Banking with Blockchain-ed Big Data

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Abstract

Blockchain is disrupting the banking industry and contributing to the increased big data in banking. However, there exists a gap in research and development into blockchain-ed big data in banking from an academic perspective, and this gap is expected to have a significant negative impact on the adoption and development of blockchain technology for banking. In hope of motivating more active engagement by academics, researchers and bankers alike, we present the most comprehensive review of the impact of blockchain in banking to date by summarising the opportunities and challenges from a bankers perspective. In addition, we also discuss the impact that big data from blockchain will have on banking data analytics in future and show the increasing importance of filtering and signal extraction for the banking industry. Whilst there is evidence of selected banks adopting blockchain technology in isolation or small groups, we find the need for extensive research and development into several aspects of banking with blockchain to overcome the challenges which are currently hindering its adoption in banking across the globe.

Keywords: Blockchain; Big Data; Banking; Opportunities; Challenges; Signal Extraction.

1 Introduction

Since its emergence, big data has successfully disrupted several industries from banking (Hassani et al., 2018) to policing (Hassani et al., 2016) whilst having a significant impact on the future of data analytics, see for example, Hassani and Silva (2015). However, technology is back to the forefront in the financial services industry with blockchain taking charge of disruption and big data banking innovations (Iskandar, 2017) with the World Economic Forum (2015) estimating that 10% of GDP will be stored on blockchains or blockchain-related technology by 2025. In fact, blockchain is expected to totally revamp the financial system along the lines of what the internet did to media (Ito et al., 2017) and today, almost every global bank is experimenting with blockchain technology, hoping for cost savings and operational efficiencies (Kocianski, 2018).

The existing relationship between the banking industry and blockchain is complex because beyond the numerous opportunities for streamlining traditional banking processes, blockchain is viewed as a threat to established models (Lang, 2017a). For example, Ikeda and Hamid (2018) proposed the peer to peer monetized economy system for barter on a global scale without the requirements of third party nor money. However, as blockchain can provide bankers with unalterable data with consensus verification and real-time access (Smith, 2018a), it is undoubtedly the future of banking. For Lang (2017b), the certainty offered by blockchains is a good enough reason for banks to switch over from its traditional approaches to business transactions, and given that payments represent a huge segment of banking, the industry is primed for disruption (Lund, 2017). For Mason (2017), the less expensive nature and speed of transactions via blockchain will be the primary reasons for its revolution in the banking industry, whilst the Citigroup (2018) identifies cost savings as the main value of blockchains in the immediate future.

The origins of blockchain technology dates back to the invention of Bitcoin as a response to the financial crisis in 2008 (Nakamoto, 2008). As as the public ledger of all bitcoin transactions (the public ledger is freely accessible via `https://www.blockchain.com/explorer`), this main technological innovation called blockchain is expected to prove to be more significant than bitcoin itself (Swan, 2015). As a simple example, Figure 1 below presents a graphical view of how blockchain technology can facilitate a transaction between two parties. As Fedak (2018) asserts, blockchain not only makes big data even bigger, but also contributes by making big data more secure and valuable, as blockchain-ed big data is structured and ready for big data analytics. For banks in particular, blockchain has the potential to save costs through reduced transaction and processing costs, but competition is also likely to increase as new fintech startups emerge given the opportunity to start a bank with lower costs (Iskandar, 2017). Furthermore, technological innovation (fintech) has a positive relationship with bank's profitability according to a research by Rega (2017) which considered 38 European Banks. Thus, embracing blockchains is the way forward for the banking industry in terms of increasing the competitiveness with fintechs, and enabling the ability to use the technology to create new business models (Kocianski, 2018).

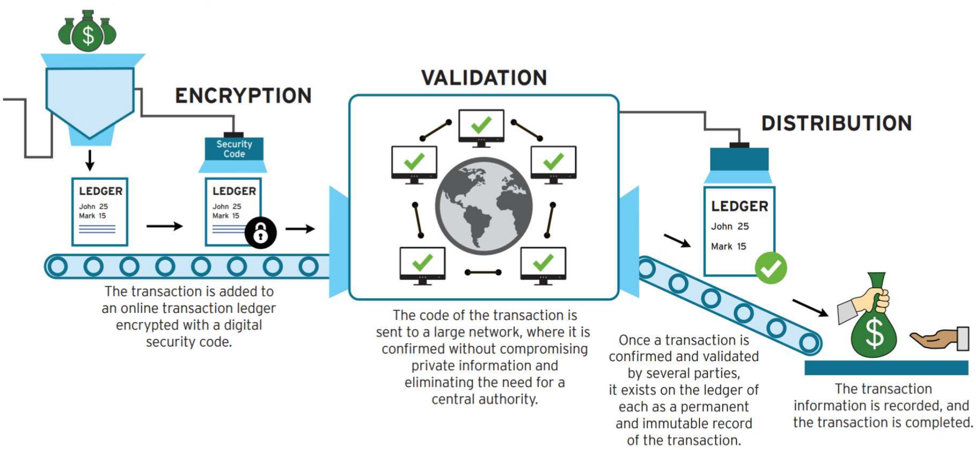

Figure 1: Anatomy of a Typical Blockchain Transaction by Sachs Insights (Tandulwadikar, 2016).

