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Review

Fantastic Beasts: Blockchain Based Banking

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Abstract: Blockchain is one of the primary digital technologies utilised in the finance industry with huge future potential. This study conducts a systematic literature review of a final sample of 407 prior literature from an initial set of 1979 records for the sample period of 2013–2020 with regard to blockchain adoption in banking. This review is further supplemented by a machine learning based textual analysis that identifies key themes, trends, divergences and gaps between academic and practitioner led industry literature. Moreover, the study highlights present, future use cases, adoption barriers and misconceptions of blockchains in banking, especially given COVID-19. Furthermore, this study identifies behavioural, social, economic, regulatory and managerial implications of blockchain based banking. In addition, our study identifies the cross-industry potential of blockchains via banking, thus, linking much disconnected prior literature. Finally, we develop a blockchain adoption framework and an adoption life cycle for banking. This study would be of interest to academics, bankers, regulators, investors, auditors and other stakeholders in financial markets.

Keywords: fintech; disruptive technology; financial services; banking; COVID-19; cryptocurrencies

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1. Introduction

Banks and payment services have been around for centuries and predate modern capitalism (Ferguson 2008; Hodgson 2015). Fintech is defined as "products and companies that employ newly developed digital and online technologies in the banking and financial services industries" (Aggarwal and Stein 2016). Blockchain (BC) is one of these key innovative technologies (Biais et al. 2019). Blockchains are distributed ledgers that can maintain, secure verifiable records and proof of transactions, reducing double spending of tracked transactions. However, even with an abundance of prior literature on general blockchain characteristics and applications, plethora of literature on cryptocurrencies, there is limited understanding of blockchain based applications and their regulation and governance specific to banking. In addition, during COVID-19 crisis, China is leveraging blockchain in the country's COVID-19 recovery. The Blockchain-based Service Network (BSN) developed by China is estimated to decrease blockchain-based business transaction costs in China by 80% (World Economic Forum 2015). Moreover, The People's Bank of China is in the process of implementing a digital yuan with many other Central banks entertaining digital currency options. Hence, research, especially regarding blockchain adoption in banking is becoming more significant as countries worldwide follow suit to aid businesses and banks transform digitally. Blockchains may have significant potential in many industries including the financial services sector (Adhami et al. 2018; Athwal 2016). However, as addressed in our study, it is also important to understand its limitations, adoption challenges, misconceptions, social, ethical, economical and legal impact. Prior literature is proliferated by media articles, cryptocurrency related research and focus on most popular general financial or cross industry applications of blockchains. Thus, identifying industry and academic literature with some relevant factors for banking can be challenging. Moreover, collating scattered literature on blockchain in a coherent manner for better understanding for future research, collaborations with the industry, and to identify gaps underexplored by prior literature remain important.

Given this setting, the purpose of this study is to develop new insights into blockchain adoption in banking by systematically reviewing a final sample of 407 prior studies (out of an initial set of 1979 records) for the sample period of 2013–2020. Moreover, we provide a behavioural view of blockchain based banking in terms of social, ethical, economical and legal impact on financial markets and stakeholders. In addition, we discuss present and future use cases, impact and challenges regarding blockchain adoption in banking. Furthermore, our study identifies similarities, trends and gaps among academic and practitioner led prior literature. Finally, we develop a framework for blockchain adoption in banking and discuss adoption potential during and post COVID-19. Our study sourced articles from key databases such as Science Direct, Scopus, and Business Source premier which allows us to include both high and low tiered journal articles along with vital industry sources such as premier IT and business media outlets. Lower tiered journal articles and industry sources are important as often they provide key novel trends and important developments regarding blockchains. In addition, our systematic review collates articles relevant to blockchain from information systems, supply chain management, accounting and taxation that can be linked via banking. We further highlight potential future cross disciplinary research in these fields that can be connected via banking.

Our research questions are as follows: 1. What are the present and future blockchain use cases in banking? 2. What are the gaps, similarities and trends between academic and industry literature in blockchain adoption in banking? 3. What are the behavioural, social, economic, regulatory and managerial implications of blockchain adoption in banking? 4. What are the barriers and misconceptions for blockchain adoption in banking? Our study would support interested stakeholders to effectively collaborate and identify over- and underexplored applications of blockchain adoption in banking. Furthermore, this study would be of interest to academics, industry practitioners, investors, regulators, professional bodies, governments and large multinational organisations.

Key results of the study include the following: 11 key domains are identified through our systematic review. These 11 domains include 1. BC governance, 2. Corporate voting and BC, 3. Cryptocurrencies. 4. Exchanges and BC, 5. Payment systems and BC, 6. Trading and BC, 7. Smart contracts, 8. Data management and BC, 9. Disruptive technologies, 10. Fintech, 11. Miscellaneous. According to our systematic review, the maximum number of academic articles (99 studies) are observed in 2017, while only 21 are observed from the industry. However, the greatest number from articles for the industry (35 studies) is observed in 2016. Academic articles primarily focus on cryptocurrencies with 110 studies and the industry on fintechs (pertaining to blockchain technology) with 27 studies. Several domains such as corporate voting (12 studies in academia and six studies in the industry), trading (four studies in academia and eight studies in the industry) and exchanges (20 studies in academia and six studies in the industry) emerge as underexplored areas.

Our study differs from previous literature as follows: 1. This study conducts a systematic review of an extensive final collection of 407 out of 1979 articles. 2. Conducts a comparison between industry and academic literature on blockchains in financial services. 3. Uses machine learning based textual analysis to survey prior literature and further identify key themes and subthemes. 4. Identifies the behavioural, social, economic, regulatory and managerial impact of blockchain based banking. 5. Develops a framework based on prior literature for blockchain adoption in banking. 6. Discusses Artificial Intelligence (AI) integration with blockchain and potential impact during and post COVID-19.

This study is organised in the following manner: Section 2 provides the review of prior literature. Section 3 details the methodology. Section 4 identifies blockchain based banking uses cases, including blockchain integration with Artificial Intelligence (AI) and provides the results of our systematic review and blockchain based banking framework. Section 5 explores the impact of blockchain adoption in banking including impact during COVID-19. Section 6 identifies challenges and misconceptions of blockchain adoption in banking. Section 7 concludes the study.

2. Literature Review

Financial technology or 'FinTech', is the use of technology in the finance industry. Within fintech, blockchain is one such technology with considerable potential (Berg et al. 2019). According to (Balyuk 2017) technology innovations in the financial sector results in increased demand for credit without overborrowing. The entrance of large tech companies and fintech into the financial services sector will have huge implications to banks' business models, margins and the way banks operate (Accenture 2016). Given this setting, it is imperative to identify one of the primary fintech technologies such as blockchain, their present and future use cases, social, economic and regulatory impact in banking.

2.1. Blockchains in General

For successful blockchain adoption and sustainability in banking, it is important to firstly recognise the technology itself and its limitations. Then the bank needs to further consider the feasibility of such a project as mentioned in our framework. Blockchain is a peer-to-peer network, distributed ledger system (Evans 2014; Swan 2015) or database that maintains a list of transactions confirmed by connected nodes (mining nodes) with no third-party intermediary. Primarily known for its application in Bitcoin (Nakamoto 2008), blockchain features a distributed transactional database. Hacking into this network and altering a block would require significant computational power (Wood 2016). Another key decision on blockchain adoption is the selection of token or coin type. Any asset that is digitally transferable between two parties is called a token. These tokens are issued on an existing blockchain. Whereas, a digital coin is an asset native to its own blockchain (Liu et al. 2017b). For example, Bitcoin, Litecoin, or Ether all exist on their own blockchain. Choosing the appropriate blockchain platform also involves selecting certain protocols as mentioned in our framework. Moreover, miners or mining computer nodes is a key component behind blockchains (Asharaf and Adarsh 2017). They validate transactions in the network by solving cryptographic puzzles to reach a consensus ensuring security. Each time a puzzle is decrypted first, most likely by a miner with the greatest resources, a transaction is written to the block. The miner earns a reward, often in the form of bitcoins (Wright and De Filippi 2015). The puzzles that miners solve are called proof-of-work (PoW) (Nakamoto 2008).

Blockchain technology can be utilised for any asset that can be stored, transacted and distributed and thus, have great potential and implications for the financial services industry (Peters and Panayi 2016). Enhanced security and efficiency can benefit many sectors including banks. With decentralised ledgers, verification of each party in transactions would result in faster transaction completion. This would result in instantaneous settlement once the ledger is updated (O'Leary 2017). Thus, blockchains can enable secure digital asset (bonds and shares) transfers. In addition, with public blockchains, banks would be able to observe customer payment histories aiding lending decisions (Raskin and Yermack 2016). From a banking customer's perspective, blockchains provide transparency regarding internal mechanisms in transaction settlement and faster completion (Raskin and Yermack 2016).

Moreover, for blockchain adoption, the type of blockchain platform needs to be identified as being public or private. Blockchains are initially developed to be public networks with full transparency (Romānova and Kudinska 2016). Permissioned blockchains which exist in many banking use cases are, however, the opposite of this. Additionally termed private blockchains, only the selected agents are provided access to the blockchain (Carvalho 2020). Table 1 provides a summarised comparison of characteristics of public, private and federated blockchains.

Table 1. Public, private and federated blockchain characteristics.

Characteristic	Public	Private	Federated
Ownership	Public	Centralised	Partially centralised management
Management	Permissionless	Permissioned list	Permissioned nodes
Mechanism	All miners	Centralised organisation	Collection of leader nodes
Identity	Anonymous	Identified users	Identified users
Anonymity	Probably malevolent	Trusted	Trusted
Consensus	Costly PoW or PoS	Light PoW, multiple preapproved stakeholder/voting consensus.	Light PoW, multiple preapproved stakeholder/voting consensus
Immutability	Near impossible	Attacks with collusion	Attacks with collusion
Read/write access	Every node can read, write and validate transactions	Only authorised nodes read, write and validate transactions	All nodes can read, write and validate transactions
Network	Decentralised	Semi decentralised	Semi decentralised
Asset	Native asset	Any asset	Any asset
Efficiency of protocols	Low efficiency	High efficiency	High efficiency
Energy consumption	High energy	Low energy	Low energy
Approval time of transactions	In minutes	In milliseconds	In milliseconds
Use cases	e.g., Bitcoin, Ethereum, Litecoin	e.g., Hyperledger, Quorum, Corda	e.g., Ripple and Stellar

Furthermore, a key development of blockchains is Smart contracts (Szabo 1994), which is a software procedure that executes contract terms (Cheng et al. 2018). All the clauses in the contract are coded into the procedure and automatically executed when certain contingencies occur without being reliant on a central intermediary. Table 2 provides a summarised comparison between the traditional centralised and blockchain enabled banking systems with regard to efficiencies, costs, security and overall customer experiences, as identified by prior literature and industry reports.

Table 2. Comparison between the traditional centralised and blockchain enabled banking systems.

	Traditional Banking (In General)	Blockchain Based Banking
Efficiency	Many intermediate links, complex clearing processes, low efficiency However, centralised banking is capable of processing enormous amounts of transactions per second, which decentralised systems have yet to replicate successfully Countries such as Canada, Finland, Sweden are known to have the safest and China, U.S. and Japan the best performing banks as of 2020	Decentralised peer-to-peer transmission, high efficiency
Cost	Considerable paperwork, duplication of tasks and records, high operational and administrative costs, time consuming	Complete automation, disintermediation and low costs
Security	Centralised storage prone to hacks and failures, easy to leak sensitive information, low security	Distributed storage less easy to hack, complex encryption and higher security
Overall Customer Experience	Geographically limited, homogeneous services, limited customer experience	Geographically independent, new products and services, real time executions, good customer experience

Sources: Publicly available information sources, Bankers database, FintechFutures.com, CBI Insights.com (accessed on 18 October 2020) and BIS Quarterly Review, September 2017.

