential impacts for blockchain technology on the banking industry, we can turn to Accenture, a company devoted to solving clients' needs through consulting, strategy, and technology.[61] Blockchain technology promises to alleviate some of the costs associated with banking by superseding "major middle and back-office funtions," providing strong consensus using a "cryptographic audit trail," and bring about near real-time settlement. Accenture indicates that blockchain technology is especially useful when it comes to complex financial assets where there is not an overwhelmingly clear central authority to monitor and regulate risk for counter-party failure. Some of these assets include FICC derivatives, syndicated loans, corporate bonds, and derivative

---

[58] Harriet Jones-Fenleigh, James Rogers, and Adam Sanitt, "Arbitrating Smart Contract Disputes: Negotiation and Drafting Considerations," *International Arbitration Report*, no. 9 (October 2017): , accessed December 11, 2017. 21.
[59] CME Group, A Trader's Guide to Futures: Guide, PDF, CME Group, 2013.
[60] Kiviat, "Beyond Bitcoin: Issues in Regulating Blockchain Transactions," 607.
[61] Accenture operates across forty industries and partners with over 75 percent of Fortune 500 companies.

collaterals.[62] Accenture also touches on the issue of smart contracts and how they may be of benefit to the banking industry. The question at hand is where the business logic of transactions should live; and since millions of business contracts are executed every day with the possibility of party failure or code malfunction, how would these problems be identified and by whom? Accenture admits that while it is possible to program what contracts should do in the event of such contingencies, "that approach is highly inefficient." They claim that "A centralized business logic engine can manage a consolidated set of rules and constructs, leaving distributed ledgers and blockchains to focus on recording transaction outcomes and details."[63] Leaving blockchains to record transaction outcomes and details is a critical aspect of creating the "cryptographic audit trail" mentioned above. Because of their auditability and transparency, smart contracts will be able to pinpoint any parties who act maliciously. The ability to determine where failure occurred is a crucial element in any industry, but particularly within the financial sector.

The idea of smart contracts should be of special importance to the legal community whose demand may fall as business models begin to welcome smart contracts. This is the mindset shared by Ahmed Kosba and others who believe that smart contracts allow parties to transact securely apart from central intermediaries, thus avoiding "high legal and transactional costs."[64] David Yermack, member of the National

---

[62] Accenture, "Are You Exploring Blockchain Technology for Your Investment Bank?" Accenture, accessed February 01, 2018, https://www.accenture.com/us-en/insight-perspectives-capital-markets-blockchain.
[63] Accenture, *Blockchain-Enabled Distributed Ledgers: Are Investment Banks Ready?* PDF, Accenture, 2016.
[64]Ahmed Kosba, Andrew Miller, Elaine Shi, Zikai Wen, and Charalampos Papamanthou "Hawk: The Blockchain Model of Cryptography and Privacy-Preserving Smart Contracts," 2016 IEEE Symposium on Security and Privacy (SP), San Jose, CA, 2016, pp. 839-858. doi: 10.1109/SP.2016.55. 839.

Bureau of Economic Research, highlights that "lawyers might see their business shrink dramatically in a world in which many contracts became self-enforcing."[65]

Blockchain technology also addresses cost issues associated with discrepancies between complete and incomplete contracts. A complete contract describes what is to happen under every possible contingency whereas an incomplete contract allows renegotiation of terms in case of unforeseeable events.[66] Incomplete contracts typically incur costs arriving from "(1) uncertainty, or unforeseen contingencies; (2) costs of writing contracts; (3) costs of enforcing contracts."[67] It should be obvious that a complete contract is impossible to execute while incomplete contracts can get expensive as unforeseeable events continually necessitate a change in the terms of an agreement. Renegotiation requires additional fees to be paid to lawyers who must take time to renegotiate and rewrite the terms of a contract. The blockchain, with smart contracts, can help alleviate the information and transaction costs associated with incomplete contracts through real-time monitoring of economic conditions. This will free up the "scale and scope" of economic activity that can be undertaken by firms.[68]

Authors Chris Berg, Sinclair Davidson, and Jason Potts suggest that the real gains to be made with blockchain technology are in "developing more powerful oracles—converting incomplete contracts to contracts that are sufficiently complete to be written algorithmically and executed on the blockchain." As mentioned previously, oracles