To this end, there is evidence of increasing interest from the global banking industry towards the adoption of blockchain (Cook, 2018a). For example, the French investment bank BNP Paribas was testing blockchain technology on its currency funds and for order processing (Allison, 2015) whilst UBS, Bank of Montreal (BMO), CaixaBank, Commerzbank, Erste Group and IBM are currently working on 'Batavia' - a global trade finance platform based on blockchain for streamlining the transfer of money and goods through greater efficiency and transparency (Keller, 2018). Meanwhile, HSBC recently executed a live trade finance transaction for international food and agriculture conglomerate Cargill using R3s Corda scalable blockchain platform (HSBC, 2018). With the greater adoption of blockchain included in China's 2016 5-year plan, over 12 public banks have adopted blockchains to facilitate various transactions (Cook, 2018a). In fact, the Agricultural Bank of China (ABC) completed loan granting of 300,000 USD using blockchain technology (Rud, 2018). Bank Hapoalim in Israel is exploring integrating blockchain technology into their user-information database whilst the Bank of America has filed for patents on 50 blockchain-patents (Cook, 2018a; Leighton, 2018). The National Bank of Dubai is adopting blockchain technology within its check-issuance system (Smith, 2018b), and over 60 Japanese banks representing 80% of the Japanese banking industry have partnered with Ripple (which is competing to replace SWIFT) to allow for relatively fast international monetary-transactions (Cook, 2018a). In UK, the Santander Bank implemented Ripples xCurrent protocol to allow for international payments of between £10 - £10,000 whilst the Bank of England has a proposal for facilitating payments and money transfers by integrating Real Time Gross Settlement (RTGS) systems with blockchain technology (Cook, 2018). According to Leighton (2018), Goldman Sachs too is using its internal funds to trade Bitcoin futures on behalf of its clients. Interestingly, even in countries like Zimbabwe where the ownership of cryptocurrencies is illegal, the Reserve Bank of Zimbabwe is said to be considering the implementation of blockchain (Cook, 2018a).

The above examples give the reader an indication with regard to the ongoing disruption by blockchain technology in banking. However, as Carson et al. (2018) states, the banking industry is not yet ready to fully exploit what blockchain technology has to offer, and this is partly because banks fail to appreciate blockchain as an enabling technology (Citigroup, 2018). In hope of encouraging more research and development into blockchain technology in banking from both academic researchers and bankers alike, this paper aims to provide the most comprehensive review of the opportunities and challenges for the adoption of blockchain in banking. In brief, the opportunities presented via blockchain include, for example, cost savings, security, transparency, traceability, accuracy and data integrity (Lowry, 2017). The consideration of challenges are equally important as there are several hurdles to overcome before blockchain can truly transform banking (Marr, 2017). It is noteworthy that Peters and Panayi (2016) presented a systematic discussion on the benefits of blockchain technology in a banking setting, and that Cocco et al. (2017) looked into the opportunities and challenges of implementing blockchain across banking with a focus on cost savings and energy efficiency. In contrast, our paper evaluates the overall opportunities (briefly noted above) and the related challenges from the banking industry's view point by relying on both industry and academic research into the subject. Also, to the best of our knowledge, this paper is the first and most comprehensive review of blockchain in banking to date, covering both industry and academic research into the subject area with over 100 articles and publications being reviewed and summarised for the reader.

As this review is being undertaken, the banking industry is making significant strides into the blockchain. Bank-based blockchain projects are expected to transform the financial services industry and IBM-backed Hyperledger Fabric project, the Utility Settlement Coin, and R3s blockchain consortium are few such examples (Harsono, 2018). The forex settlement giant CLS has partnered with IBM in creating a blockchain app store for banks which is now in its final testing stages and is expected to standardize global forex markets and reduce costs (Partz, 2018a; Allison, 2018). However, there is also evidence of resistance towards the adoption of blockchain in banking. For example, whilst Visa is exploring the possibilities with distributed ledger technologies, its Chief Executive Officer stated that they do not currently see the potential for blockchain in its core business (Kulkarni, 2018). Other banks are opting to embrace the cloud at the expense of blockchain technology for the time being (Noto, 2018). Given the alternating views, it is interesting to consider Deloitte's (2017) four scenarios (Figure 2) on how blockchain could develop in future along what Deloitte considers to be two key variables: "trust in the established system" and "overcoming technical hurdles".

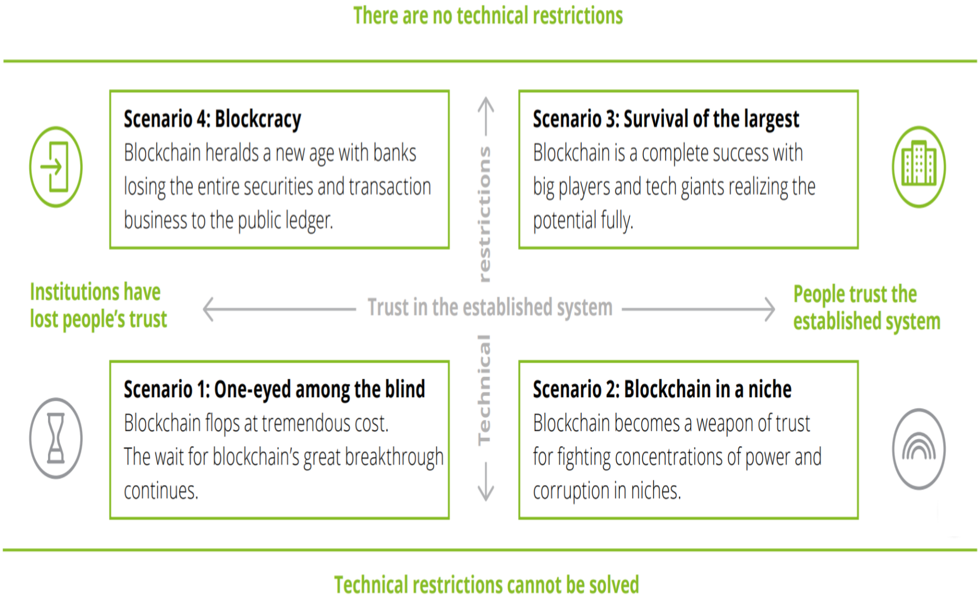

Figure 2: The future of blockchain according to Deloitte (2017).