2.2. Blockchain and Banking

Why do banks exist and what impact would blockchains have on banking? Banks conduct asset transformation and store liquidity and utilise economies of scale providing services based on any storable asset (Bunea et al. 2016). They form a centralised intermediary, facilitating a myriad of marketplaces for stored assets for uses and sources of funding with different exit mechanisms for stakeholders (Coase 1937). Therefore, this view of banks can also be interpreted differently as a set of centralised ledgers of transactions for payments, storage, services revolving around assets for stakeholders involved (Frame and White 2014). Blockchains can decentralise these banking functions and provide more cost effective, efficient, transparent and secure banking solutions. Therefore, directly disrupting the banking business model (Bunea et al. 2016).

For example, fintechs (e.g., lendoit.com, accessed on 18 October 2020) using blockchain technology have implemented P2P lending platforms where sellers of capital are matched with buyers with minimum transaction costs. These fintechs are mimicking the two-sided market model for banks explained by Rochet and Tirole (2003) for matching excess capital savers with excess demand from borrowers in a decentralised manner. In our present and future use cases sections, we further explain additional areas of blockchain adoption in banking.

Presently, blockchains are utilised in a diverse array of banking applications including financial asset settlement, economic transactions, market predictions and business-related services (Haferkorn and Diaz 2015). Blockchain is anticipated to be central for sustainable global economic development in the future, benefiting society and consumers in general (Nguyen 2016). Several studies explore blockchain based applications developed for fiat currencies, securities and derivatives (Christensen et al. 2015; Fanning and Centers 2016; Peters and Panayi 2016; Paech 2017; Nijeholt et al. 2017). Blockchains provide significant innovation to financial markets with increases in efficiency and operational performance with regard to digital payments and settlement (Papadopoulos 2015; Min et al. 2016; Beck et al. 2016; English and Nezhadian 2017; Yamada et al. 2017; Lundqvist et al. 2017; Gao et al. 2018), derivatives and securities trading (Van de Velde et al. 2016; Wu and Liang 2017), commercial banking processes (Cocco et al. 2017), auditing (Dai and Vasarhelyi 2017) processes for loan management (Gazali et al. 2017), or digital currency exchanges, settlement and payments (Rizzo 2014; Cawrey 2014). Other financial applications include casualty and commercial claims processing, contingent convertible bonds, syndicated loans, automated compliance, asset rehypothecation, proxy voting and over-the-counter markets (McWaters et al. 2016; Deloitte 2016a; F.R. Ltd. 2016; Infosys Consulting 2016). Cost savings can be achieved by applications of blockchains such as centralised operations, reporting, compliance and business operations (Accenture 2017a, 2017b). However, regulatory uncertainty or the lack thereof, still remains an issue as discussed in Section 6. Shanaev et al. (2020) identify the relevance of regulatory frameworks for cryptocurrencies by analysing 120 regulatory events. They find economically and statistically significant impact from 300 tokens and coins of issuance and anti-money laundering regulation.

2.3. Blockchain Economics

Buterin (2015) states that the potential and economic value of blockchain is independent of Bitcoin value. Blockchains can be viewed as a decentralised database that is transparent and efficient (Bresnahan and Trajtenberg 1995; Lipsey et al. 2005). Blockchains can be utilised to disrupt any existing centralised transaction-based system with valuable information (Wright and De Filippi 2015). Although centralised databases are unable to compete with blockchains, regulation and initial investment costs might still be a deterrent for blockchain technology adoption from an economic point of view. Another feature of blockchain in banking is reducing exit costs for stakeholders. For example, blockchains can reduce the transfer or transition costs from one institution to another due to their permissionless nature (Thierer 2015). In our opinion, due to the nonterritorial global nature of the internet, they can allow stakeholders to partially exit the present institution. However, permissionless exit from a blockchain financial system cannot exist for functions where competing blockchain systems are unavailable. Although, it is worth noting that the initial transition from the traditional bank-based market to a blockchain based financial system will have costs (Pagano and Vatiero 2015). Competing set ups may arise among different banking consortiums such as R3 using different blockchain technologies bringing in interoperability issues, eroding frictionless blockchain enabled banking. Thus, Blockchains may be able to provide banking services uninhibited by geographical locations to some extent (Guo and Liang 2016).

The majority of blockchain related literature focuses on cryptocurrencies. Our focus is solely on blockchain adoption in banking and not cryptocurrencies. These literature focus on many cryptocurrency aspects such as price bubbles (Cheah and Fry 2015; Fry and Cheah 2016; Cheung et al. 2015; Corbet et al. 2018a; Gandal et al. 2018; Bianchetti et al. 2018; Chaim and Laurini 2019; Geuder et al. 2019; Kallinterakis and Wang 2019; Sifat et al. 2019; Xiong et al. 2019; Shu and Zhu 2020), Bitcoin price determinants and characteristics (Akyildirim et al. 2020; Ammous 2018; Beneki et al. 2019; Bianchetti et al. 2018; Bouoiyour et al. 2016; Cagli 2019; Caporale et al. 2018; De Sousa and Pinto 2019; Dwyer 2015; Corbet et al. 2018b; Corbet et al. 2019a, 2019b, 2019c; Flori 2019; Corbet et al. 2020a, 2020b; Handika et al. 2019; Hayes 2019; Fry 2018; Mensi et al. 2019; Ma and Tanizaki 2019; Nadler and Guo 2020; Nguyen et al. 2019a, 2019b; Panagiotidis et al. 2018; Phillips and Gorse 2018; Puljiz et al. 2018; Pyo and Lee 2019; Sensoy 2019; Urquhart 2016; Urquhart 2017; Su et al. 2018; Wheatley et al. 2019; Wei 2018; Van Vliet 2018; Zargar and Kumar 2019), Bitcoin futures (Akyildirim et al. 2019; Corbet et al. 2018c; Fassas et al. 2020).

However, we do identify the importance of such research and find that price bubbles and volatilities in cryptocurrencies are key barriers against wider adoption by banks as an alternative for fiat currencies. Jayasuriya Daluwathumullagamage and Sims (2020) discuss blockchains in corporate governance. Felix and von Eije (2019) and Dean et al. (2020) discuss initial coin offering related literature at length. Kyriazis et al. (2020) conducts an excellent review on bubble dynamics and cryptocurrency prices. They identify bubble periods for various digital currencies including Ethereum that effectively distort cryptocurrency prices. Symitsi and Chalvatzis (2019) find diversification benefits of including Bitcoins into a portfolio. Nguyen et al. (2019a) identify new altcoin creation reduced Bitcoin returns by 0.7%. This result is significant as Bitcoins obtain average and daily mean returns of 0.63% and 0.27%, respectively. Kumar et al. (2020) discuss blockchain based applications and future research in the marketing sector. Although the latter study is not related directly to banking, they still provide interesting insights into blockchain applications in marketing that would be of use within the financial services industry in general.

2.4. Blockchain Adoption Framework

Our blockchain adoption in banking framework is developed by identifying key domains/themes and subthemes from the systematic review and textual analysis. In addition, careful review of the final sample of articles is conducted to identify additional factors of interest for the adoption framework. The framework developed based on prior industry and academic literature is designed to help banks create a clear mission, achieve clarity, ensure value from their efforts, maintain scope and focus on blockchain adoption and sustainability in banking. This section defines the key domains and factors included in the framework. The framework is linked to our research questions 3: What are the behavioural, social, economic, regulatory and managerial implications of blockchain adoption in banking? and 4: What are the barriers and misconceptions for blockchain adoption in banking? by the key components included by analysing prior literature. Figure 1 outlines the adoption framework. The latter six components identified in our framework such as 'Blockchain governance factors', 'Barriers to adoption', relate to research question 4 and 'Limitations' and 'Stakeholders' relate to research question 3.

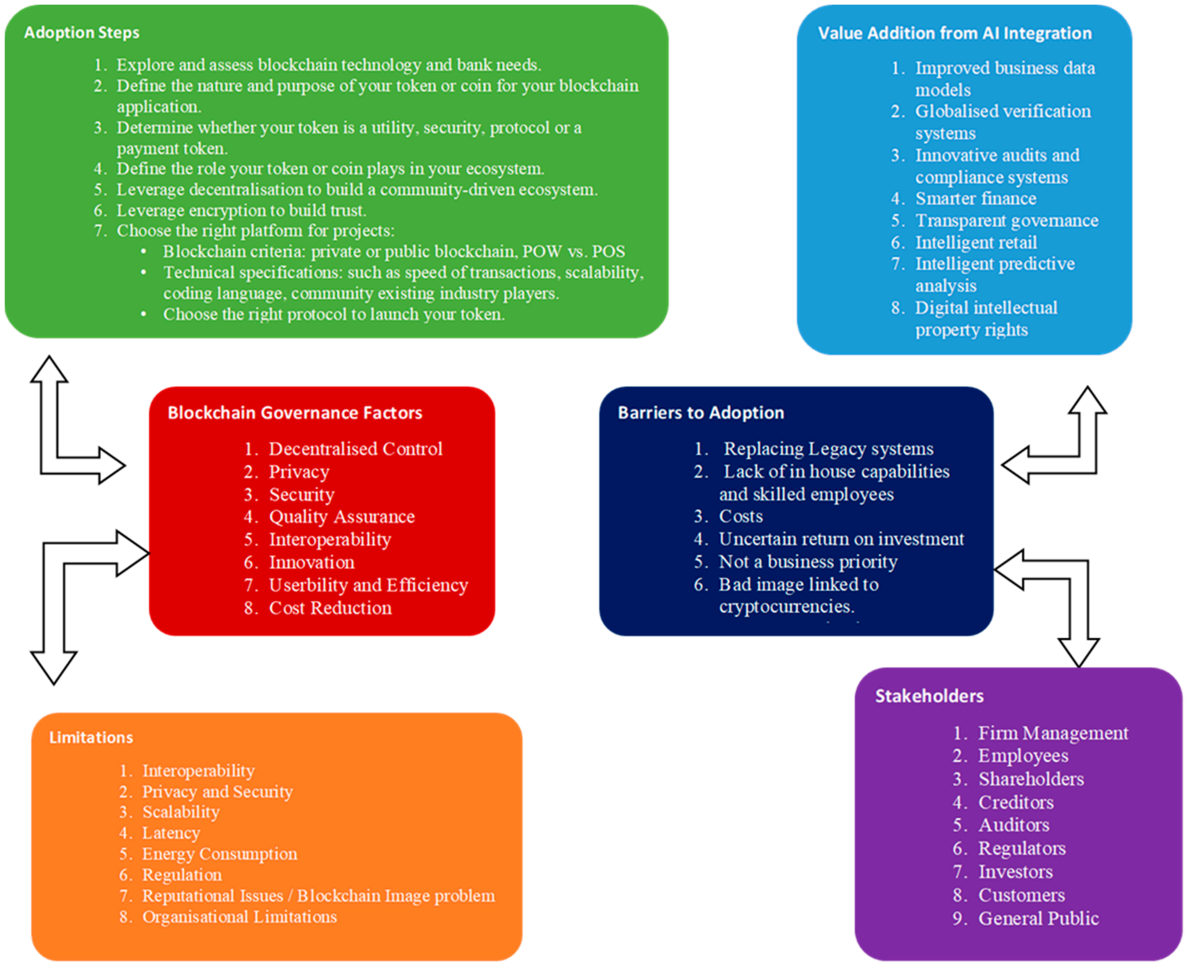

Figure 1. Blockchain adoption framework.