---

[65] David Yermack, "Corporate Governance and Blockchains," Review of Finance 21, 1 (March 1, 2017): Accessed November 27, 2017, doi:10.3386/w21802. 32.
[66] Cryptoeconomics Team, "The Blockchain Economy: A Beginner's Guide to Institutional Cryptoeconomics."
[67] Sinclair Davidson, Primavera De Filippi, and Jason Potts, "Economics of Blockchain," 9.
[68] Ibid.

would be used to monitor economic conditions pertinent to the automatic execution and enforcement of smart contracts. As adoption of smart contracts increases, this will inevitably lead to an increase in the demand for oracles that can reliably record economic conditions relevant to the terms of the smart contract. Moreover, as oracles become more advanced and nuanced with the types of information they can collect, the scope and intricacies of the terms of smart contracts will increase.

Because blockchains cannot access information outside of their own network, they will need to rely on third-party oracles to feed them information.[69] In this sense, there is no completely decentralized solution for carrying out the terms of a smart contract. There is also no doubt that some would have great concern over trusting third parties to relay accurate information to be used by smart contracts. However, if the companies employing the information-feeding oracles receive cryptocurrency as remuneration for providing accurate information, they will have an incentive to keep doing so. Like the incentives miners face to propagate legitimate transactions onto the blockchain, companies providing information through oracles have these same incentives. Supplying inaccurate data would cause distrust in the smart contract system, thus devaluing the underlying cryptocurrency and imposing significant costs on the offending oracle service provider. Nonetheless, because smart contracts rely on the propagation of accurate information and because businesses who supply oracles would

[69] "Blockchain Oracles," BlockchainHub, Accessed November 29, 2017, https://blockchainhub.net/blockchain-oracles/.

receive cryptocurrency as a result of relaying accurate information to the blockchain, there will likely be a spike in the development of information-collecting oracles.[70]

It should be noted that smart contract technology is dependent on how much human discretion plays a role in transactions. Obviously, demand for traditional, written contracts increases when the outcomes of a contract may be extremely hard to measure or need some level of subjective interpretation. Simply speaking, there are a number of contract possibilities for which the blockchain is unsuitable and for which traditional methods would be more reasonable. For example, if two parties have a smart contract with one another and *both* of them are heavily displeased with the outcome of the contract, they have no option but to accept the results of the code written in the smart contract. Don and Alex Tapscott sum up the problem nicely,

> This very high degree of certainty—mathematical certainty—as to the outcome of a transaction or a smart contract is unprecedented in society. It delivers greater efficiencies and effectively eliminates non-performance risk because we have no choice of breach, no choice of damages. But that's also a downside. It allows no room for human beings.[71]

Josh Farfield of Washington and Lee University School of Law believes that this will cause a lot of messiness and more fights between parties. He does not think, however, that this means blockchain technology is bad.[72] This simply means that smart contracts need to be implemented in those areas where they make the most sense.

---

[70] For a brief introduction to the various types of oracles and the information they can collect, follow this link: https://blockchainhub.net/blockchain-oracles/

[71] Alex Tapscott and Don Tapscott, *Realizing the Potential of the Blockchain*, 23.

[72] Ibid.

Farfield's concern does raise the important question of smart contracts' scalability. If there is no way for smart contracts to handle disputes, then their applications will be extremely narrow, focusing on very basic agreements consisting of simple if-then statements. Understandably, there are many dispute risks involving smart contracts. One of the biggest concerns, a concern that is discussed later, is whether or not the government will recognize smart contracts as legally binding. Other concerns include coding errors that may cause performance issues, language discrepancies between the coded contract and natural language contract, desire to terminate the contract on the grounds of misrepresentation or mistake, new laws rendering the terms of a smart contract void, or the inaccurate feeding of information to the smart contract.[73]

Max Raskin, writing for the *Georgetown Law Technological Review*, identified the modification of smart contracts as one exceptionally important area of consideration. Current law practices recognize that certain circumstances absolve a party for performance on their end of a contract, for example, impossibility of execution or illegality of some of the terms of the contract. Under either of these circumstances, both parties are excused from their obligations. The situation is different for smart contracts. Raskin asserts that "There needs to be a method by which smart contracts can be updated to incorporate changes that may be required by the evolving legal landscape."[74] One of the proposed solutions by Raksin is that the relevant jurisdiction create a public database and an "application programming interface (API)" that would call up the terms of a smart

[73] Harriet Jones-Fenleigh, James Rogers, and Adam Sanitt, "Arbitrating Smart Contract Disputes: Negotiation and Drafting Considerations," *International Arbitration Report*, no. 9 (October 2017), 22.
[74] Max Raskin, "The Law and Legality of Smart Contracts," *Georgetown Law Technology Review*, 1 no 2, (September 2016), 327.

contract and update certain provisions as needed.[75] The other solution is to have the parties themselves police each other by requiring them to update the code of a smart contract.[76] Either one of these options, Raskin notes, offers the chance for two parties to rectify any ex post problems of smart contracts.