In the next section we present the reader with details on the blockhain-ed opportunities in banking and follow this up by identifying the existing challenges. Thereafter, we consider a discussion around blockchain-ed big data and show the importance of filtering and signal extraction for banking big data beyond the blockchain age. Finally, we present some concise conclusions for the future of blockchain in banking.

2 Blockchain-ed Opportunities in Banking

2.1 A Better Way to Know Your Customer (KYC)

Verifying the authenticity of consumer identities is a frequent and important task for banks owing to anti money laundering regulations (Sarnitz and Maier, 2017). Given the ever increasing problems of terrorism, KYC is a crucial aspect related to the prevention of criminal use of banking funds and services in the form of money laundering and terrorism (Marr, 2017). However, KYC also represents a significant cost for banks with Thomson Reuters (2016) estimating that financial institutions spend between 60 million - 500 million USD per annum to keep up with KYC. Therefore, the current KYC processes are not only expensive, but also inefficient and feeds towards poor customer experience for banks (Walker, 2018). In addition, 4th EU Money Laundering Directive requires consumer data to be monitored and constantly updated (Wolos, 2017) whilst the General Data Protection Regulation (GDPR) requires strict internal controls pertaining to consumer security (Walker, 2018).

As such, blockchain technology, if implemented correctly for KYC can be extremely useful. This is because, the use of blockchain technology can do away with the need for filling out endless KYC questionnaires when opening a bank account (Sarnitz and Maier, 2017). An example of a blockchain based KYC process in banking is demonstrated via Figure 3.

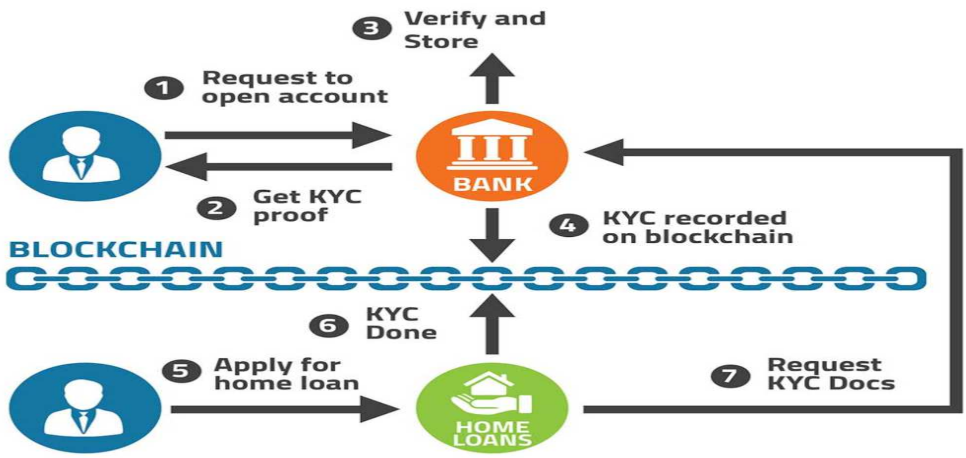

Figure 3: An example of a blockchain based KYC process (Persistent Systems, 2018).

As Lang (2017a) states, blockchain can enable banks to share customer information across their company securely and thereby simplify the administrative process by reducing unnecessary duplication of information and requests. Blockchain helps cut down on duplication as it can allow the independent verification of one client by one bank to be accessed by other banks (Marr, 2017). Standardized sharing of customer account opening information using blockchain creates a single non-editable KYC record further demonstrating compliance with regulations (Walker, 2018). To this end, recently, several banks completed a KYC app test on the R3 blockchain platform (Partz, 2018b) whilst a major Polish bank, PKO BP started using a blockchain-based document management system earlier this year (Biggs, 2018). Yet another emerging trend is the increasing importance of inclusivity across sectors. Blockchain technology could also be a means of enhancing inclusivity in banking as consumers who do not have a credit score can create a verifiable, decentralised, self-sovereign digital identity and thereby gain access to banking services (Garcia, 2018a). As Luu (2017) asserts, efforts to KYC are more important today than ever before as decentralization of cryptocurrencies opens it up to the risk of money laundering and terrorism financing.

2.2 Improved Transaction Speeds

You thought digital payments were fast? The use of blockchain technology can enable banks to speed up the time to settlement through the certainty it provides by enabling individuals and corporations to transact directly and view the same ledger of transactions updated through consensus and made immutable through cryptography (Lang, 2017a). In fact, Tapscott and Tapscott (2016) notes that settlement times can be cut down to minutes or seconds via blockchain technology whilst Ho (2016) alerts us of the possibility of processing bank transaction 24/7.