2.5. Why Use This Adoption Framework?

Most bank transactions revolve around the financial intermediation function of asset transformation, payment systems and the use of financial market exchanges (Brynjolfsson and McAfee 2014). Maintaining focus with all these applications of blockchain and achieving shareholder objectives such as wealth and profit maximisation, managing complications, risks and costs, privacy and security can be challenging (Buchak et al. 2017). Hence, our framework aids banks and collaborators to maintain the larger picture in mind. Frameworks aid us to unify how we foresee and link unclear, novel and complex concepts. Thus, a suitable framework at an advanced level on the key factors of blockchains would deliver clearness and purpose for all interested parties and ensure successful adoption. Our framework has five main components: 1. Adoption steps, 2. Value addition from AI integration, 3. Blockchain governance factors, 4. Barriers to adoption, 5. Limitations, and 6. Stakeholders.

The adoption process identified in our framework can be further explained as a blockchain adoption life cycle model. In the adoption process at the exploration and assessing stage it is important to draw a timeline for adoption. In the first 6 months identify potential use cases within the bank, key collaborators on fintechs, if required, and obtain bank-wide buy in for the project. Next year would involve building a proof of concept and identifying business partners. Within the following three years, the bank can integrate the blockchain into the core customer eco systems. Following these three years, the bank can maintain the blockchain adoption life cycle and establish blockchain as the standard technology for information systems and deployment (Ernst and Young 2017). Section 4.1

explores the barriers to adoption and impact identified in our framework. Section 6 in this study outlines limitations and governance factors identified in our framework in more detail. Section 4.1.8 discusses blockchain integration with AI. Apart from all the literature cited throughout our study, the framework and textual analysis further incorporates concepts from the below mentioned studies: (Financial Stability Board 2013; King 2013; Kroll et al. 2013; Maxwell 2013; Meiklejohn et al. 2013; Möser 2013; Miers et al. 2013; Ron and Shamir 2013; Sompolinsky and Zohar 2013; Eyal and Sirer 2014; Financial Stability Board 2014; Komlos 2014; Kitahara et al. 2014; Rochard 2014; Powell 2014; Ruffing et al. 2014; Segendorf 2014; Viacoin 2014; Garrett 2015; Greenspan 2015a, 2015b, 2015c; Gulamhuseinwala et al. 2015; Herbert and Litchfield 2015; Hoskins and Labonte 2015; Hyperledger Project 2015; Hutchinson and Dowd 2015; Kanzler 2015; Jakšič and Marinč 2015; KPMG and H2 Ventures 2015; Lomas 2015; Morse 2015; Noizat 2015; Pagano and Vatiero 2015; Pass and Shelat 2015; Price Waterhouse Coopers 2015a, 2015b; Robertson 2015; Sarr et al. 2015; Swanson 2015; The Decentralized Library of Alexandria 2015; World Economic Forum 2015; Wright and De Filippi 2015; Eris Industries 2016; Ernst and Young 2016; Eyers 2016; FED 2016; Federal Reserve Bank of Chicago 2016; Frey et al. 2016; Gerstl 2016; Greenspan 2016; Harwick 2016; Hung and Luo 2016; IBM Corporation 2016, 2017; Huertas 2016; Ivashchenko 2016; Jaag and Bach 2016; Jooyong and Eunjung 2016; Jopson 2016; Kosba et al. 2016; Kraft 2016; Kravchenko 2016; Kursh and Gold 2016; Lemieux 2016; Liu 2016; McConaghy 2016; McKinsey Company 2016; Mills and McCarthy 2016; Mukhopadhyay et al. 2016; Mori 2016; Office of the Comptroller of the Currency 2016; Parker et al. 2016; Parliament 2016; Philippon 2016; Primm 2016; Proof-of-Stake 2016; Reijers et al. 2016; Shedden and Malna 2016; Siegel 2016; Symp Koulu 2016; Tschorsch and Scheuermann 2016; Van Alstyne et al. 2016; Vigna and Casey 2016; Walport 2016; Wang et al. 2016; World Bank 2016; Zavolokina et al. 2016; Zhao et al. 2016; Zhu and Zhou 2016; Gaetani et al. 2017; García-Barriocanal et al. 2017; Gattermayer and Tvrdik 2017; Goldfeder et al. 2017; Gomber et al. 2017; Greenwood et al. 2017; Hull 2017; Infosys Limited 2017; Jagtiani and Lemieux 2017; Irrera 2017; Jiang et al. 2017; Jin et al. 2017; Kaal 2017; Kaal and Vermeulen 2017; Kalra et al. 2017; Kendall 2017; Kim et al. 2017; Kiyomoto et al. 2017; Klems et al. 2017; KPMG International 2017; Kshetri 2017; Kumar and Rahman 2017; Lai and Van Order 2017; Lamberti et al. 2017; Larios-Hernández 2017; Leiding and Norta 2017; Li et al. 2017; Lin and Liao 2017; Liu et al. 2017a; López-Pintado et al. 2017; Mainelli 2017; Malinova and Andreas 2017; Malwarebytes 2017; Meter 2017; Moura and Gomes 2017; Neisse et al. 2017; Nofer et al. 2017; Nordrum 2017; Nowiński and Kozma 2017; Ou Yang et al. 2017; Parity Wallet Security Alert 2017; Pauw 2017; Pazaitis et al. 2017; Pokrovskaia 2017; Proof of Existence 2017; Prybila et al. 2017; Rimba et al. 2017; Sankar et al. 2017; Schindler 2017; Schulz and Schafer 2017; Scott et al. 2017; Scuffham 2017; Seebacher and Schüritz 2017; Spearpoint 2017; Subramanian 2017; Sullivan and Burger 2017; Sullivan 2017; World Government Summit 2017; Sutton and Samavi 2017; Tama et al. 2017; Tapscott and Tapscott 2017; Vo et al. 2017; Vranken 2017; White 2017; Wijaya et al. 2017; Xia et al. 2017; Xu et al. 2017; Yamada et al. 2017; Yermack 2017; Yue et al. 2017; Zachariadis and Ozcan 2017; Zikratov et al. 2017; Economist 2018; Fridgen 2018; Governatori et al. 2018; Government Accountability Office 2018; Kalra et al. 2018; Hawlitschek et al. 2018; Holub and Johnson 2018; International Standards Organization 2018; Khalilov and Levi 2018; Kodak 2018; Li and Mann 2018; Makridakis 2018; Mavridou and Laszka 2018; Meng et al. 2018; Mengelkamp et al. 2018; Office of the Comptroller of the Currency 2018; Panagiotidis et al. 2018; Pearson 2018; Suhaliana et al. 2018; Wang et al. 2018; Wei 2018; Yoo and Won 2018; Zalan 2018; Zheng et al. 2016; Foley et al. 2019; Li and Yi 2019; Li et al. 2019; Mussomeli 2019; Philippi et al. 2019; Schuetz and Venkatesh 2019; Song and Thakor 2019; Vallee and Zeng 2019; Zhu 2019; Frizzo-Barkera et al. 2020; Jayasuriya Daluwathumullagamage and Sims 2020; Kyriazis et al. 2020; LedgerInsights 2020; Shanaev et al. 2020).

3. Methodology

Systematic reviews are a meta-analysis technique designed to collate, analyse, and summarise existing knowledge and gaps in literature and specific concepts (Briner et al. 2009). Academic and industry literature on blockchain use cases in general and benefits are beginning to proliferate the knowledge domain. Nevertheless, these prior studies possess limited scope regarding applications in banking and reflect diverse findings. Moreover, the web is proliferated with short articles, notes on blockchain adoption in general in finance, across various industries and technical articles. This results in risks towards knowledge aggregation and integration of findings in both the industry and academia (Briner et al. 2009). Thus, our study attempts to effectively collate these fragmented, dispersed articles in a coherent manner to identify gaps, trends and parallels between industry and academic discourse.

In addition, as depicted in the literature review section, we further developed a blockchain adoption framework for banking based on our analysis of prior industry and academic literature.

Given this setting, to provide a systematic review of literature on blockchain based banking we follow Moher et al. (2009) and Briner and Denyer (2012). The key methodological steps are as follows: 1. Identifying the motivation and research question development, 2. Identifying the pertinent literature from academia, industry reports, quality assessment, data extraction and data synthesising. 3. Conduct extensive analysis for framework development and identification of gaps and trends between industrial and academic (we supplement our systematic review findings by textual analysis using machine learning techniques). 4. Finally, the results of the review are discussed.

3.1. Research Question Definition

A systematic review's first phase involves research question definition (Coghlan and Holian 2007). This study provides a synopsis of present academic and industry literature in blockchain technology with some factors relevant for blockchain adoption in banking. In addition, the study explores use cases that are relevant for banking, identifies common trends and gaps and develops an adoption framework. To this end, we developed the research questions formulated below:

1: What are the present and future use cases in banking according to academic and industry literature?

This simple research question unentangles, present and potential applications of blockchains from a myriad of industries to that of banking.

2: What are the gaps, similarities and trends between prior academic and industry literature in blockchain adoption in banking?

This research question is formulated to obtain a complete overview of which areas the industry and academia overexplore and underexplore specific to blockchain adoption in banking. This would aid in facilitating future research and collaborations between academia and industry.

3: What are the behavioural, social, economic, regulatory and managerial implications of blockchain adoption in banking?

Identifying and understanding the impact of blockchain adoption in banking on the relevant stakeholders is important for successful deployment and sustainability of the technology in banking. This will aid academics and practitioners to better understand present use cases of blockchain that can effectively address bank, customer, regulator and societal needs.

4: What are the barriers and misconceptions for blockchain adoption in banking?

Understanding the limitations, challenges, common misconceptions and barriers of adoption is beneficial, especially at the early stage of deployment. This further aids in the decision making of future projects, effective maintenance of the adopted technology and future development efforts of blockchain adoption in banking.

3.2. Locating and Selecting Articles

To answer our research questions, a systematic literature search was carried out in Scopus, Science Direct and Google Scholar. The methodological approach to firstly identifying the key papers relevant for the literature survey and framework development are as follows: (1) Identify the databases (Scopus, google scholar and Science direct); (2) select keywords and search criteria (for the original search which excludes news and magazine articles, and subsequently refine search criteria); (3) identify relevant papers and analyse further; (4) classify the papers and group them into major themes; (5) highlight the research gaps, trends, similarities between industry reports and academic literature; (6) use textual analysis to further identify key themes and subthemes to create the blockchain adoption framework. In addition, we supplement the gaps, parallels and trends identification between industry and academic literature from the systematic review via textual analysis.

Our sample period was selected from 2013 to 2020. We decided upon 2013 as the beginning of our sample period as Yli-Huumo et al. (2016) identifies the first blockchain related technical being published in 2013. The papers were searched using various permutations of the following keywords: "Blockchain+financial intermediaries", "Artificial intelligence+banking", "banking+blockchain", "decentralised system+banking", "decentralised network+banking", "decentralised ledger+banking", "cryptocurrencies+financial services", "digital currencies+banking", "bitcoin+financial services", "Ethereum+financial services", "financial services+blockchain", "security+blockchain", "ethics+blockchain", "fintech+blockchain", "COVID-19+blockchain", "regulation+blockchain" in the title, keywords and abstract fields of the search engine. In addition, relevant articles' reference lists were also searched to identify any missed key articles. Initial search of all databases yielded 1979 records. These articles include published and in press research articles, conference papers, book chapters and short notes etc. Subsequently, industry and academic articles were segregated. Our final sample included 407 blockchain articles that have factors relevant for blockchain adoption in banking. Out of these, 102 were industry articles. Table 3 summarises the inclusion and exclusion criteria implemented in our study to obtain the final article sample.

Table 3. Exclusion and inclusion criteria.