Because of these concerns it would be wise for parties to include an arbitration provision in their smart contract that accomplishes a number of things. First, as these issues become more pronounced, people will need to include an arbitration clause in their smart contracts showing that both parties consent to a predefined form of arbitration. This option is often added to regular contracts when two parties would like to undergo private arbitration by third parties should a dispute arise. Additionally, because the blockchain operates in a decentralized manner with nodes in a number of different geographic locations, parties are going to have to include in their arbitration clause a specified seat for the arbitration to take place. Parties need to take careful note that their seat is not illegal and that the smart contract's arbitration agreement will be recognized and upheld by other courts. Moreover, when drafting an arbitration section of a smart contract, the parties involved need to make sure that they are agreeing on an arbitrator or set of arbitrators familiar with smart contract technology. Parties also need to determine whether or not their arbitration ought to be settled in a public or private manner. If they decide on the latter, then the parties need to agree upon this in their arbitration agreement. Finally, parties to a contract need to make sure that their arbitration agreement meets any

[75] Ibid.
[76] Ibid.

formality requirements required by the arbitrating body.[77] Having a predefined arbitration mechanism to deal with the many potential shortcomings of smart contracts is essential for their integration within the marketplace.

One area where most smart contract theory is lacking is in the area of privacy. For some contracts, privacy may not be that big of a concern. In these cases, there is no worry about having terms of the agreement distributed on a public ledger; people may find it more beneficial to contract with one another in this manner to save on enforcement costs and keep each other accountable by allowing the terms of their contract to be propagated onto the blockchain. In the financial sector however, the situation is different. Parties to contract in the financial sector will often lay out personal and sensitive information. The blockchain can "be trusted for correctness and availability, but *not for privacy* . . . Despite the expressiveness and power of the blockchain and smart contracts, the present form of these technologies *lacks transactional privacy*."[78] Even on the blockchain, where you can always create a new pseudonym to remain anonymous, the data associated with transactions, including balances, remain visible.[79] One proposed solution to this problem is Hawk, a privacy-preserving cryptography method for smart contracts that contains two parts: (1) a private portion to aggregate the parties' sensitive inputs and (2) a public portion that does not go near private information and can be propagated onto the blockchain for consensus purposes. This program also contains two main security

---

[77] Ibid., 23-24.
[78] Kosba, Miller, Shi, Wen, Papamanthou "Hawk: The Blockchain Model of Cryptography and Privacy-Preserving Smart Contracts," 839.
[79] Ibid.

guarantees: (1) on-chain privacy which stipulates that transactional privacy will be maintained unless the parties agree to disclose the information and (2) contractual security to protect the parties from whatever selfish motives they may have to exploit the terms of the contract.[80] In sum, the proposed Hawk framework seeks to remedy the concern of parties being able to keep sensitive data confidential but still implement smart contracts on a distributed ledger.[81] Perhaps Hawk offers the proper solution to this concern, or maybe the proper solution has yet to develop. Certainly, other solutions are bound to emerge as demand for transactional privacy increases.

Even if this issue is addressed, gains from industry adoption of smart contracts will have to be balanced against potential regulatory oversight by the federal government concerning cryptocurrencies. When it comes to the discussion of smart contracts, special attention is devoted to the Ethereum blockchain because it is a "foundational general-purpose cryptocurrency platform that is a Turing-complete virtual machine (meaning that it can run any coin, script, or cryptocurrency project) . . . it can run all blockchains and protocols, rather like a unified, universal development platform."[82] If government regulation negatively affects the Ethereum cryptocurrency, it could very well lead to distrust with the Ethereum blockchain, thereby decreasing its demand and hurting the market for smart contracts.

What has been made abundantly clear in the literature is that cryptocurrency tokens operate in a regulatory grey area. A recent report by the Securities Exchange

---

[80] Ibid., 840.
[81] See footnote 65 for the link to an article which offers an in-depth look at the cryptography behind the Hawk system.
[82] Swan, *Blockchain: Blueprint for a New Economy,* 21.

