Beyond Bitcoin:
The Rise of Blockchain World

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The twilight of the gods?

Bitcoin was the first currency not controlled by a single entity (Nakamoto 2008). Bitcoin is a cryptocurrency, built on blockchain technology. Initially known to only a few nerds and criminals it now has hundreds of thousands of daily transactions. Bitcoin has achieved values of more than US$15,000 per coin (as of the end of 2017). Rising value attracts attention. For some, Bitcoin is digital fool's gold. Others see the underlying technology blockchain as the beginning of a new digital era. Both could be right. The fortunes of cryptocurrencies do not define blockchain. The biggest effects of blockchain might lie beyond Bitcoin, beyond cryptocurrencies or even beyond the economy. Not all the technical questions about blockchain are answered. There remain questions about high levels of processing intensity and energy use. These questions will, no doubt, be confronted over time. If the technology fails, the future of blockchain will be different. This paper assumes technical challenges will be solved, and while it attends to some technical issues, these are not the main focus of this paper.

The Economist argued in an article titled "The Trust Machine" that the biggest effects of blockchain are on trust (Economist, 2015). The article meant public trust that economic institutions such as organizations and intermediaries will act as expected. When they do not, trust deteriorates. Trust in economic institutions has not recovered from the recession of 2008 (Edelman, 2016). Technology can exacerbate distrust: online trades with distant counterparties make it hard to settle disputes face to face. Trusted intermediaries can be hard to find. That is where blockchain comes in. Permanent record-keeping that can be sequentially updated but not erased creates visible footprints of all activities conducted on the chain. This reduces the uncertainty of alternative facts or truths, creating the "trust machine" *The Economist* describes. As trust changes, so too does governance (Mougayar 2016).

Vitalik Buterin (2013) of the Ethereum blockchain platform calls blockchain "a magic computer" to which anyone can upload self-executing programs. All states of every program are publicly visible, with cryptographic guarantees that programs will execute as specified by the blockchain protocol. (Buterin later abandons the term magic in favor of Turing-complete.) Blockchain might, as the subtitle of this article suggests, usher in a new world. Some refer to blockchain as the most promising new technology since the Internet (Mougayar 2016). The gods of powerful institutions (*e.g.*, central banks), are challenged by blockchain. Whether blockchain will force these gods into the twilight is unclear, but it is big enough and powerful enough to bring major changes.

What is Blockchain?

Blockchain as it is used today is a tamper-resistant database of transactions consistent across a large number of nodes. The blockchain is cryptographically secured against retrospective manipulations, and uses a consensus mechanism to keep the database consistent whenever new transactions need to be validated. Data storage on the blockchain is secured by cryptographic hashes in which data being hashed return a fingerprint that verifies the authenticity of the data. Alteration of the original data causes the hash of the altered data to no longer match the original fingerprint. Transactions on the blockchain are grouped and stored in blocks. The combined hash of these transactions is also stored, and each subsequent block saves the combined hash of the previous block. This creates a chain of cryptographically secured and linked blocks containing the information – the blockchain. Any attempt to change information necessitates rehashing not only the block relevant to the transaction, but all subsequent blocks. This is possible theoretically, but it is impractical since the blocks grow continuously as other nodes add blocks to the blockchain (Underwood, 2016). Technical details are summarized in a paper by Ethereum's Gavin Wood (2014). The Ethereum blockchain goes beyond Bitcoin to allow user-created smart contracts executed on a generic, programmable blockchain under decentralized control, using a built-in Turing-complete programming language. This allowed smart contracts and customized (even arbitrary) rules for ownership, transaction formats, and state transition functions. These smart contracts allow the distributed user community to resolve some issues without depending on trusted centralized authorities.

The foundation of blockchain is the security of code and data in the blocks. Bitcoin uses a "Merkle tree" to store data from new transactions with pointers to original block locations for unchanged data. Transactions are repeatedly paired, merged, hashed and rehashed until only one hash – the Merkle root – remains. Each subsequent block saves the Merkle root of the previous block. Ethereum blocks contain the entire state of the Ethereum system stored in a "Patricia tree," an evolved Merkle tree. Chained hashing keeps blocks well formed and difficult to tamper with. This helps keep the blockchain secure and almost unbreakable. A blockchain is not run from a single server, but on a network of computers that hold all data and changes to the data in the blockchain. These computers are called "miners," validator nodes, essential to a blockchain that uses a proof of work mechanism to achieve consensus (Buterin, 2013). Proof of work is the most common consensus mechanism, used by Bitcoin and Ethereum and dating back to 1992 (Dwork and Naor, 1992).