Decentralising via blockchain speeds transactions further as it can enable buyers and sellers to deal forex in real time in addition to doing away with the need for intermediaries for processing transactions (Hillsberg, 2018). Moreover, traditional banking practices and local banking standards dictate various necessities for financing which results in significant delays in completing a single transaction (Lowry, 2017). Blockchain allows trade partners to interact with greater trust by using a shared version of the truth about transactions in real-time and thereby increasing efficiency with regard to access to funding and saving time throughout the trade process (Smith 2018a; Lang 2017a).

Companies like Ripple (`https://ripple.com/`) are completing cross-border payments today in seconds (Sarwar, 2018) but SWIFT is competing rapidly without blockchain technology by showing that nearly 50% of gpi payments are credited to end beneficiaries within 30 minutes, and almost 100% of payments within 24 hours (Wass, 2018). As the average transaction rates have reached 1000 to 2000 transactions per second (TPS) for blockchain technologies, Miyamae et al.(2018) proposed a more efficient application programming interface between containers and achieved a transaction rate improvement by 86%. Asian banks are also exploiting blockchain with banks in India turning to blockchain to speed up internal trade deals (Satija and Antony, 2018). Furthermore, Mitsubishi UFJ Financial from Tokyo is to launch a 10 million transactions per second blockchain payment platform in 2020 (Asia Times, 2018) whilst more recently, Takahashi (2018) noted that Liqueneqs blockchain bank payments scales to millions of transactions per second for both commercial and consumer purposes.

However, not all authors agree that blockchain will be the answer to improved transaction speeds. For example, Marr (2018) highlights that the complex, encryption based and distributed nature of blockchain transactions can take a considerable amount of time to process when compared to traditional payment systems, and therefore requires more advances in engineering and processing speeds which leads to several challenges which are considered later on.

2.3 Enhanced Security

Security is of paramount importance to the banking industry. As Tapscott and Tapscott (2017) stated, 45% of financial intermediaries are experiencing economic crimes in comparison to the 20% and 27% for the professional services and technology sectors. Therefore, applying blockchain for extra sense of security is a critical component of the future digital banking model (Maiya, 2018). Blockchain can offer enhanced security for banking data as historical information cannot be altered and the new information which is added in real-time is essentially shared by multiple entities and thus making it difficult to manipulate the data (Garcia, 2018b; Harsono 2018). As Patel (2018) points out, any alterations to data within a block can be tracked and monitored to prevent fraud and misuse and more importantly blockchain technology allows for real-time communication and updating on potential scams (Patel, 2018).

Blockchain is also affecting the antecedents of trust including confidence, integrity, reliability, responsibility and predictability (Beck, 2018). The transparency in blockchain's distributed ledger is also useful as it would enable regulators to easily scrutinize financial actions (Tapscott and Tapscott, 2016). As a trust network, consumer data stored via blockchain can only be accessed by trusted sources in addition to the data security attainable via the encryption capabilities of blockchain (Patel, 2018). Blockchain can also achieve simultaneous security and privacy by enabling confidentiality through "public key infrastructure" and by maintaining the size of a ledger (Schou-Zibell and Phair, 2018).

Since the 2008 financial crisis, there has been a surge in the importance of risk management and the development of risk management capability (Silva et al., 2013). Furthermore, loan asset integrity is identified as a major problem leading to the 2008 financial crisis (Moore, 2018). To this end, the adoption of blockchain in banking can enable low risk credit transactions. For example,the Global Debt Registry (`https://www.globaldebtregistry.com/`) is evaluating the use of blockchains to ensure the integrity of loan assets and protect pledged assets on the network from errors or misrepresentation in the future (Moore, 2018). Assets can be placed on the decentralized ledger which will generate an immutable record of each asset, enabling all participants in the lending ecosystem to trust and be certain they are looking at the same loan data (Moore, 2018; Tapscott and Tapscott, 2016).

Fraud reduction is another form of enhanced security offered by blockchain technology.

Risk.net (2017) recognised fraud as one of the top operational risks in 2017 whilst PwC (2014) notes that 45% of financial intermediaries suffer from economic crimes each year. The centralised nature of banking systems make it more vulnerable to cyber attacks as it has one point of failure, unlike with blockchains which are less susceptible to fraud as each block contains a timestamp and holds batches of individual transactions with a link to a previous block (Marr, 2017). In India, there is an interest in evaluating whether blockchain technology can be a means of stopping bank frauds (D'souza, 2018). As Mauri (2017a) asserts, the distributed, immutable and permissioned nature of blockchain will help prevent fraud. In fact, Chiles Santiago Exchange plans to use blockchain to technology to reduce errors and possible fraud in its short selling system for securities lending (Mauri, 2017b). In addition, the UAE's Emirates Islamic was the first Islamic bank to adopt blockchain technology to issue new cheque books as a means of fraud prevention (Lyon, 2017) whilst the Bank of Thailand too is considering blockchains as a means of fraud reduction (Yakubowski, 2018). The recent Facebook data scandal has heightened the case for data privacy and blockchain can support this process as data can only be shared or sold with the consent of the individual (Garcia, 2018a). Technology giants such as Microsoft (2008) are also researching into developing 'Corda' an enterprise-grade ledger that enables banks to limit who sees what information and selectively share data with only relevant parties as a means of reducing the risk of fraud. They also envision their efforts can lead to reducing many other forms of banking risks in future.