Commission reveals that "the classification of digital tokens will need to be reviewed on a case by case basis."[83] Considering the number of initial coin offerings (ICOs)[84] that have taken place, the answer to the question of whether or not certain cryptocurrencies will be treated as securities remains speculative. For those defined as securities, they will be subject to strict regulation. Additionally, the possibility of retrospective prosecutions must be considered for cryptocurrencies that have already been issued but may be in violation of certain SEC regulations. In this case,

> there is a chance that issuers and those associated with the offer and sale of tokens may be retrospectively pursued by multiple regulatory bodies. The chances of this happening are likely to increase as the sums being raised by ICO's increases, coupled with the increased pool of token holders who may be affected by the way the ICO has been structured on issuance and traded in secondary markets.[85]

This is a serious concern amidst the increase in ICOs in the past year as well as cryptocurrencies' massive returns on investment. Ethereum, the platform on which many of these ICOs have been developed[86], has seen a return on investment of 149,177 percent since its ICO 3 years ago.[87] No doubt that the government would benefit from taxing

---

[83] Avtar Sehra, Philip Smith, and Phil Gomes, "Economics of Initial Coin Offerings," Allen & Overy, August 23, 2017, Accessed November 15, 2017, http://www.allenovery.com/SiteCollectionDocuments/ICO-Article-Nivaura-20170822-0951%20%20-%20Final%20Draft.pdf. 23.

[84] Initial coin offerings are very similar to initial public offerings (IPOs). An IPO is the is the first time a newly-formed company's stock is available for sale to the public. Similarly, an initial coin offering is an organization's issuance of tokens to the public. These tokens allow holders to participate in a good or service at some advantage to the market while the coins can be traded for other cryptocurrencies or international currencies on an exchange.

[85] Sehra, Smith, Gomes, "Economics of Initial Coin Offerings," 23.

[86] Chance Barnett, "Inside the Meteoric Rise of ICOs," Forbes, September 26, 2017, Accessed November 25, 2017, https://www.forbes.com/sites/chancebarnett/2017/09/23/inside-the-meteoric-rise-of-icos/#f6a945a5670c.

[87] "ICO Stats," ICO Stats | Track ICO Performance, Accessed December 2, 2017, https://icostats.com/roi-since-ico.

these monstrous capital gains from cryptocurrencies. Not surprisingly, current IRS regulations mandate that companies report all types of Bitcoin transactions, no matter how small.[88] Because the IRS treats Bitcoins as assets or property, as is the case with stocks, using them for transactions as simple as buying groceries makes the buyer susceptible to capital gains taxes. The IRS dictates that Bitcoins held for less than one year are susceptible to short-term capital gains taxes set at the individual's current rate of taxation. Holding Bitcoins for over a year subjects the holder to long-term capital gains taxes: 0 percent for those in the 10-15 percent income tax bracket, 15 percent for those in the 25-35 percent tax bracket, and 20 percent for those in the 39.6 percent tax bracket.[89] With the value of Ethereum slowly growing behind Bitcoin, who is to know what the extent of government regulation of Ethereum will be? Speculators will need to keep a close eye on the government's treatment of Ethereum and how potential regulation could alter the value of the blockchain.

The issue of regulatory scope is clearer outside of the United States. As of now, five countries have totally outlawed Bitcoin: Bangladesh, Nepal, Kyrgyzstan, Ecuador, and Bolivia. Other countries, although they do not outlaw ownership of the coin, criminalize trading in Bitcoin or warn against oncoming regulations that may result in prosecutions. Additionally, countries will only recognize Bitcoin as a means of payment, not as a money[90]

---

[88] Kushal Agarwal, "Are There Taxes On Bitcoins?" Investopedia, April 5, 2015, Accessed December 1, 2017, https://www.investopedia.com/articles/investing/040515/are-there-taxes-bitcoins.asp.
[89] Ibid.
[90] "Legality of Bitcoin by Country or Territory," Wikipedia, December 06, 2017, Accessed December 06, 2017, https://en.wikipedia.org/wiki/Legality_of_bitcoin_by_country_or_territory.