Proof of work mathematically ensures validity as long as no single entity holds enough computing power to add an illegitimate block to the blockchain. Each miner competes with other miners to earn the reward of being able to add a block to the blockchain. This is accomplished by the miner doing computationally intense work. Bitcoin requires the miner to find a string that, when concatenated with a hash of the previous block header and then re-hashed, returns a particular string. Anyone trying to "spoof" the blockchain (*e.g.*, changing data on old transactions) must recalculate the proof of work for all subsequent blocks. Convincing the system to use a bogus chain would require continuously adding blocks to the chain faster than a legitimate chain would evolve. Ethereum is developing an alternative consensus scheme that uses proof of stake that does not require the computational resources of proof of work, largely in response to processing intensity and energy use as noted earlier.

Each miner that joins the blockchain increases the level of decentralization, and also strengthens the consensus mechanisms. Transactions on decentralized blockchains are transparent and visible to users, in contrast to centralized systems where the users typically do not enjoy such

transparency and trust the provider (De Filippi, 2016). Miners who have been able to solve the cryptographic puzzle are rewarded, so miners continuously try to create the next blocks that can be added to the chain. No central authority decides this. Miners that try to add different blocks than those agreed on through the consensus mechanism are disregarded by the rest of the system. This forces uniformity in the blockchain. It is nearly impossible to cheat the blockchain without circumventing the consensus scheme that dictates nodal agreement that a miner has a right to be a block in a given blockchain.

Security and transparency helps blockchain to provide a single version of what is the case and how that case was achieved – what some call "the truth." In this, Bitcoin and Ethereum are similar. Ethereum goes beyond by permitting smart contracts, a piece of code that enables the Ethereum Virtual Machine (EVM) to execute on the blockchain. The EVM is similar to other virtual machines, compiling instructions from a programming language into low level code for the computer on which it runs. The EVM is a large decentralized computer containing millions of objects called "accounts." Accounts can maintain internal databases, execute code and talk to other accounts. A smart contract is itself an account. The EVM allows for externally owned accounts (EOAs) controlled by a private key through a user, allowing an account to send ether and messages from the EOA.

A smart contract cannot be altered once the code is set, although storage of the smart contract can be altered. The piece of code acts as an agreement, available for anyone to use. Smart contracts are made possible by the Turing-complete programming languages compiled into EVM bytecode. Smart contracts have addresses and execute code based on the data they receive. Smart contracts can call other smart contracts through messages. To avoid malicious behavior, infinite loops or distributed denial of service attacks, execution and creation of smart contracts uses Ethereum's internal cryptocurrency. The amount needed for a contract is determined by the computations and storage entries of bytecode that the EVM compiles the smart contract into. Specific computation costs are calculated by the complexity of the computation, with basic computations (addition, subtraction, and multiplication) costing less and more complications costing more. Miners are paid for use of their computational power. As of 2015, the computing power available on blockchains was small, about equivalent to a 1999 smartphone (Buterin, 2015). However, with powerful smart contracts this could change quickly.

Access to a blockchain is for transaction validation or transaction entry. Transaction validation depends on whether the blockchain is permissionless (all nodes can validate transactions) or permissioned (only preregistered can validate transactions). Transaction entry is available to all nodes in public blockchains. Only preregistered nodes can submit new transactions in private blockchains. Public blockchains can be either permissioned or permissionless (Peters & Panayi, 2016).

The core ideas behind blockchain are well-established: fidelity and transparency. Fidelity is the truthful rendering of the state of things. People trust those things are as represented. The technical structure of the blockchain is that blocks containing requisite information are secured cryptographically, and consensus mechanisms ensure that blocks along the chain agree with the creation of and/or change in the information to be held. Transparency is the ability of anyone to examine the entire record of changes to determine when, how and why changes were made. The architecture of blockchain is such that any effort to "hide" information on the chain is obvious,

causing other users of the chain to ask why this is happening. The technology does not guarantee that a blockchain *cannot* be corrupted, but it makes corruption difficult enough to generate trust.

Blockchain and trust

Trust is complicated and difficult to define precisely. It has numerous meanings and many different forms. Yet trust is the underlying fabric of human interactions, of central importance to inter-personal and inter-organizational relationships. Blockchain affects trust. People sometimes refer to blockchain as a technology that overcomes the need for trust in human interactions. It is unclear that overcoming the need for trust is possible. Instead, it is more productive to assess blockchain's effect on the antecedents of trust, including confidence, integrity, reliability, responsibility and predictability. If one can be confident that collaborations will be executed as intended, and that there is only one version constituting truth, integrity is guaranteed. When contracts are executed as coded, blockchain is seen to be reliable. Roles and responsibilities are determined in advance, and outcomes are predictable. When these trust antecedents are handled effectively by blockchain, certainty can replace uncertainty. This is a major hope for blockchain; time will tell if it is realized.