Nevertheless, it is noteworthy that whilst many authors harp on the immutable nature of blockchains, Schou-Zibell and Phair (2018) note that blockchains are technically prone to modification. As such, the challenges pertaining to the security aspect of blockchain are discussed further in what follows. Nevertheless, security expert Frank Abagnale is of the view that blockchain is the future of secure information processing and data settlement (Marinova, 2018) and English (2018) notes that while blockchain is not immune to all forms of cyber risk, its unique structure provides security capabilities not present in other legacy technologies. This is because, the distributed nature and computing power required to make changes renders modification nearly impossible. In fact, altering a blockchain requires control of more than 51% of computers in the same distributed ledger and alteration of all of the transactional records within 10 minutes for Bitcoin (Schou-Zibell and Phair, 2018). Those interested in more insights into how blockchain is impacting the security landscape in banking are referred to Gupta (2017).

2.4 Cost Reductions

Economics will always play an influential role in the adoption of technology, and its no different when it comes to blockchain technology. The banking sector will have to consider a cost/benefit analysis to determine the feasibility of implementing blockchain. First and foremost, the enhanced trust made possible by blockchain can reduce friction that comprises all kinds of direct and indirect costs and efforts due to the lack of trust, and bring certainty via transaction logic instantiated as code (Beck, 2018). MacDonald et al. (2016) summarized that the permission-less and non-territorial features of blockchain can significantly reduce the institutional exit costs. In brief, Accenture (2017) concluded that blockchain can result in dramatic costs savings for banking along the lines of 8 billion USD whilst a 2016 Goldman Sachs report (as cited by Garcia (2018b)) suggests that blockchain technology could save financial institutions between 11 and 12 billion USD per annum via reductions to the number of mistakes that result in fees and higher operating costs. According to Santander, blockchain-based solutions could generate cost savings of up to 20 billion USD per annum (Meola, 2017).

In addition, settlement periods resulting from traditional banking processes cost the financial industry between 65-80 billion USD per annum and blockchain has the potential to reduce or even eliminate settlement times (Harsono, 2018). Further cost reductions are made possible by doing away with the need for intermediaries (Marr, 2017) and their associated charges when completing bank transactions in a world where global enterprises could pay up to 25USD for an international transaction (Hillsberg, 2018). The ability to share information openly across banks via the blockchain system would also significantly reduce administrative costs for compliance departments (Marr, 2017). Those interested in a more detailed discussion on cost savings from blockchain for banking are referred to Cocco et al. (2017), and Nguyen (2016) for an outlook from the sustainable development perspective. Below, some practical examples of cost reductions made possibly by blockchain are presented.

IBM's blockchain app store (LedgerConnect) is a sound example of how blockchain can help reduce back-end costs for banks by providing financial companies access to seven vetted blockchain vendors enabling banks to streamline their trading processes and back-end operations by establishing one set of records (Garcia, 2018b). There is also evidence that the ICICI Bank and Emirates NBD are researching into the use of blockchain technology for reducing transactional costs (Higgins, 2016). Furthermore, banks can reduce infrastructure costs by 30% using blockchain technology, which translates into savings of 8-12 billion USD annually (Ngo, 2017). Finally, the Central Bank of India estimates cost reductions between 15-20 billion USD by 2022 via the use of blockchain for interbank transactions (Richter, 2018). Banks can also seek to integrate fintechs as service providers and this will prevent costly interaction efforts (Drasch et al., 2018). Therefore, it is evident that significant cost reductions are attainable through the adoption of blockchain technology, however, the challenges around investments required for setting up the systems are discussed later on.

2.5 Smart Contracts

Contracts are complex and time consuming affairs in the financial world. Blockchains can be used to create smart contracts by programming and storing a computer code that can be executed to create contracts or authorise financial transactions once two or more parties enter their keys and meet a certain set criteria (Marr, 2017). Figure 4 below summarises the process underlying smart contracts. The Accenture Technology Vision (2018) report found 60% of all surveyed executives believing that blockchain and smart contracts would be critical over the next three decades.

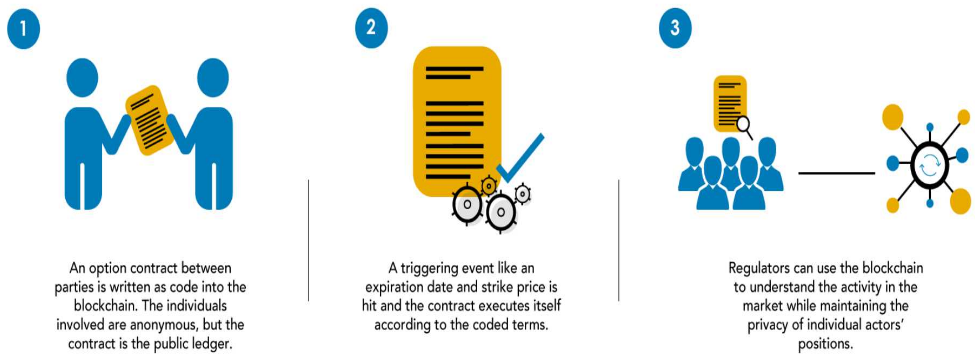

Figure 4: Smart contracts simplified (Institute of International Finance, 2016).