Now even if we can assume that the value of Ethereum will remain unaffected by government regulation, there still remains the issue of governments recognizing smart contracts as legitimate contracts at all. Melanie Swan articulates this problem well,

> There are many considerations raised by smart contracts and systems of cryptographically activated assets with regard to whether we need a new body of law and regulation that distinguishes between technically binding code contracts and our more flexible legally binding human contracts. . . We need to determine and define what kinds of social contracts we would like with 'code law,' automatically and potentially unstoppably executing code. Because it could be nearly impossible to enforce smart contracts with law as currently enacted, the legal framework is essentially pushed down to the level of the contract.[91]

In essence, smart contracts are going to require a shift, and a gradual one at that, in society's perceptions as to what contracts *should* look like and *how* they should be enforced, a shift which strongly depends on law-making authorities. Because smart contracts represent an entirely new realm of contract law, concerns about how the government will affect the adoption of smart contracts remain wholly speculative. Researchers at Cornell University are among the leaders in the examination of these questions and are still unsure as to how smart contracts will interact with the law. In the meantime, there are organizations such as The Initiative for Cryptocurrenices and

[91] Swan, *Blockchain: Blueprint for a New Economy,* 17.

Contracts (IC3) that employ smart contract enthusiasts who are devoted to keeping up with studies related to this area.

All in all, smart contracts offer a new model of trust across transactions. They are autonomous, meaning that the two parties involved are making the agreement; there is no third party on whom you need to rely, which means there is no room for third party manipulation or error. Because they are stored on a distributed, robust ledger, smart contracts are trustworthy. There is no risk of one party backing out because they have lost the contract or cannot remember its terms; the information is always there. Additionally, as a result of increased speed and accuracy, smart contracts will cut down on costs where applicable. Under traditional models, the parties to a contract would have to spend significant time shuffling through paperwork to process documents, but the code behind the smart contract handles this automatically. A code-based contract will help parties avoid any errors that can come from filling out piles of paperwork, provided that the code is written and executed well.[92] We have to keep in mind that despite these advantages, smart contracts are a very nascent technology whose worth has yet to be proven in the business world; but the research interest generated by businesses has been encouraging.

Moving forward, what attitude should we take towards smart contracts? More specifically, how should we react to the economic integration of blockchain technology? As a decentralizing technology, the blockchain has the potential to uproot conventional models of trust while ushering in new, trustless forms of economic interaction. By

[92] Blockgeeks, "What Are Smart Contracts? A Beginner's Guide to Smart Contracts," Blockgeeks, January 01, 1969, Accessed December 11, 2017, https://blockgeeks.com/guides/smart-contracts/.

convention, the majority of society has accepted that the government is necessary for providing trust and ensuring that free market organizations "play by the rules." As a result, the government has commanded a significant amount of control over key economic institutions. The blockchain is here to challenge that notion. It is here to introduce new models of trust by way of distributed ledger technology and will most certainly disrupt our conventional understanding of how the economy ought to work, hopefully swaying society into favoring decentralization. Thanks to the work of Friedrich Hayek, we know that decentralized knowledge is more conducive to prosperous markets than centralized information,

> If we can agree that the economic problem of society is mainly one of rapid adaptation to changes in the particular circumstances of time and place, it would seem to follow that the ultimate decisions must be left to the people who are familiar with these circumstances . . .We need decentralization because only thus can we insure that the knowledge of the particular circumstances of time and place will be promptly used.[93]

This sentiment is further expressed through writers like Douglas North who says that

> Efficient markets are a consequence of institutions that provide low-cost measurement and enforcement of contracts at a particular moment . . . The institutions therefore must not only provide low-cost measurement of property rights and bankruptcy laws, but also provide incentives to

[93] Friedrich A. Hayek, "The Use of Knowledge in Society," American Economic Review 35, no. 4 (September 1945): Accessed December 12, 2017, http://www.econlib.org/library/Essays/hykKnw1.html.

> encourage decentralized decision making and effective competitive markets.[94]

Both of these opinions taken together represent good cause for an acceptance of blockchain technology. It promises the decentralized propagation of economically relevant information to increase efficiency in the marketplace. Having information in as many hands as possible will no doubt aid in the entrepreneurial process of economic calculation and ensure a more efficient use of resources across a variety of production processes. Of course there will be skeptics who are doubtful of the blockchain's ability to perform alongside our current infrastructure, but that is always the beginning to the beautiful process of infrastructure inversion.

[94] Douglas C. North, *Transaction Costs, Institutions, and Economic Performance*, PDF, International Center for Economic Growth, 1992.