Selection Criteria	Scientific Database	
Inclusion rules	Peer-reviewed high and lower tiered research papers and ones in press, conference papers, consulting reports, technical reports, and short articles	Scopus, Science Direct, Business Source Premier
	Sample period beginning from 2013	
Exclusion rules	Before being uploaded to the bibliographic manager	Non-English language articles, missing abstract articles, editorials
	Screening of titles	Generic blockchain architecture articles with no application possibility in finance
	Screening of abstracts	Blockchain related software development articles
	Screening of full-texts	Studies purely on technical hardware and software aspects of blockchain development

3.3. Final Article Sample Selection and Evaluation

Articles in the final sample were selected based on the predefined inclusion and exclusion criteria discussed in Table 3. The exclusion criteria are based on document type (notes, editorials), language, and subject relevance. In the first phase, all article abstracts and introductions were evaluated. Afterward, any article that met the exclusion criteria was removed from the sample. After a full text review, several more articles were also further excluded from the sample. Several research studies from finance and survey methodologies were incorporated to the reference list but excluded from the systematic review analysis as they were not on blockchain technologies. Finally, several articles were excluded for being purely focused on blockchain's architecture and other technical aspects. Articles that met the inclusion criteria were carefully read and further analysed using 'Leximancer', a machine learning based textual analysis software. Significant themes and subthemes were further identified through Leximancer to aid in the development of our blockchain adoption framework. Additional factors were included into the framework through careful review of the final sample of articles.

3.4. Textual Analysis

Traditional methods of collating, analysing a large number of studies both from academia and the industry for qualitative studies are time consuming and resource heavy. Therein comes the use of machine learning to analyse a large number of textual data and identify key concepts, their interlinks and subthemes. To this end, we utilised machine learning based software Leximancer to identify the key concepts, subconcepts and themes emerging from the academic and industry reports. Leximancer helped us narrow down the key themes relevant to banking from the vast sea of research on blockchain studies, industry reports and regulatory body publications. We further used these key themes and subthemes to develop our blockchain adoption framework and to identify impact of blockchain in banking to various stakeholders. The algorithms used were statistical, but they employed nonlinear dynamics and machine learning. The conceptual map provides a broad view of the content, identifying the key concepts contained in the collections of documents of interest. This analysis further helped us compare and differentiate between industry reports and academic literature as discussed in Section 5.2.

3.5. Limitations of Our Study

Systematic reviews can face selection bias issues due to search and selection criteria distortions used to finalise the article sample. To mitigate selection bias, we used several combinations of different search keys, back tracked other key literature key words on blockchains without a primary relevance to finance. Furthermore, we used search database alterations of the search criteria through several layers of searches. Moreover, our study enhanced our article sample by perusing the reference list of already collected articles to identify any missing key articles from prior literature. Another limitation of our study is that of inconsistent coding or data interpretation. Thus, we supplemented our analysis through Leximancer by reviewing the articles manually.

Finally, given the lack of valid databases and the reluctance of banks to disclose blockchain related investments individually, we followed the systematic review and textual analysis approach using machine learning to answer our research questions rather than collecting empirical data on the topic. Leximancer usage limitations happen to be the significant time required to prepare the data and obtaining meaningful insights from the Leximancer output.

4. Results and Discussion

Firstly, this section details the Blockchain banking use cases, provides the results from the systematic review that identify, gaps, parallels and trends among industrial and academic literature. Moreover, this section discusses the results from the textual analysis and adoption framework. Studies included in the final sample of 407 articles possess factors that can be repurposed or relevant for blockchain adoption in banking.

4.1. Blockchain Based Banking Use Cases

This section answers our research question 1: What are the present and future use cases of blockchain applications in banking? In sum, this section identifies that blockchain based banking would result in reduced costs, faster processing times for transactions, no intermediary requirement for authentication, independence from centralised repositories, less paperwork, more transparency, security and data integrity (Energy Web Foundation 2018). The global appetite for blockchain investments in banking is expected to significantly grow during the next couple of years (Wang et al. 2016). Blockchains are expected to reduce transaction costs by over 50% by eliminating intermediary costs and increased efficiencies and security (PwC 2016). The key blockchain service providers in banking can be categorised as applications and solutions, middle ware, services and infrastructure and base protocols (Romānova and Kudinska 2016). Present blockchain applications in banking primarily revolve around core banking, payments, smart contracts, supply chains, trade finance, financial markets, risk management, compliance, insurance, digital identity management (Disparte 2017; Watson 2017; Beikverdi and Song 2015; Benet 2014). In banking, the interaction channel in blockchain adoption is segmented into bank branches, websites, call centres and mobile applications for large to small and medium sized enterprises (McKinsey and Co 2015, 2016). The key fintech players involved in competing with banks and also partnering with banks according to our findings are IBM Corporation (US), Microsoft Corporation (US), Ripple (US), Amazon Web Services, Inc. (US), Bitfury Group Limited (US), Oracle Corporation (US), Digital Asset Holdings (US), Chain Inc (US), Earthport PLC. (UK), Auxesis Group (India), RecordsKeeper (Spain) and BTL Group (Canada). Table 4 provide examples of blockchain use cases by application category and their advantages and disadvantages.

Table 4. Blockchain use cases by application category and their advantages and disadvantages.

Area in Banking	Present Use Cases	Pros	Cons
Exchanges and Trading Platforms	Nasdaq reported its first stock trade on 30 December 2015 using Blockchains. Linq platform established with Chain.com and IDEO facilitated this transaction.	Blockchain based trading decreases information redundancies and results in performance improvements (Economist 2016).	Trading with blockchain can impose risks such as loosing private keys.
	In 2015, the Australian Stock Exchange (ASX) initiated replacement possibilities for the Clearing House Electronic Sub Register System (CHESS) and collaborated with Digital Asset Holdings, LLC to establish a blockchain based clearing and settlement system.	To control blockchain size, only large transactions can be on the chain. Whereas, smaller transactions between traders can be completed off chain. Multisignature transactions that can be integrated into the asset trading applications running on blockchain technology may alleviate this issue.	All transactions being placed on a blockchain results in much larger blockchains being replicated in several computers and gives rise to a storage issue.
	International Business Machines Corporation (IBM) and the Japanese Exchange Group (JPX) are collaborating on blockchain based trading platform developments.	Signatures of all parties before agreeing upon a transaction can prevent the keys from being stolen and the ownership from being changed.	
	Moscow Exchange (MOEX) collaborated with the National Settlement Depository (NSD) to develop a blockchain network and completed e-e-voting for bondholders.		
	Korea Exchange collaborated with Blocko to establish start-up Korea Start-up Market (KSM) for start-up firm shares to be traded in the open market.		
	India's National Stock Exchange (NSE) implemented a trial for blockchain based know-your-customer (KYC) data test with ICICI, HDFC Securities, IDFC, Kotak Mahindra, RBL and IndusInd.		

Table 4. *Cont.*

Area in Banking	Present Use Cases	Pros	Cons
	Deutsche Börse Group has explored blockchain based solutions for cross border share transfers by collaborating with Liquidity Alliance.		
	The London Stock Exchange is exploring blockchain based post-trade settlement options.		
	The Luxembourg Stock Exchange has established a blockchain based security system that maintain official signatures by Appointed Mechanism (OAM), document type and URL.		
	Santiago Exchange is collaborating with IBM to explore blockchain based solutions for Chile's financial industry.		
	The Toronto-based TMX Group reported the development of a blockchain based service for the Natural Gas Exchange (NGX).		
	Blythe Masters' Digital Asset Holdings with the Hyperledger, Epiphyte, Clearmatics Overstock with T0 and SETL are all examples of blockchain based solutions in the financial industry.		
Know Your Customer	The Pit supports a collection of fiat and cryptocurrencies in 200 countries. USD, GBP and EUR can deposit via bank transfers to buy or sell BTC, ETH, LTC, BCH, PAX and USDT.	With blockchain based banking, customers would only have to register once, any other service provider within the blockchain network would not require repeat registration.	Blockchain based identity verification applications are underdeveloped and all nodes would have visibility of data on the blockchain.
	Tradle and Cambridge Blockchain are working on blockchain based customer identification.		
	ID2020 is a blockchain based application aimed at creating digital identities for individuals without paper identities. This development is funded by the Rockefeller Foundation in collaboration with Accenture, Microsoft.		
Payments	Ripple is a "real-time gross settlement system" (RTGS) is a blockchain based currency exchange and remittance platform established in 2012. This is an application that can be used by banks that would benefit their customers.	Blockchain based banking cross-border payment and settlement systems are much speedier, efficient and less expensive relative to legacy systems.	Blockchain service provider's bankruptcy or hacking would result in the funds being lost without an intermediary to reimburse customers.
	Westpac collaborated with Ripple to facilitate blockchain based payments and settlement in 2016 for cross border transactions.	Costs for remittances are approximately 2–3% of the total transaction amount relative to 5–20%, presently held by third party intermediaries.	Fluctuating exchange rates between fiat and cryptocurrencies may make blockchain based cross border payments problematic. (Bitcoin ETf Channel 2018)

Table 4. *Cont.*

Area in Banking	Present Use Cases	Pros	Cons
	CBA, in 2015 collaborated with Ripple to develop a blockchain based payment system between its subsidiaries.	Without third party authorisation and verifications, blockchain based payments can be processed significantly faster compared to legacy systems.	
	U.S. Federal Reserve collaborated with IBM in 2016 to establish a digital payment system. Other banks such as Deutsche Bank, BNP Paribas and Barclays Banks followed suit.		
Remittances and P2P	BitPesa, Abra, and Circle are examples of blockchain based remittance and P2P platforms. Circle facilitate social payments and BitPesa allow B2B payments in Africa.	Blockchain based P2P transactions would not have geographical limitations allowing remittances to originate and be transferred anywhere in the world (Biryukov et al. 2014).	P2P users need to expect cryptocurrency price volatilities would affect conversion values to fiat currencies and subsequent transaction costs.
	LHV Bank of Estonia is exploring with coloured coins named "Cuber" as a form of deposits that are cryptographically protected. This would allow the banks' fintech arm called Cuber Technology to implement blockchain based apps that can facilitate free P2P fiat currency transactions.	Blockchain based transactions occur in real time resulting in recipients receiving the funds without daily or weekly time lags.	Additions of fiat currencies to cryptocurrency transactions may slow down even blockchain based P2P platforms.
	Collab, VISA and the BTL Group are collaborating to provide blockchain based cross-border payments among banks in Europe.		
Trade Finance	Ornua, a dairy products manufacturer from Ireland collaborated with Barclays to complete the first blockchain based banking transaction in 2016.	In traditional international trade legacy systems, participants would need to maintain their own database of transactions unlike with blockchains.	Blockchain use in trade finance maybe hindered by trade embargos.
	IBM and Maersk partnered to explore blockchain based solutions in supply chain management.	A single error in any of the legacy systems between two parties would be duplicated unlike in blockchains where one digital document updates all in real time approved by all members reducing errors.	Blockchain-based networks could not be used to impose sanctions without a proper BIS licence or OFAC.
			Difficult to transfer information on a blockchain to non-blockchain users.
Syndicated Lending	Credit Suisse, R3, Ipreo and Symbiont collaborated to develop blockchain based solutions for the syndicated loan market.	Compliance procedures completed by one bank in the blockchain would not have to be repeated by other banks.	Blockchains cannot overcome all syndicated loan market issues as all banks in the syndicate needs agree on protocols (Cohen et al. 2017).
	BNP Paribas, HSBC, BNY Mellon, State Street, ING and Natixis developed a blockchain based syndicated loan platform by collaborating with Fusion LenderComm by Finastra in 2018.	Information can be easily shared through blockchains across all participating banks.	Interoperability issues, and negotiations of control, read, write access may persist across the banks in the syndicate with regard to blockchains.
		Blockchains reduces regulatory requirement process costs and time to be compliant for all banks in the syndicate.	