There is evidence of the banking sector already exploiting smart contracts. For example, Gatteschi et al.(2018) has systematically analyzed the implementations of blockchain based smart contracts in insurance and finance. Furthermore, a smart contract for travel insurance and automatically issuing refunding was developed based on the Ethereum blockchain by Bertani et al. (2017) whilst the Commonwealth Bank of Australia exploited smart contracts with blockchain technology to monitor and track the shipment of 17 tonnes of almonds (Mittal, 2018). However, as Sarnitz and Maier (2017) argue, smart contracts could make the role of banks in contract management redundant in future. Thus, banks must look into ways in which it can exploit smart contracts and the related technology to its benefit and one such option would be to become the provider of the said facility. Those interested in more details around blockchains and smart contracts are referred to Alharby and van Moorsel (2017).

2.6 More Transactions with More Transparency

As it stands, there is considerable disagreement within the banking industry with regard to the transaction capacity of blockchain technology. As a result, this issue is both an opportunity and challenge (discussed later on). Currently, Visa's transaction capacity is at 20,000 TPS, but research and development into Ethereum's Plasma multi-child-chain solution blockchain technology has the potential to enable 1 million TPS (Cook, 2018a). In addition, Japans Mitsubishi UFJ Financial Group (MUFG) is also competing with Ethereum by researching into a blockchain-based financial-transaction solution capable of conducting over 1 million TPS (Cook, 2018a). More recently, the South Africa Reserve Bank used blockchain technology to settle the country's typical 70,000 daily payment transactions within two hours (average settlement rate of 1-2 seconds per transaction) while preserving full anonymity (Zhao, 2018a).

Transparency is an increasingly important consideration along side the increase in transaction capacities. Whilst the traditional banking system is extremely secretive, blockchain technology presents means of making the entire banking process more transparent and secure as it locks records and then enables users to access the full historical data with possibilities of giving authorised parties only access to shared transaction ledgers (Hillsberg, 2018). Moreover, any changes made to public blockchains are publicly viewable by all parties (Ho, 2016). In fact, as Tapscott and Tapscott (2016) asserts, blockchain technology can lower or even eliminate the need for trust in transactions and make auditing transparent and real-time. It is also promising for automating financial reporting (Collomb and Sok, 2016) and the transparent nature of blockchain allows banks and regulators to communicate in real-time and enables swift action when compliance violations take place (Patel, 2018).

3 Blockchain-ed Challenges in Banking

3.1 Costs and Standardization Requirements

Developing a blockchain enabled system is a high cost affair, and if the banking industry is to make the most of the system, then it should be standardized across banks (Walker, 2018). For example, for KYC information to be usefully shared across the banking industry, a common policy on identification and verification of consumers is mandatory (Walker, 2018). As Clarence-Smith (2018) asserts, KYC blockchain-based registries are unlikely to get buy-in from all banks because of their wariness about relying completely on third party verifications of data.

As it stands, each bitcoin transaction costs about 0.20 USD and can only store 80 bytes of data (Bauerle, 2018). The lack of harmonized industry standards (Schou-Zibell and Phair, 2018), unless addressed, will be a major hindrance to the adoption and development of blockchain in banking. Bech and Garratt (2017) proposed the money flower taxonomy of money, where the central bank creates its own cryptocurrency. To this end, the Bank of Canada is validating the implementation of a digital currency CAD-coin for the use of interbank transfers (Iansiti and Lakhani, 2017).

Another concern is the energy cost required to power blockchain algorithms. If we take Bitcoin as an example, Galeon (2017) pointed out that the energy required to mine bitcoin is equivalent to more energy than what 159 countries consume in a year. In fact, if cryptocurrencies were to grow to 5% of global money supply, it is estimated that the processing would require 10% of the energy consumed by China (Caplen, 2018). Moreover, as a result of electricity costs, the single transaction cost for Bitcoin can vary between 75-160 USD (Bloomberg, 2018).

The cost of storage is yet another growing concern for blockchain technology in banking with some estimating that the long-term storage cost per gigabyte for a Bitcoin node will exceed 22 million USD or more (Bloomberg, 2018). There is also a cost in terms of lost revenue for banks. This is because blockchain technology threatens the livelihood of middlemen and banks make huge profits playing this role (Marr, 2018). However, to support the wide adoption of blockchain, e-identity validation services will be crucial, for which, the banks may still be able to take significant role as a trusted organization (Buitenhek, 2016). Therefore, the question remains as to whether the cost reductions from adopting blockchain technology can in fact outweigh the operating costs of maintaining same.

3.2 Currency Stability

Bankers are not open to the use of bitcoin as a currency (Hillsberg, 2018). One major concern for the adoption of blockchain payments in banking is the stability of the underlying currency, especially as the cryptocurrency market is extremely volatile (Luu, 2017). Currency stability is crucial for ensuring that neither the buyer nor the seller loses out in trade due to price fluctuations (Lund, 2018).

Instead of regular crytocurrencies, Lund (2018) suggests a 'stable coin' which is basically a digital token that will have low price volatility as a result of being pegged to some underlying fiat currency, thereby acting as a store of value, a medium of exchange and unit of accounting for blockchain payments. An example of a stable coin is Stronghold USD (Corradino, 2018) which is backed by USD deposits and is currently undergoing research and development at IBM as a credible token for blockchain payments (Lund, 2018). Another example is the digital coin called utility settlement coin backed by six of the world's largest banks with the aim of allowing financial groups to pay each other or to buy securities without waiting for traditional money transfers to be completed (Arnold, 2017; Harsono, 2018).