Bibliography

Accenture. "Are You Exploring Blockchain Technology for Your Investment Bank?" Accenture.
Accessed February 01, 2018. https://www.accenture.com/us-en/insight-perspectives-
capital-markets-blockchain.

——. *Blockchain-Enabled Distributed Ledgers: Are Investment Banks Ready?* PDF. Accenture,
2016.

Agarwal, Kushal. "Are There Taxes On Bitcoins?" Investopedia. April 5, 2015. Accessed December 1, 2017. https://www.investopedia.com/articles/investing/040515/are-there-taxes-bitcoins.asp.

Aitken, Roger. "Smart Contracts On The Blockchain: Can Businesses Reap The Benefits?"
Forbes. November 21, 2017. Accessed November 29, 2017.
https://www.forbes.com/sites/rogeraitken/2017/11/21/smart-contracts-on-the-blockchain-
can-businesses-reap-the-benefits/#5e7f50c31074.

Antonopoulos, Andreas M. *Mastering Bitcoin: Unlocking Digital Cryptocurrencies*. (Sebastopol,
CA: OReilly, 2015).

——. *The Internet of Money: A Collection of Talks by Andreas M. Antonopoulos.* Vol 1. 2 vols.
Middletown, DE: Merkle Bloom LLC, 2016.

"AWS Blockchain Partners." Amazon Web Services, Inc. Accessed January 31, 2018.
https://aws.amazon.com/partners/blockchain/.

Bargar, Dylan, "The Economics of the Blockchain: A Study of its Engineering and Transaction
Services Marketplace" (2016). *All Theses*. Paper 2417.

Barnett, Chance. "Inside the Meteoric Rise of ICOs." Forbes. September 26, 2017. Accessed November 25, 2017. https://www.forbes.com/sites/chancebarnett/2017/09/23/inside-the-meteoric-rise-of-icos/#f6a945a5670c.

Buterin, Vitalik. "Visions Part 1: The Value of Blockchain Technology." Ethereum Blog (web log), April 13, 2015. Accessed October 26, 2017. https://blog.ethereum.org/2015/04/13/visions-part-1-the-value-of-blockchain-technology/.

Bennett, Martha. "Predictions 2018: The Blockchain Revolution Will Have to Wait a Little Longer." *Https://go.forrester.com/blogs/predictions-2018-the-blockchain-revolution-will-have-to-wait-a-little-longer/* (web log), November 9, 2017. Accessed November 28, 2017. https://go.forrester.com/blogs/predictions-2018-the-blockchain-revolution-will-have-to-wait-a-little-longer/.

"Blockchain Oracles." BlockchainHub. Accessed November 29, 2017. https://blockchainhub.net/blockchain-oracles/.

Blockgeeks. "What Are Smart Contracts? A Beginner's Guide to Smart Contracts." Blockgeeks. January 01, 1969. Accessed December 11, 2017. https://blockgeeks.com/guides/smart-contracts/.

Catalini, Christian, and Joshua Gans. "Some Simple Economics of the Blockchain." SSRN. November 27, 2016. Accessed November 22, 2017. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2874598.

CME Group. A Trader's Guide to Futures: Guide. PDF. CME Group, 2013.

Cryptoeconomics Team. "The Blockchain Economy: A Beginner's Guide to Institutional Cryptoeconomics." Medium. September 26, 2017. Accessed November 18, 2017. https://medium.com/@cryptoeconomics/the-blockchain-economy-a-beginners-guide-to-institutional-cryptoeconomics-64bf2f2beec4.

"Cryptocurrency Market Capitalizations." CoinMarketCap. Accessed November 27, 2017.
https://coinmarketcap.com/.

Dale, Oliver. "Beginner's Guide to Ethereum Casper Hardfork: What You Need to Know."
Blockonomi. November 07, 2017. Accessed November 29, 2017.
https://blockonomi.com/ethereum-casper/.

Davidson, Sinclair, Primavera De Filippi, and Jason Potts. "Economics of Blockchain." SSRN.
March 9, 2016. Accessed November 30, 2017.
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2744751.

"Hashrate Distribution." Blockchain. Accessed December 2, 2017.
https://blockchain.info/pools.

Hayek, Friedrich A. "The Use of Knowledge in Society." *American Economic Review* 35, 4.
(September 1945): 519-30. Accessed December 12, 2017.
http://www.econlib.org/library/Essays/hykKnw1.html.