Table 5 summarises blockchain use cases in banking by fintechs and their impact on banking. Table 6 provides a summary of present use cases of blockchain by banks and partnerships between banks and fintechs. The section below discusses in more detail numerous applications of blockchain in banking and focuses on several underexplored areas of adoption as identified from our systematic review and textual analysis.

Table 5. Blockchain adoption in banking by fintechs and their impact.

Fintechs in Banking	Location	Description	Impact
PAXOS	New York, NY	Paxos is a blockchain based trust that makes payments and settlements simultaneously.	New York Department of Financial Services has approved Paxos which is one of the few stable coins approved by them.
		With trust powers similar to a traditional bank, 1 PAX token is equal in value to USD 1. PAX is an Ethereum-based stable coin that can facilitate digital transactions of instant settlement.	PAX is presently listed in eight different platforms.
JIBREL NETWORK	New York, NY	Jibrel is blockchain based platform that allows the tokenisation of assets such as loans, commodities and ICOS.	Jibrel is a member of the Enterprise Ethereum Alliance (EEA) which is the largest open source blockchain initiative in the world for blockchain based industry architecture and best practices implementation.
		Asset tokenisation allows Jibrel users to obtain higher liquidity.	
REPUBLIC	New York, NY	Republic is a blockchain based investment platform that provides users opportunities to invest in ICOs starting from USD 10.	Republic at present has 14 firms listed on their platform.
		Republic has a variety of firms with different purposes and businesses to invest from. These firms can raise capital either using fiat or cryptocurrencies from investors.	Examples of these firms are BANDWAGON which is a start-up concentrated on stopping fraudulent ticket sales and Nori which is a start-up concentrated on mitigating climate change.
		Republic's DPA token allows firms to presell and manage crowd sale tokens.	
SALT LENDING	Denver, CO	SALT lending platform allows members to use their cryptocurrencies as leverage for cash-based loans without having to sell digital assets.	SALT is operating across 35 states in U.S. since 2016 and is expanding to include more tokens as collateral.
		Platform users have the choice of loan maturity from 1 to 36 months, interest rate and type of cryptocurrency that are leveraged such as Ether, Bitcoin, Litecoin and Dogecoin.	Proof of access allows users on to modify loan conditions using SALT tokens.
AIRFOX	Boston, MA	Airfox is an emerging market blockchain based banking platform catering to the underbanked. Users are able to receive loans without credit rating checks.	Airfox collaborates with Via Varejo, a Brazilian retail giant to provide its financial services to 60 million users in Brazil. The platform is supported by approximately 1000 Via Varejo stores for digital banking.
		AirToken (AIR) is a blockchain based digital utility token where an individual's creditworthiness is verified using cell phone data. Phone records are used to assess credit worthiness to provide loans based on immutable data.	Airfox ecosystem interactions on a daily basis allows users to earn AIR tokens granting them credit.
UULALA	Irvine, CA	Uulala's blockchain based P2P platform provides banking services to the underbanked and unbanked.	Uulala is exploring further expansions in Mexico, Brazil and U.S.
		Uulala ecosystem allows cash to be loaned via decentralised ledgers using cell phones essentially making these cell phones portable ATMs.	This app reduces time and costs related with borrowing by eliminating the need for intermediation.

Table 5. *Cont.*

Fintechs in Banking	Location	Description	Impact
RIPPLE	San Francisco, CA	Ripple's blockchain based financial services platform allows banks to conduct real time cross border transactions. Banks are able to access a standardised decentralised network of institutions for efficient, transparent and faster transactions.	Approximately 75 financial institutions use Ripple for cross border payments including BMO, BBVA, Santander, MoneyGram and American Express.
PAYGINE	New York, NY	Paygine is banking infrastructure blockchain based network that processes close to USD 115 million worth of transactions on a monthly basis.	Paygine plants to expand to U.S. and Asia after establishing core banking processes in Europe.
		Paygine provide remittances, payments, cryptocurrency exchange facilities, KYC and lending.	
SPRING LABS	Marina del Rey, CA	Spring Labs is a permissioned blockchain based network that allows information sharing among financial institutions without having to actually share the underlying data. This sharing mechanism allows more security for data.	Spring Labs was founded in early 2018 and Avant, a Chicago based online lending platform is one of its first participating institutions.
BLOCKFI	New York, NY	BlockFi is a blockchain based lending platform that lends cash by maintaining cryptocurrencies as collateral. Online loan applications are provided to customers and once approved, cryptocurrencies such as Bitcoin and Ethereum can be transferred to a secure storage address on a blockchain.	Customers include Block 8 Ventures and Climb Credit CEO Angela Ceresnie where the loans are utilised to fund new projects. These loans are available for individuals and corporations.
ALPHAPOINT	New York, NY	AlphaPoint is a blockchain based platform that allows the trading and digitisation of assets such as currencies, loans, shares. Processes and workflows are automated using smart contracts.	AlphaPoint Indexes is an extension of AlphaPoint and is a statistical platform where the index is used to benchmark the performance of most liquid and high values cryptocurrencies and measure their performance.
TRADLE	New York, NY	Tradle is a blockchain based platform used by financial institutions for KYC purposes. Tradle uses bots to scan relevant information such as employment history, finances to obtain verifiable background checks on customers. The gathered information is held securely on a blockchain that can be shared across bans and to other external data transfer mechanisms.	Lloyd's, R3 and AIA have tested their products and Tradle has won numerous awards such as the blockchain company 2016 by KPMG and the Citi KYC company to watch award.
Overstock (OSTK)	New York, NY	Coinsetter is set to establish a corporate bond asset exchange blockchain based platform called T0 that can clear over the counter transactions in T + 10 min.	General U.S. exchange-based share or bond purchase would involve around T + 3 days to settle.

Table 6. Present use cases of blockchain by banks and partnerships between banks and fintechs.

Banks and Fintech Partnerships	Description
	Banks
JP Morgan Chase	Quorum is a division established to explore blockchain based applications such as annual certificate of deposits at variable rates with smart contracts to ensure speedy transactions.
Bank of America	Has filed a patent for a permissioned blockchain network to maintain secure records, authentication of personal and business data. Allowed users will be able to access the data and keep a record of all entries and existing legacy storage systems would be combined into one blockchain based ledger.
Goldman Sachs	Circle is a blockchain based cryptocurrency start up focused on solving volatility issues of digital currencies enabling crypto options to be more viable in the financial services sector.
Barclays (BCS)	Is exploring both internal applications and external collaborations of blockchain based services with start-ups in the financial sector.
BNP Paribas	Is exploring the use of blockchain based solutions for order processing and its currency funds.
Citigroup Inc	Has initiated around three blockchain-based applications such as creating CitiCoin, its own cryptocurrency.
	Standard Chartered, Société Générale, Deutsche Bank, The Bank of England, DBS Bank, LHV Bank, BBVA, BNY Mellon, CBW Bank, Commonwealth Bank of Australia and Westpac are all exploring blockchain based banking solutions.
JPMorgan blockchain initiative	JPMorgan, ANZ and Royal Bank of Canada have been testing The Interbank Information Network which has expanded to more than 75 banks. IIN is developed is developed by Quorum and is a permissioned Ethereum based blockchain that allows frictionless cross border payments with transactions speeds due to compliance responses and data related inquiries.
	Fintech Partnerships with Banks
UBS	Batavia was established by collaborating with IBM in 2015, to facilitate live transactions for corporate clients. Cross border transactions such as car sales and textiles in Austria has been completed so far.
Credit Suisse	By partnering with ING, the bank explores the establishment of a blockchain based transaction network maintained via smart contracts which in future can enable customer networks and cryptocurrency systems.
Santander Group	Several financial institutions collaborated with Clearmatics, a blockchain development firm from London to develop a blockchain based transaction platform.
Bain & Company	Bain & Company, a U.S. based large management consulting firm is collaborating with several financial institutions to launch Voltron a blockchain based documentary trade platform. Voltron partners include CTBC Holding, Standard Chartered, ING,
	Bangkok Bank, BNP Paribas, HSBC, NatWest, CryptoBLK and SEB.
we.trade	Developed on the IBM blockchain, we.trade enables real time trade settlement and incorporates KYC verifications, and automatic payment settlement via smart contracts. The application has 14 financial institution partners including HSBC, Nordea, Santander, Rabobank, Eurobank, Deutsche Bank, KBC, Natixis and Société Générale. These banking customers can trade across 14 European countries.
Fujitsu	Fujitsu is collaborating with the Japanese Bankers Association (JBA) to test digital currencies and blockchain based interbank settlement applications. Trials will be implemented by Payment Clearing Network, (Zengin–net).
Ripple	SBI Holdings is launching a Ripple powered mobile application for payments named MoneyTap which will be used by a consortium of Japanese banks including Suruga bank, Resona Bank and Sumishin Bank.
R3CEV	R3CEV is establishing a private blockchain for over 40 banks including JP Morgan, Barclays, Bank of America, UBS and RBS.
Depository Trust and Clearing Corporation (DTCC)	Rebuilding trade information warehouse using blockchain technologies in partnership with IBM, R3 and Axoni.
Dianrong	The Chinese P2P partnered with R3 to facilitate supply-chain financing by the distributed ledger technology that underpins cryptocurrencies.

4.1.1. Exchanges

Blockchains provide a novel method for asset trading without intermediaries or a centralised system and the risk of double spending (Economist 2015). Some of the key exchanges in the world as shown in Tables 4 and 5 are implementing and exploring blockchain based solutions for their pre-trade, post-trade, trade transaction, custodial and security servicing functions. Although algorithmic trading enables trade execution in a matter of seconds, trade settlement remains a bottleneck being time consuming, error prone and cost inefficient (Khaqqi et al. 2018). This is primarily due to intermediation, operational trade clearance and regulatory processes. Old or existing systems are centralised, tedious to upgrade, not transparent and require an intermediary such as a bank resulting in lesser security (PwC 2017). Thus, the adoption of blockchain has the potential to streamline these processes through decentralised automation by cutting transaction costs, increased security, compatibility and trust (Goldstein et al. 2019). Blockchains can securely automate post-trade processes, ease the paperwork burden of legal ownership, trade and security (Da Rin and Penas 2017). The instructions, guidelines and regulations can be hard coded in via smart contracts and imposed with every trade with the blockchain network itself working as the intermediary and regulator alike (Cortez 2014; Financial Conduct Authority 2016).

Automation of post-trade events would reduce counter parties and operational risk with security settlement occurring in a matter of minutes improving liquidity and increased transparency (Dapp et al. 2014). In our opinion, the blockchain network would be an automated partial regulator surveying the transactions with built in characteristics to track, block and report illegitimate attempts of trades. Furthermore, intermediaries such as brokerages, clearing house or settlement processes would not be required. Thus, resulting in lesser costs due to eliminated intermediation, reduced record keeping, auditing and trade verification costs (Tanaka et al. 2017). With the reduction of inefficiencies and costs, barriers to entry would be lower with higher market participation and better access ultimately increasing liquidity and investments (PwC 2017). Moreover, margin payments could be executed instantly with more frequent securities valuations even daily as compared to weekly, reducing overall credit risks within the exchange (Crosby et al. 2016). Thus, in the future, clearing houses, intermediaries and exchanges can be replaced by a blockchain network of marketplaces (Cocco et al. 2017).

4.1.2. Primary Market Issuance and IPOs

In addition, stocks and bonds can be issued on a blockchain network where they are sold immediately by an exchange also existing in a blockchain network (De Meijer 2016; Bloomberg 2018). This would significantly cut down disclosure costs, marketing road shows and underwriting fees. Thus, becoming a significant disruptor for investment banks (Watson 2017).