3.3 Security

The security element features as both an opportunity and challenge for the adoption of blockchain in banking. It is no secret that banking requires high security. Historically, banks had to only be concerned with protecting their safes and deposits in high street banks. The move to online banking saw the emergence of a new security threat from hackers around the globe, thus creating a job market for cyber security and increased costs for banks. In the recent past, cyber attacks have resulted in losses of 100 million USD in the banking sector and therefore, banks are cautious with regard to letting its financial data sit outside their secure firewall (Hillsberg, 2018).

As a security measure, miners can verify daily records in the blockchain, but given that transactions are irreversible, manual data entry errors can prove extremely problematic (Hillsberg, 2018). Satoshi Nakamoto highlighted the '51% attack' which means if half of the computers working as nodes to service the network tell a lie, the lie will become the truth (Bauerle, 2018). Data privacy too remains a concern within blockchain technology as transactions can be seen throughout network nodes which produce meta data leading to pattern recognition (Schou-Zibell and Phair, 2018). However, "self-sovereign identity" which allows consumers to control personal information and have better control over with whom they share it is an emerging solution to the privacy concerns (Schou-Zibell and Phair, 2018). Also, it is noteworthy that blockchains are more secure than a centralised system in many ways (Schou-Zibell and Phair, 2018).

Another security challenge posed by blockchain is anonymity. As blockchain technology allows for anonymity, such untraceable transactions would threaten the banking sector and the regulator as it increases the difficulty to tax and can also aid criminals with money laundering (Cook, 2018a). For retaining privacy to its maximum extent, there are cryptographic techniques like zero knowledge proofs, which allows the block verification and transaction correctness without providing visibility into the details of the transactions (Eyal, 2017). As a possible solution, more countries are moving towards crypto and Initial Coin Offering (ICO) legislation (Cook, 2018b; Cook 2018a).

3.4 Legislation & Regulations

In an early review by Guo and Liang (2016), the authors addressed the significance of establishing a regulatory sandbox, so that the implementation and operation of blockchain will have a restricted scope and still maintain sufficient space for innovation. Red tapes associated with Central Bank rules and bank secrecy regulations are adversely impacting the adoption of blockchain in banking with government intervention likely to be blocked further by lobbyists battling against this disruption (Hillsberg, 2018). The General Data Protection Regulation (GDPR) and other privacy laws too hinder the full exploitation of blockchain technology in banking. A recent report suggests that regulators are now working with banks to develop more blockchain friendly regulatory frameworks (Kocianski, 2018) whilst other authors are urging Central Banks to start adapting to blockchain technology (Thew, 2018). However, as Iansiti and Lakhani (2017) stated, every party of monetary transactions will be required to adopt it, which challenges the government and institutions that have been overseeing and managing these transactions for a long time.

3.5 Scalability

It is agreed that as it stands, blockchain has very limited transaction capacity (Caplen, 2018). In fact, limited scalability is one of the serious concerns underlying blockchain technology (Schou-Zibell and Phair, 2018). Bitcoin was built to be decentralized and secure at the expense of scalability (Tomaino, 2018). This is formally referred to as the "scalability trilemma" in which only two of three properties decentralization, security or scalability can be attained (Schou-Zibell and Phair, 2018). Therefore, more research and development is required for enhancing the scalability of the blockchain technology to process more transactions than Visa for a start.

There is also disagreement between the actual scalability of blockchains as Thew (2018) states, currently, the bitcoin blockchain can only process 7 TPS whilst Caplen (2018) states bitcoin can process only 3-4 TPS in relation to Visa's 4500 transactions per second. Furthermore, some Central Banks like De Nederlandsche Bank is of the view that distributed ledger technology is not suitable for existing financial payment infrastructure owing to scalability restrictions for large volumes of transactions (Zhao, 2018b). Therefore, the scalability issues, when coupled with the energy concerns, suggests that blockchain is more suited to wholesale banking solutions than the mass market (Caplen, 2018).

4 Discussion

The big data trend keeps getting bigger and blockchain will further add to increasing the size of big data in banking, as well as influencing the exchanging or trading platform for big data (Chen and Xue, 2017). Therefore, any blockchains used in the banking sector will need the software and infrastructure to handle big data as never seen before (Marr, 2017). Whilst blockchains are likely to result in more structured big data, the analysis would have to overcome significant issues pertaining to increased signal and noise ratios which are already a problem in pre-blockchain era big data (Hassani and Silva, 2015).

This in turn means that investments into research and development of denoising and signal extraction in big data is likely to be a worthwhile investment for the banking sector. As an example, we consider the number of Bitcoin transactions added to the mempool per second (`https://www.blockchain.com/charts/transactions-per-second`) as a proxy for banking blockchain transactions in future. This is a reasonable assumption given that the entire globe could be transacting on blockchain in future should the banking industry exploit the opportunities and overcome the aforementioned challenges. The proxy time series captures data for 1680 seconds from 26th July 2018 to 2nd August 2018 and is represented via the first time series in Figure 5. Here, we rely on a filtering and forecasting technique called Singular Spectrum Analysis (see, Hassani and Silva (2018), Silva et al. (2018) and Hassani et al. (2017), and references there in for recent examples of applications) to denoise and extract signals underlying Bitcoin transactions on the blockchain. Note that in Figure 5, SSA(L,r) refers to the Singular Spectrum Analysis (SSA) choices of window length L and number of eigenvalues r used to filter and reconstruct the Bitcoin transaction data.