Decentralized and autonomous

Much is made of blockchain, decentralization and autonomy. However, nothing in blockchain *requires* decentralization or autonomy. Decentralization and autonomy are *enabled* by blockchain, but a choice can be made based on the needs of the application. Authorities (*e.g.*, central banks) can adopt and apply blockchain technology, but blockchain provides an alternative that might have implications for control, authority, power, etc. Beyond this, it might be possible to implement previously unavailable solutions when requirements for centralized authority are lifted. As formerly impractical solutions become practical, blockchain's impacts might go beyond "least expected" to "not expected at all."

A useful way to think about this is R.H. Coase's work (Coase 1937). He asked why, assuming a market-oriented economy, economic activity is not limited to individuals interacting on markets? Why are there firms? Coase was an economist, but his ideas reach beyond economics. Firms emerge to handle "transactions" (searching, negotiating, monitoring, enforcing, coordinating) required by markets. In his model, when transaction costs are high, the firm emerges as more efficient than the market. The choice is between market and firm, but Coase recognized that a third "hybrid" form can emerge around collaborations, alliances, or joint ventures. These hybrids did not conform to products and services of the 1930s, and Coase did not elaborate on them.

In principle, blockchain allows for hybrids, enabled by the option of decentralized mechanisms to make claims, attest to things, or enforce rights (*e.g.*, property rights). Blockchain enables trust that a transaction will be completed even if there are slight variances in protocol. One can see that the ends are achieved. Friction from lack of trust can be reduced, and blockchain can bring certainty via transaction logic instantiated as code. Agreements such as contracts can be electronically executed without friction costs associated with trust. Blockchain can be used for transparent and secure transactions among individuals, between individuals and organizations, and among organizations. Blockchain might reduce or even eliminate the friction related to trust.

Dependency on central, hierarchical organizing and planning is common because it is often the only way to do things. Blockchain might change that, allowing for decentralized enforcement of transactions, in a manner similar to the way the Internet enabled changes in social relationships, commerce, etc. The constraints that now lead to centralized solutions might evaporate if the transaction logic can be orchestrated and enforced without the central authority. Blockchain can generate real-time information flows of transactions to allow new ways of digital auditing that ensure agreements are honored. This would be a paradigm shift toward a system that organizes transactions reliably, possibly without human interaction, following a protocol. Blockchain allows something like unstaffed, autonomously navigating vessels that safely move passengers from A to B using a protocol capable of minimizing exceptions (malicious and accidental) and getting humans out of the loop. In principle, blockchain could be a backbone of the Internet-of-things, enabling tamper-proof coordination such as between delivery drones and their delivery stations.

Whether any given application is controlled in centralized or decentralized manner becomes a matter of choice, not a default to centralized because that is the only way to do it. It is less important for requiring a particular solution than for enabling multiple solutions, thereby increasing the options of those who pay for, design, use, or otherwise interact with blockchain applications.

Blockchain World

Blockchain World is the combination of traditional ways of doing things plus what is enabled by blockchain. Third-parties might still ensure trustworthiness, but they do not have to do so, nor do those who seek assurance have to depend on third-parties. A transaction might be conducted as agreed upon solely because blockchain enables those interested to see the status of the transaction, know what is going on, and remind others of their obligations. Or a party could turn to another system (*e.g.*, the criminal justice system) for enforcement. Blockchain could support many codified agreements handled by traditional means, including trading of stock, monitoring of contracts, management of land records, security of foodstuff, preserving provenance, and maintaining the chain of custody. Blockchain will become *part of* the infrastructure of daily life, affecting commerce, social interaction, law, education, entertainment, nutrition, livelihood, housing and so on.

Just because Blockchain World is *part of* a larger infrastructure does not mean its effects are trivial. The Internet has had a profound effect, enabling (just to name a few things) social media and the sharing economy. Blockchain will be complementary to what has already happened, providing an option of decentralized governance in addition to centralized governance by enabling so-called decentralized autonomous organizations (DAO) implemented among participants without being their own legal entity. DAOs make transactions transparent to DAO members, which in turn makes fraudulent behavior difficult to hide.

In principle, a DAO can run autonomously as a decentralized, transparent, and secure system for operation and governance among independent participants. Blockchains need not be controlled by any participants while serving as a trusted third party to provide the role of proxy and enforcement of rules. To use Coase's insight, a DAO might reduce transaction costs while providing setup, maintenance, regulation, and supervision like traditional third-parties. The

results would not be trust-free, but trust would shift from trust in a counterparty or a third party to the blockchain system itself and the rules coded therein.

One might say the DAO is a shift from socio-technical system to a techno-social system. Socio-technical systems handle control over transactions through social systems. Techno-social systems handle control over transactions through technical systems that can be autonomous (Quintana Diaz 2014). How this would work, exactly, is as yet unclear in many ways, but blockchain technology offers the chance to experiment with secure, decentralized systems. This might enable new social models that go well beyond the economy. Realizing these models will require people with process and management knowledge, information technology skills including programming, design sensibilities, and the ability to see the big picture. Blockchain World promises much even though many of the details are as-yet unclear.

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