4.1.3. Payments

A key challenge for the banks is to sustain and main existing relationships with payment companies such as VISA. In addition, there are blockchain based cryptocurrency payment fintechs cropping up across the globe (Birch et al. 2016). The majority of present payments specialise in a single payment activity (e.g., B2B payments) with others engaged in three activities or more (Carney 2016). Merchant services involve processing payments for merchants that accept cryptocurrencies (Bolt and Van Oordt 2019; Bonneau et al. 2015). In addition, almost every payment company must perform know your client (KYC) checks which are generally performed internally. Adoption of blockchain for payment systems would increase the speed of money transfers by making payments real-time (Canaday 2017). Thus, with permissioned transparency, real time execution, detection and prevention of fraudulent transactions at faster speeds may be achieved (Accenture 2016, 2018). Furthermore, through tokenisation via cryptography and permissioned access to trade data would ensure the confidential nature of trade transactions. According to several industry reports, significant cost and time savings of approximately USD 20 billion may be achieved via blockchain adoption in trade finance (CBS 2015).

4.1.4. Fraud Reduction

The traditional centralised nature of banking databases, exchanges and clearing houses have made them more susceptible to hacking and security threats. In contrast, the decentralised nature of blockchains would deter such attacks and the real time execution of payments would allow real-time detection and prevention of fraud (Lo et al. 2017; Bonneau et al. 2014). Moreover, blockchain network transactions would aid in identifying fraudulent entities through a trail of transactions and cryptocurrencies (Nath 2016). Data within the blockchain could be analysed by regulators to identify fraud and illegal activities (Cai and Zhu 2016).

4.1.5. Remittances and Other Peer-to Peer (P2P) Transfers

Several developing countries have significant contributions to their entire gross domestic product (GDP) from remittances. On average, according to world bank, global remittances are approximately 0.7% (USD 1 trillion) of the global annual GDP (Braggion et al. 2020). Remittances allow funds to be transferred from one bank account to an individual's account internationally. All existing P2P transfers have limitations of being able to transfer within a certain geographical area, failure to transfer if both peers in same country, large commissions for transfers, lack of security for sensitive data (Bruce 2013; Deer et al. 2015). These issues can be solved via blockchains. At present, banks and companies such as Western Union provide remittance services across the globe. However, there are already several blockchain based international transfer systems in place such as Abra, BitPesa (Focus on B2B payments for Africa), and Circle (focus on social payments). On the blockchain, these transactions are peer-to-peer (P2P) and encrypted remaining more protected (Infosys Consulting 2016). Not just individuals, but corporates and international banks themselves rely on these remittances. Blockchain based remittances could be an additional revenue stream for banks ((Brühl 2017; Tang 2019).

4.1.6. Syndicated Lending

Syndicated lending involves a group of lenders providing a secure loan to a firm or an individual. With several participating banks in the syndicate to provide the loan, traditional processing times may take up to 19 days (Gazali et al. 2017). Each bank in the syndicate face challenges in KYC, being compliant with anti-money laundering (AML) and bank secrecy acts (BSA). Blockchain based loan syndication can make this process less costly, more transparent among the banks and the customer and more efficient in general (Ernst and Young 2017). Banks can dispense tasks to complete BSA, KYC, and AML compliances and connect the subsequent checks to a single customer (Fuster et al. 2019).

4.1.7. Accounting and Improved Record Keeping

Banks globally collectively maintain trillions of records pertaining to customers, transactions and purchases (Cong et al. 2018). All these records could be moved to a blockchain as a decentralised digital ledger (Karafiloski and Mishev 2017). Thus, increasing the traceability, security and accessibility of these records (Coyne and McMickle 2017). Since counterparties in every transaction would also be connected to the blockchain and have the same record, this would subsequently reduce disputes resolution costs (Hassani et al. 2018). In addition, bank accounts could be represented on a more secure, accessible and less costly manner from a blockchain. Thus, alleviating unsubstantiated rumour driven bank runs (Jagtiani and Lemieux 2017).

Therefore, blockchains even have the potential to disrupt the accounting (O'Leary 2017; Jayasuriya Daluwathumullagamage and Sims 2020) and shadow banking sector (e.g., Dianrong, Libra by Facebook). For banks to adopt blockchains, they would have to choose permissioned over public blockchains allowing only trusted party's access including regulators (International Monetary Fund 2017).

4.1.8. Decentralised Intelligent Banks

Are decentralised artificially intelligent banks a match made in heaven or a disruptive integration? This section discusses integration of blockchain with Artificial Intelligence (AI) and the value addition factors identified in our framework. This section also adds to answering research question 1. What are the present and future use cases of blockchain applications in banking? AI integration with blockchains may impact security by providing two layers of protection against cyber-attacks (Dapp et al. 2014). Thus, integrating Blockchain with AI might aid in overcoming one of the key limitations of blockchain adoption regarding privacy and security (Dannen 2017). Therefore, we surmise from prior literature that blockchain and AI integration would result in improved business models for banks, efficient global verification systems, innovative bank auditing and regulatory compliance, intelligent retail payment systems, transparent governance, predictive analytics and digital intellectual property rights for financial market assets (Deloitte 2016a, 2016b, 2016c; PwC 2016; Chen et al. 2019). Apart from these banking related applications, increase of security, efficiency, trust, smart storage would be additional technical benefits of such integration (Atzei et al. 2017).

4.1.9. Challenges of Merging AI and Blockchain

AI programs may make mistakes and it would be difficult to spot these errors. Compliance might be another issue. Blockchains and AI solutions will necessitate data collation, which can be challenging (Dapp et al. 2014). Moreover, although data required for AI model training can be acquired utilising IoT devices, expertise knowledge to develop the AI algorithms that can be implemented on a blockchain platform may be difficult to find (Do and Ng 2017). Finally, merging AI and blockchains would require significant computing hardware resources (Fan et al. 2018).

4.2. Systematic Review Results

Our final sample of studies for the systematic review includes 407 articles where 102 are from industrial literature from 2013 to 2020. Research question 2: What are the gaps, similarities and trends between prior academic and industry literature in blockchain adoption in banking? is answered in this section. By carefully analysing the final sample of articles, 11 key domains or themes are identified. These 11 domains include 1. BC governance, 2. Corporate voting and BC, 3. Cryptocurrencies. 4. Exchanges and BC, 5. Payment systems and BC, 6. Trading and BC, 7. Smart contracts, 8. Data management and BC, 9. Disruptive technologies, 10. Fintech, 11. Miscellaneous.

Figure 2 illustrates the academic and industry article numbers through time and Figure 2 shows the same by domain for academic, industrial articles and the sum of both. Several articles may overlap across few domains in Figure 3. Figure 3 allows us to further identify the gaps, similarities and trends among industrial reports and academic studies.

Figure 2 shows that articles skyrocket in 2017 in academia with 99 articles while only 21 are observed from the industry. However, the greatest number from articles for the industry of 35 is observed in 2016. In this case, the academic literature appears to lag the industry by one year with regard to studies with relevance for blockchain based banking. Following Nakamoto's publication in 2008, it took several years for the research community to focus on blockchain applications in other domains (Cuccuru 2017). Most research conducted in the early years focused on infrastructure development which led to research on blockchain applications in other domains emerging primarily during 2013 and 2014. However, a steady increase of academic and industry articles can be observed until 2017 from 2015 (26 academic and 21 industry articles) and 2016 (53 academic and 35 industry articles). Stringent regulations and bans in 2018 resulted in considerable decreases in output of articles post 2018 (Allan and Hagiwara 2018). In our sample 42 academic articles are observed for 2019. However, with China's investment in Blockchain technology (BSN) and COVID-19 crisis may drive many banks and firms towards digital transformation of their businesses. Thus, interest in this area would burgeon in the future with already 15 academic articles observed so far for 2020.

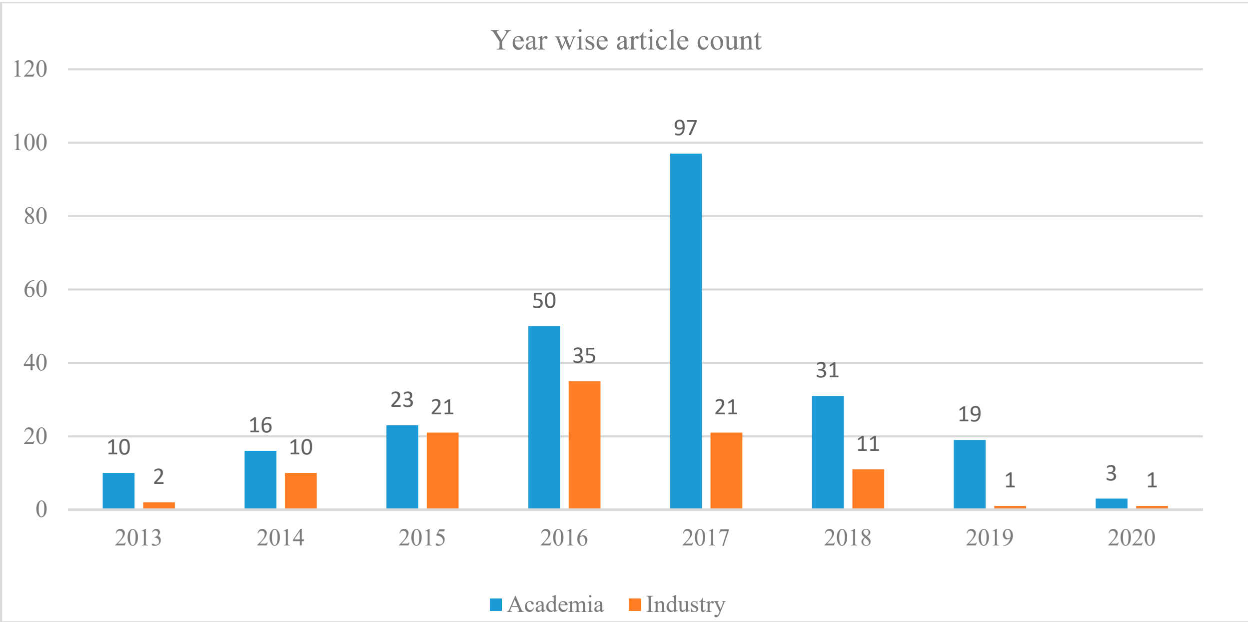

Figure 2. Article count across time.