As evident, the original time series is considerably noisy with outliers affecting the distribution over time such that the true signal is hidden from the naked eye. We apply SSA to denoise the series and initially extract a smoothed signal (trend and periodic fluctuations) from the raw transaction data. Note how the SSA(480,1-4) decomposition and reconstruction enables the reader to clearly see the underlying trend patterns and periodic fluctuations in bitcoin transactions every second. It is noteworthy that the outliers visible in the raw time series are no longer part of the filtered transaction series. This in turn allows for better decision making and planning as the banking system will be able to identify the times and periods corresponding peaks and troughs in blockchain transactions and thereby achieve more efficient programming of systems and energy-related resource allocations to ensure no outages or slowdowns occur during transaction peaks whilst allowing for better energy allocations during the less busy periods. In the bottom half of Figure 3, through the SSA(480,1-13) graph, we include further signals to the initially filtered smooth series to provide a better indication of the actual bitcoin transaction movements each second and the final graph, SSA(480,14-480) shows the noise that was extracted using SSA. It is evident that the outliers are now filtered out as noise, thereby reducing the random elements in the data and enabling far more accurate decision making. Moreover, such denoising efforts would also help banks to improve the forecasts of future movements in blockchain transactions as the random elements (noise) are reduced, thereby enabling forecasting models to produce a better fit to the data.

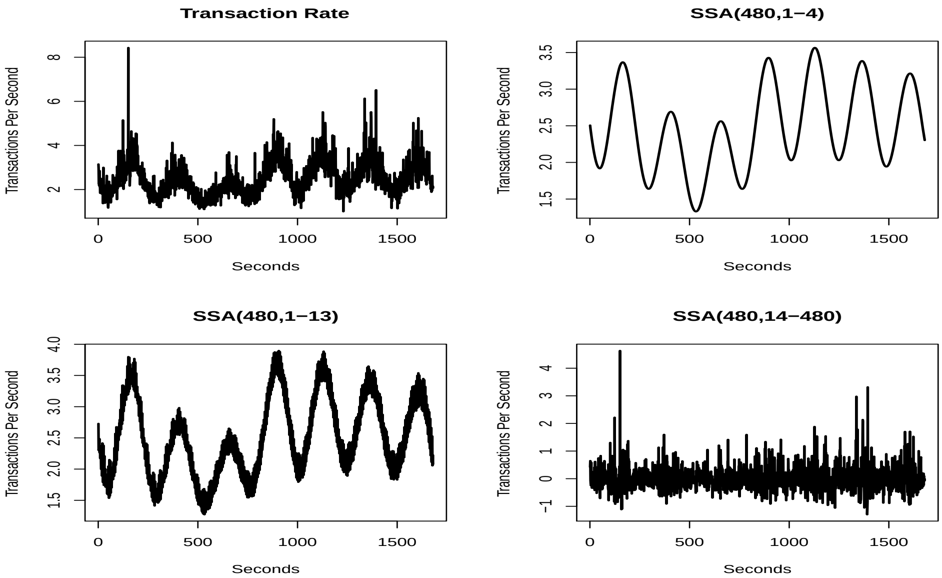

Figure 5: Denoising the blockchain transaction rate per second (26th Jul 2018 - 2nd Aug 2018).

5 Conclusions

Following the disruption in banking as a result of big data, blockchain has taken control of the process and it is not only creating several opportunities, but also threatening existing business models in banking. For some, blockchain is as revolutionary as the internet, whilst for other it is overhyped (Caplen, 2018) or seen as a threat to traditional banking operations. This paper begins by briefly summarising the evolution of blockchain in banking and our research uncovers a lack of academic interest in this subject area, in comparison to the interest shown by researchers in other sectors. In hope of encouraging more research and development into blockchain-ed big data in banking, we review over 100 articles (mainly industry related and few academic) and present the opportunities and challenges related to the adoption of blockchain in banking, from a bankers point of view.

We find enhancements to KYC processes, transaction speeds, and security, and cost reductions, smart contracts, transparency and the potential to increase the number of transactions a bank can process as the key opportunities. In contrast, we also find setup and operating costs, standardization requirements, stability of the currency, security (which is interestingly both an opportunity and challenge in some aspects), legislations and regulations, and scalability to be the key challenges faced by banks looking into adopting blockchain technology in the modern age. Whilst majority of these challenges could be overcome through extensive research and development, the lack of academic research based interest in this subject area is of concern. It is expected that this review can act as a means of easily identifying existing research gaps for blockchain-ed big data in banking and thereby motivate more academics, researchers and bankers to delve into this subject area and find solutions to the challenges at hand whilst improving upon the existing opportunities.

As part of the discussion element, we also consider the importance of filtering and signal extraction techniques to the banking sector in future. Using real data as an example, we illustrate how the banking sector could benefit from knowledge and research into filtering and signal extraction in big data as it seeks to adopt blockchain technology and expand its operations.

In conclusion, it is clear that there is a lack of consensus within the industry with regard to the feasibility and usefulness of blockchain in banking. However, the opportunities presented can easily outweigh the challenges the moment the industry reaches agreement on how best to move forward and the regulator recognizes the benefits this disruption can have on banking around the globe. Big data is here to stay, and so is blockchain technology. In an age where innovation determines survival in a highly competitive and volatile market, banks must choose whether they will innovate and bank with blockchain-ed big data or risk being left behind and lose the competitive edge in a rapidly progressing technological environment.

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