Hays, Demelza. "Central Banks Are Driving Many to Cryptocurrencies." Mises Institute. June
16, 2017. Accessed December 12, 2017. https://mises.org/blog/central-banks-are-driving-
many-cryptocurrencies.

"ICO Stats." ICO Stats | Track ICO Performance. Accessed December 2, 2017.
https://icostats.com/roi-since-ico.

Jones-Fenleigh, Harriet , James Rogers, and Adam Sanitt. "Arbitrating Smart Contract Disputes:
Negotiation and Drafting Considerations." *International Arbitration Report*, no. 9
(October 2017): 21-25. Accessed December 11, 2017.

Kiviat, Trevor I. "Beyond Bitcoin: Issues in Regulating Blockchain Transactions." Duke Law
Journal 65, 3. (December 7, 2015): 569-608. Accessed November 27, 2017.

Kosba, A. Miller, E. Shi, Z. Wen and C. Papamanthou, "Hawk: The Blockchain Model of Cryptography and Privacy-Preserving Smart Contracts," *2016 IEEE Symposium on Security and Privacy (SP)*, San Jose, CA, 2016, pp. 839-858. doi: 10.1109/SP.2016.55.

"Legality of Bitcoin by Country or Territory." Wikipedia. December 06, 2017. Accessed December 06, 2017. https://en.wikipedia.org/wiki/Legality_of_bitcoin_by_country_or_territory.

Marino, Bill. "Smart Contracts: The Next Big Blockchain Application." Cornell Tech. December 2, 2015. Accessed December 1, 2017. https://tech.cornell.edu/news/smart-contracts-the-next-big-blockchain-application.

North, Douglas C. *Transaction Costs, Institutions, and Economic Performance*. PDF. International Center for Economic Growth, 1992.

Panetta, Kasey. "Why Blockchain's Smart Contracts Aren't Ready for the Business World." Smarter With Gartner. June 26, 2017. Accessed December 1, 2017. https://www.gartner.com/smarterwithgartner/why-blockchains-smart-contracts-arent-ready-for-the-business-world/.

Raskin, Max, "The Law and Legality of Smart Contracts." *Georgetown Law Technology Review*, 1, no. 2 September 22, 2016: 305-326. Accessed December 12, 2017. https://ssrn.com/abstract=2959166

Rosic, Ameer. "Proof of Work vs Proof of Stake: Basic Mining Guide." Blockgeeks. July 24, 2017. Accessed November 29, 2017. https://blockgeeks.com/guides/proof-of-work-vs-proof-of-stake/.

Sehra, Avtar, Philip Smith, and Phil Gomes. "Economics of Initial Coin Offerings." Allen &
Overy. August 23, 2017. Accessed November 15, 2017.
http://www.allenovery.com/SiteCollectionDocuments/ICO-Article-Nivaura-20170822-
0951%20%20-%20Final%20Draft.pdf.

Shen, Lucinda. "Blockchain Could Start Making Some Real Waves the Banking Industry Next
Year." Fortune. September 8, 2016. Accessed November 28, 2017.
http://fortune.com/2016/09/28/blockchain-banks-2017/.

Swan, Melanie. *Blockchain: Blueprint for a New Economy.* Sebastopol, CA: OReilly Media,
Inc., 2015.

Tapscott, Alex, and Don Tapscott. *Blockchain Revolution: How the Technology Behind Bitcoin
is Changing Money, Business and the World*. NY: Portfolio/Penguin, 2016.
———. “Realizing the Potential of the Blockchain”. PDF. World Economic Forum, June 28, 2017.

Wang, Kyle. "Cryptoeconomics: Paving the Future of Blockchain Technology." Hacker Noon.
July 21, 2017. Accessed November 25, 2017.
https://hackernoon.com/cryptoeconomics-
paving-the-future-of-blockchain-technology-13b04dab971.

Ward, Andrew. "BP Experiments with Blockchain for Oil and Gas Trading." Financial Times.
October 2, 2017. Accessed December 01, 2017.
https://www.ft.com/content/100622d0-
a680-11e7-93c5-648314d2c72c.

White, Lawrence H. "The Market for Cryptocurrencies." *Cato Journal* 35, no. 2 December 14,
2014: 383-402. Accessed October 12, 2017. doi:10.2139/ssrn.2538290.

Yermack, David. "Corporate Governance and Blockchains." Review of Finance 21, 1 March
1, 2017: 7-31. Accessed November 27, 2017. doi:10.3386/w21802