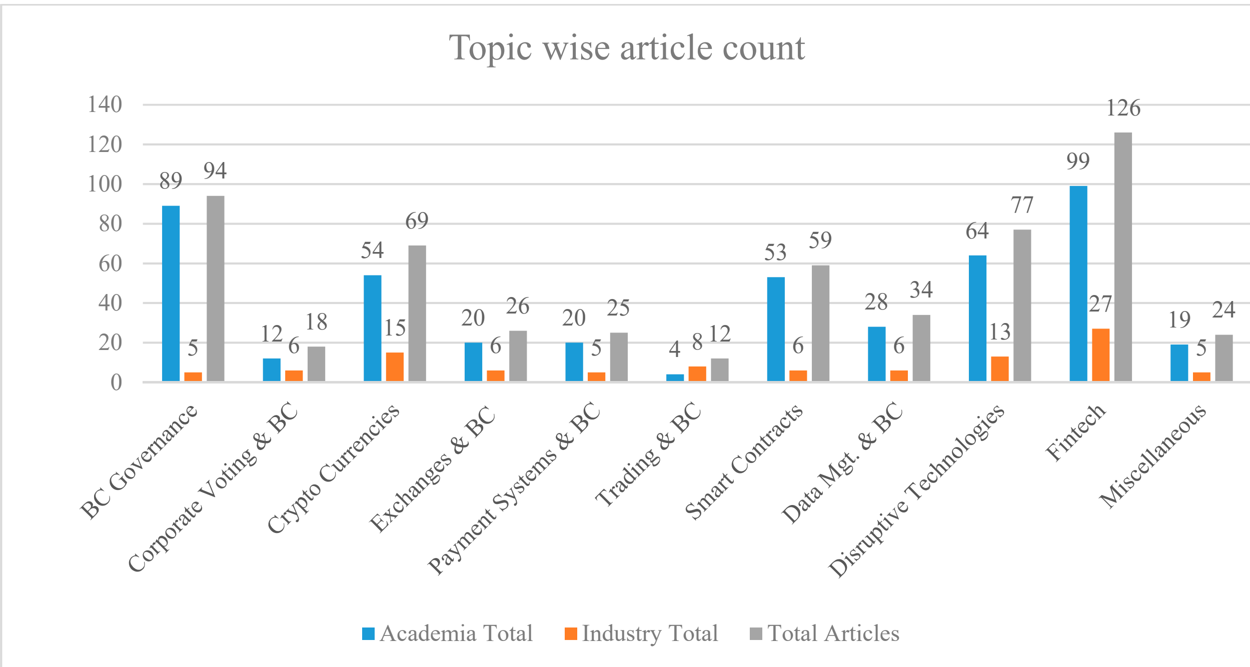

Figure 3. Article count among industry and academia across themes.

Figure 3 outlines the domain dispersal of our 407-final sample of studies. According to Figure 3, the academia mainly focusses on cryptocurrencies with 110 studies and the industry on fintechs with blockchain as the key technology of interest with 27 studies. The second most popular domain for academia is fintech with 99 studies and cryptocurrencies for the industry with 15 studies. The third most popular area for academia is blockchain governance with 92 studies. Meanwhile, the third most popular area for the industry is the disruptive nature of blockchains with 13 studies. Figure 3 clearly highlights that there is more space for exploration with regard to blockchain adoption in banking with most academic and industry articles concentrated on general applications, cryptocurrencies and blockchain governance. Thus, several domains such as corporate voting (12 in academia and six in the industry), trading (four in academia and eight in the industry) and exchanges (20 in academia and six in the industry) emerge as underexplored areas. The miscellaneous domain (24 in academia and five in the industry) identifies applications that may be repurposed for banking but primarily focus on other industries such as supply chain management, health, education and government.

4.3. Textual Analysis

Leximancer is essentially a machine learning based textual analysis tool that is used to examine large collections of documents and to visually present the mined material. The resource map provides a bird's eye view of a huge volume of material at a glance. The strength of the direct relations between concepts are indicated by the brightness of the link between concepts on the map. Themes that are not strongly linked semantically can be placed far apart on the resource map while concepts that are strongly linked will be closer to each other. In addition, the word cloud in each map places words such that, frequently occurring words are depicted in larger sizes and placed centrally. Figure 4 shows the resource map for academic literature in blockchain adoption and Figure 5 provides the resource map for the 102 industry articles.

Figure 4. Resource map for academic reports on blockchain.

Although ‘blockchain’ appears as a prominent theme for both academic and industry resource maps as shown in Figures 4 and 5, respectively, the links to other themes differ in several aspects. In addition, ‘blockchain’ as a theme is placed centrally in industry literature whereas, it is placed to the right in academic literature where ‘bitcoin’ is placed centrally. Moreover, in academic literature ‘blockchain’ as a key theme is closely associated with ‘currency’, ‘competition’, ‘paper’ and ‘governance’. Whereas, in industry literature ‘blockchain’ as a theme is more closely associated with ‘transactions’, ‘information’, ‘credit’, ‘value’ and ‘money’. This again highlights the fact that academic literature focuses mostly on theoretical aspects of blockchain whereas industry literature would primarily focus on blockchain applications and disruptions. It is again interesting to observe that although ‘fintech’ appears as a central theme in academic literature, this is not the case for industry literature and their close associated themes also differ significantly. For industry literature, the ‘fintech’ theme is closely associated with ‘services’, ‘currency’, ‘chain’, ‘finance’ and ‘money’. Whereas, for academic literature the ‘fintech’ theme is closely associated with ‘markets’, ‘discuss’, ‘fees’, ‘model’ and ‘virtual’ themes. ‘Technology’ which is another common key theme also shows similar results where it is more centrally placed in industry literature with several closely associated themes such as ‘bank’, ‘sector’, ‘cost’, ‘bitcoin’ and ‘market’. Meanwhile, in academic literature it is placed at a corner on the top with very few themes closely associated with it such as ‘financial’, ‘review’ and ‘protocol’. Even from the closely associated subthemes to the more prominent themes one can observe a divergence in interests between academic and industry literature. In addition, ‘banking’ is identified as a prominent theme in the industry literature bringing together other subthemes such as ‘ledger”, ‘products’, ‘development’ and ‘business’. Meanwhile, academic literature focuses more towards key themes such as ‘markets’ and ‘exchanges’ which are associated with ‘information’, ‘issue’, ‘settlement’, ‘bitcoin’ and ‘consensus’, ‘digital’, ‘contracts’, ‘special’, ‘fees’, ‘settlement’, respectively.

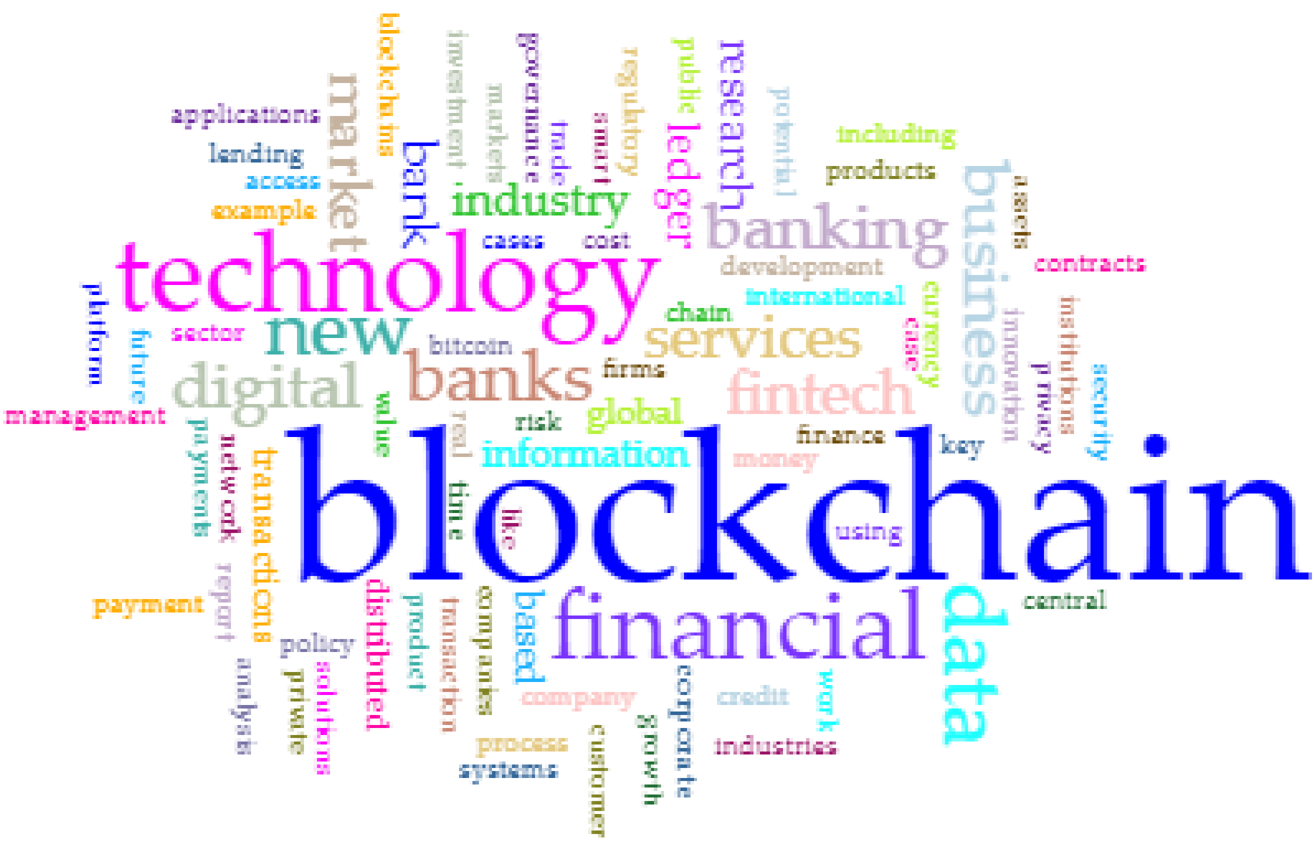

Figure 5. Resource map for industry reports on blockchain.

According to Figure 4 some the key themes arising from prior academic literature (305 studies) are 1. Blockchain (currency, competition, paper, governance) 2. Fintech (markets, discuss, fees, model, virtual) 3. Research (question, future, innovation, protocol, mining, value, time, mechanism) 4. Financial 5. Bitcoin (innovation, market, work, value, information, applications) 6. Cryptocurrency (decentralised, finance, discuss, markets) 7. Exchange (consensus, digital, contracts, special, fees, settlement) 8. Market (information, issue, settlement, bitcoin) and 9. Technology (financial, review, protocol). Within these themes we can further identify interrelated subthemes that we included in parentheses.

According to Figure 5, the key themes emerging from the industry reports are 1. Blockchain (transactions, information, credit, value, money) 2. Technology (bank, sector, cost, bitcoin, market) 3. Financial (data, work, credit, company) 4. Digital (sector, payment, management, value) 5. Services (chain, global, international, fintech) 6. Banking (ledger, products, development, business) 7. Fintech (services, currency, chain, finance, money) 8. Business (innovation, product, currency) 9. Data (central, financial). Again, the subthemes are depicted within parentheses. Thus, when comparing these two resource maps we see similarities in terms of common themes arising such as blockchain, fintech and technology. However, it is interesting to note that very few academic papers solely concentrate on blockchain in banking and the industrial reports focus more on banking use cases.

5. Behavioural/Social Impact, Economic, Regulatory and Managerial Impact

This section discusses the impact on the stakeholders identified in our framework. Herein, we answer our research question 3: What are the behavioural, social, economic, regulatory and managerial implications of blockchain adoption in banking? It is vital for banks to identify and explore and identify the impact on all these stakeholders on blockchain adoption to successfully maintain the adoption process and to achieve project objectives of profit maximisation, efficiency enhancements and cost decreases (Davidson et al. 2018).

5.1. Behavioural and Social Impact

The social impact of blockchain adoption in banking can be considerable. These would stem from privacy, transparency, security and efficiency gains by blockchains. For individuals who appreciate a stable, more transparent, and efficient banking system, blockchains might be an appealing solution. However, the use of any technology is as good as its users. Therefore, if banks create consortiums and implement permissioned blockchains that are not accessible to all parties, the transparency and security issues might still persist (Braggion et al. 2020).

5.2. Challenges

However, several challenges persist from a social and behavioural point of view for mass blockchain adoption in banking, for example, although transparency is a good thing, permissioned and only trusted party access is still important. Public disclosure of trades and transactions by institutional investors such as mutual funds and hedge funds via blockchains to retail investors may trigger market collapses or rallies that are not driven by fundamental value changes (Carvalho 2020). Another issue would be the maintenance of security standards across blockchains. Clearing systems operating on blockchains may result in a new type of fee. For example, if blockchain based exchanges request transaction fees from investors for transaction clearance. Then, investors would be racing against each other to have transactions settled. In addition, speedy scalability, quicker loan originations resulting in fast credit approvals may undermine regulatory loan-to-value (LTV) caps, thus, increasing credit risk (Braggion et al. 2020). Moreover, liquidity risks might increase to some extent from faster maturities, simultaneous retail fund withdrawals that are unexpected.

5.3. Economic Impact

Economic impact of blockchains in banking can be mostly identified by the industry (Catalini and Gans 2016). For the financial industry, banks and financial markets, blockchains offer a myriad of benefits including the elimination of single point failures through decentralisation (Beck et al. 2017; Basu et al. 2019). In addition, blockchains would streamline processes, reduce costs, decrease settlement times, digitise processes and workflows, reduce operational risk, counterparty risk and fraud (Akins et al. 2013). Thus, as a result the financial services sector and markets in general would be more accessible, transparent and efficient to its stakeholders and the general public. In addition, alternative fund raising mechanisms for blockchain based startups such as initial coin offerings will have significant impact on banks as these markets develop further (Bedi and Nashier 2020). (Albrecht et al. 2019) explores how sentiment impacts the success of blockchain startup using social media initial coin offering data.

Fichman et al. (2014) state that the banking industry is most suspicious and resistant to disruptive technologies. However, with the identified use cases in our study, we observe a change in this pattern with most banks embracing new technology through partnerships with fintechs or inhouse developments. J.P. Morgan CEO Mr. J. Dimon stated in 2014 that "Silicon Valley is coming with alternatives to traditional banking". For example, banks have already initiated blockchain based peer-to-peer (P2P) services. However, transferring to new technology such as blockchains can also create problems with existing legacy systems, firm culture, employee training and customer perceptions. In addition, the banking business model would fundamentally change with the adoption of blockchains. They would, in our opinion, become more accountable with increasingly transparent governance systems, more efficient business processes, improved alignment of objectives between banks and stakeholders. Subsequently, banks would gain access to a wider capital base, create new products and services via blockchains and experience efficient regulatory compliance and oversight (Hill 2016).

5.4. Blockchain Adoption in Banking during COVID-19 Crisis

This section also aids in answering our research question 3 in a more topical manner regarding the present state of the world. The COVID-19 crisis has accelerated not just banks but whole businesses towards digital transformation. However, blockchain plays a central role in this digital transformation, especially for banks (De Reuver et al. 2017). Key initiatives regarding blockchain in banking during COVID-19 have been on data integrity, prediction and reporting. In our opinion, focusing on payment-related services will be a good starting point for banks with blockchain adoption during COVID-19 through collaborations with fintechs. For example, digital versions of fiat currencies are not a new concept but has recently risen in popularity as a way to disperse cash at a scale (Kewell et al. 2017). International payments in banking will also benefit from regulatory friendly and compliant infrastructure. Countries such as Sweden with the e-Krona, South Korea and Japan are in late stages of implementing central bank based digital currencies (Ying et al. 2018). Management of digital identities would be another blockchain application (which can be linked to track type software and apps designed to reduce pandemic spread via community transmissions). Small to medium enterprises (SMEs) struggle to obtain financing from banks because of transparency issues with their financial data. Ant DuoChain is a blockchain based supply chain finance platform developed by Ant Financial that allows corporate customers and suppliers to share transaction details increasing trust among these parties.

5.5. Regulatory Impact

Regulatory issues regarding blockchain adoption in banking involve: 1. Privacy, 2. Money transmission, 3. KYC, 4. Informational reporting, 5. Securities law, 6. Financial reporting, 7. Taxation 8. Bank specific regulation such as Basel III, 9. Smart contract enforceability, 10. Geographic specific regulation. In the past, regulation on new technological innovations and their applications have met with considerable time lags. Regulators require time to understand the new technology, its evolving nature and applications in banking (Butenko and Larouche 2015). However, proper regulation by legal authorities in each jurisdiction can also be a positive for blockchain adoption in banking. Lack of adequate policy in a certain country may result in loosing competitive advantage of using blockchains in banking and developments would move to favourable jurisdictions (Fenwick et al. 2016a, 2016b; Barefoot 2015). In addition, lack of regulation may create criminal enterprises profiting from innovative technology (De Lis 2016). To this end, blockchain access to regulators would enhance monitoring, timely action and improve overall trust and oversight (Chanson et al. 2017). Hendrickson and Luther (2017) discuss adverse regulation (bans) towards blockchain's prime application of bitcoin and its implications. Presently, there are several regulations regarding initial coin offerings (ICOs) which is a fund-raising mechanism for blockchain related start-ups (Chen 2019). Although these financing methods are not widely used by banks, banks may partner in future with fintechs using such funding. Jayasuriya Daluwathumullagamage and Sims (2020) and Dean et al. (2020) discuss regulation on ICOs.

5.6. Managerial Impact and Ownership Rights

Given the question of regulation of blockchains for applications in banking, several issues arise.

For example, digital assets placed on a blockchain for trading or payment purposes need to possess ownership rights. The problem arises from how to enforce ownership rights created via a blockchain. In a blockchain, technically, assets can be transferred only by using the private key, safeguarding ownership to some extent. However, legal enforcement requires analysis of trading profiles and settlement agreements. Thus, blockchains would need to store information of the digital asset holder. Moreover, due to the decentralised nature of blockchains, there is no central party responsible for such information or to reconcile individual holdings (Brummer 2015). This may result in problems regarding investor protection. Nevertheless, the decentralised nature of blockchains increases continuity and eases crisis management especially for trading and payment settlement systems.

In blockchains, securities would be credited to a web account electronically. Then the legal question arises of who is the legal entity? The blockchain operator or the investor? Who has voting rights? However, using blockchains would be more transparent rather than centralised payment and exchange systems (Boucher 2016; Brandon 2016). Moreover, each digital currency used in the blockchain is unique and identifiable relieving enforcement duties of having to trace payments.

6. Limitations and Misconceptions of Blockchain in Banking

This section answers our research question 4. What are the challenges, misconceptions and limitations for blockchain adoption in banking? This section identifies that present and future blockchain use cases in banking face the following challenges: upgrades of regulations and legislation, security, standards for identity verification, interoperability, latency, scalability, reputation, transparency and energy consumption (Bartoletti et al. 2017; Baxendale 2016). Along with its numerous advantages in banking, blockchain has challenges unique to its nature. These challenges and limitations are identified in our framework from prior literature and iarediscussed in detail in this section. A key challenge often lost among the many technical challenges of blockchain adoption is the reputation challenge (Andolfatto 2018). Most customers would perceive blockchain to be connected to cryptocurrencies. Hence, any blockchain based or digital currency application might be met with increased privacy and security concerns (Krugman 2013). In addition, further limitations as identified by our framework include organisational challenges at banks such as bank culture (Llewellyn 2016), proper data governance, lack of skilled employees, attitudes of incumbents and productivity paradoxes (Deitz 2014; Carney 2017). Moreover, absence of good governance practices, user experience and education, understanding and awareness, absence of, privacy and security controls, regulatory uncertainty (Deloitte 2017; Hughes et al. 2019) further hinders adoption.

6.1. Interoperability

A key problem with regard to blockchains is the lack of international standards, rules and regulations. Therefore, the compatibility and interoperability among blockchains implemented by several banks, exchanges would be a key issue (Koteska et al. 2017). Another challenge would be integrating legacy systems with blockchains (Salah et al. 2019). In addition, there is a low supply of user-friendly blockchain application programming interfaces (Chen and Xue 2017).

6.2. Privacy and Security

Data stored in the blockchain should be kept secure even with trusted party access and permissioned blockchains (Ahram et al. 2017). Private keys are an important element of blockchains (Augot et al. 2017). However, the generated private key must be kept securely as misplaced or lost keys would be problematic. In addition, the encryption methods utilised to store the data may be compromised by accessing network loopholes (Mendling et al. 2018). Blockchain based banking systems need to be made more robust security-wise by using more advanced security protocols that can restrict stakeholders to only access permissions given to them (Chepurnoy et al. 2016; Cong et al. 2020).

6.3. Scalability

Blockchain based banking systems would have to be able to handle large volumes and significant instant growths in real time (Andolfatto 2018). The number of transactions and blocks will keep increasing and the network should be able to sustain this growth, and traffic efficiently while maintaining speeds (Zetzsche et al. 2017; Babich and Hilary 2019).

6.4. Latency

Adequate secure creation of a Bitcoin transaction takes approximately 10 min per transaction (Blockchain Weaknesses 2017). Thus, to obtain security and efficiency gains, more time would need to be spent on creating a block, taking longer to complete transactions (Karafiloski and Mishev 2017). This is problematic as at present VISA takes only a few seconds to complete a transaction.

6.5. Energy Consumption

Energy consumption is increased by using proof-of-work method to reward miners in blockchains due to the massive computational power required (Blockchain Hash Rate Distribution 2017). Thus, banks would have to be conscious about leaving this carbon footprint and wasting energy. For example, mining Bitcoin wastes USD 15million/day. Alternatives such as proof-of-stake may have to be used (World Energy Council and PwC 2018).

6.6. Regulation

Wide adoption of blockchains in banking would require international standards and regulation to become mandatory (Zhou et al. 2015). At present, cryptocurrencies are the most popular application of blockchain and have no uniform regulation making them susceptible to volatile price changes (Tsukerman 2015; Castellanos et al. 2017). Such large prices swings would have to be avoided for wider adoption of blockchains in banking (Dimon 2014). In the U.S., blockchain focused regulation was newly created or present regulation was modified to incorporate minimum identification requirements (Dierksmeier and Seele 2016; Arner et al. 2017). Nevertheless, international exchanges may be used by investors to circumvent such regulation. This shows the significance of even international standards and regulation such as the Basel accords and international accounting standards for blockchains.

In addition, regulations similar to the General Data Protection Regulation (GDPR) may affect data gathered for blockchains from third parties

Firms and stakeholders would be wise not to include personal information on blockchains, rather this information should be stored off-chain (Axon 2015). Additionally, it is yet another reason why permissioned blockchains are likely to be used in financial markets rather than public ones.

7. Conclusions

Emergence of blockchain technology especially in banking, simultaneously interacts and challenges firms, traditional financial intermediation methods, stakeholders and financial markets (Christensen 2016; Cai 2018). These factors inform our motivation to focus on the adoption of blockchain in banking. To our knowledge this is the first study to conduct a systematic review of blockchain adoption solely focused on banking, develop a framework for banking based blockchains and identify gaps and parallels among industrial and academic literature. Our systematic review included 407 final articles from 2013 to 2020 from an initial record search of 1979 articles. Our objective was to demystify blockchains and highlight the widespread development and adoption of different blockchain platforms in banking. Moreover, our study brings together the widely dispersed blockchain literature with regard to banking and identify trends, issues and adoption drivers and limitations in a coherent manner. This study further identifies behavioural, social, economic, regulatory and managerial implications of blockchain adoption in banking. Our analysis would be of interest to banks, fintechs, investors in banks and fintechs, regulators and other stakeholders and interested parties.

Based on our systematic review and textual analysis of 407 articles, we conclude that both academic and industry literature focus on common themes such as blockchain, fintech and technology. However, a disparity arises with regard to individual applications of blockchain in banking with industry reports focusing more on banking use cases and academic literature largely focusing on fintech and cryptocurrencies. We were also able to identify underexplored areas in both academic and industry literature such as corporate voting, trading and exchanges. The study further highlights challenges of blockchain adoption in banking which includes but is not limited to reputational issues, culture, interoperability, scalability, latency, privacy and security, regulation and energy consumption. Although blockchain enabled banks may be fantastic beasts, where to find them might yet be in the future.

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