CHAPTER 10

Blockchain Beyond Cryptocurrencies

Pierangelo Rosati and Tilen Čuk

Abstract It is claimed that blockchain technology has the potential to revolutionise how financial services firms conduct their business. This chapter presents the main characteristics of blockchain technology and summarises the extant research around the potential implications of blockchain adoption for four main financial activities: payments and remittance, credit and lending, trading and settlement, and compliance. Current gaps in the literature are discussed in order to identify avenues for future research.

Keywords Blockchain · Distributed ledger technology

P. Rosati (✉)
DCU Business School, Dublin City University, Dublin, Ireland
e-mail: pierangelo.rosati@dcu.ie

T. Čuk
Centre Perelman de Philosophie du Droit,
Université Libre de Bruxelles, Brussels, Belgium

T. Lynn et al. (eds.), *Disrupting Finance*, Palgrave Studies
in Digital Business & Enabling Technologies,
https://doi.org/10.1007/978-3-030-02330-0_10

10.1 Introduction

The financial services industry plays a key role for businesses and society since it enables saving and investment, provides protection from risks and supports the creation of new jobs and enterprises (World Economic Forum 2013, 2016). Developments in information technologies have changed the industry over time by enabling an enormous increase in transactions and diversified products (Gardner 2011). However, the pace of innovation in the sector has traditionally been very slow (Gardner 2011; Michel 2014). This is mostly due to the regulatory burden and to the conservative culture embedded within the industry (Gardner 2011; Michel 2014; Das et al. 2018). The result is a linear and predictable innovation pattern (Luftenegger et al. 2010) with only five major technological innovations in a 50-year period, namely: (1) computerised information systems in 1950s (Luftenegger et al. 2010), (2) automatic teller machines (ATMs) in 1960s (Batiz-Lazo 2009), (3) electronic stock trading in 1970s (Terrell 2010), (4) mainframe computers in 1980s, and (5) the Internet in the 1990s/early 2000s (Desai 2015).

However, things have changed significantly over the last decade. As the industry moves to what the International Data Corporation refers to as the "third platform"—a technology trend towards ubiquitous computing, big data, and the widespread adoption of social and mobile technologies (IDC 2012) in response to customer expectations for more innovative and personalised products. Regulatory changes such as, for example, the new EU Payment Service Directive (PSD2), which is discussed in Chapter 7 of this book, aim to significantly lower the barriers to market entry, therefore increasing competition. These recent changes have triggered what scholars and practitioners refer to as the "FinTech revolution" (Mackenzie 2015; Gomber et al. 2018), built around three main pillars: (1) capital availability both for start-ups in the form of venture capital and for incumbents; (2) new technologies; and (3) new business models (Gomber et al. 2018).

As an enabling and disruptive technology, blockchain is arguably at the core of the FinTech revolution and has the potential to radically change a large number of activities and processes within the industry. These changes are expected to provide huge improvements in efficiency, generating potential savings of $16–20 billion a year (Santander 2015; Capgemini 2016).

Blockchain is mostly known as the technology underpinning Bitcoin, "*a payment system based on cryptographic proof instead of trust*" (Nakamoto 2008, p. 1), also referred to as cryptocurrency. While cryptocurrencies have been discussed in Chapter 9, this part of the book explores other blockchain applications for the financial sector and discusses related literature gathered from the finance, information systems and computer science fields. The rest of the chapter is structured as follows. The next section provides an overview of blockchain technology. This is followed by a discussion of the current challenges that the technology poses for financial services firms, and the impact of blockchain on four main financial activities: (1) payments and remittance, (2) credit and lending, (3) trading and settlement, and (4) compliance. The chapter concludes with a discussion of further avenues for research.

10.2 What Is Blockchain?

Commercial transactions have been stored in ledgers since ancient times. Initially kept on clay tablets or papyrus, they then moved to paper and ultimately to bytes with the advent of computerised information systems (Rosati and Paulsson 2017). Regardless the format in which ledgers were kept, they have traditionally relied on human inputs; as such, ledgers have been prone to errors which translate into additional costs and inefficiencies for organisations and for the economic system as a whole. Digital distributed ledgers promise to fix these issues through a unique combination of distributed networks and cryptography. Blockchain technology is by far the most famous example of distributed ledgers technologies (Beck et al. 2017). It was first launched in 2008 by either a programmer or a group of programmers under the pseudonym of Satoshi Nakamoto (Nakamoto 2008) and today is mostly known for being the technology underpinning Bitcoin, arguably the most famous open-source peer-to-peer digital currency (Mougayar 2016). However, potential applications of blockchain extend beyond digital currencies, potentially impacting corporate governance, social institutions, democratic participation, and the functioning of capital markets (Wright and De Filippi 2015).

Blockchain can be defined as a decentralised, transactional database that enables validated, tamper-resistant transactions across a large number of participants (i.e. nodes) in a network (Glaser 2017;

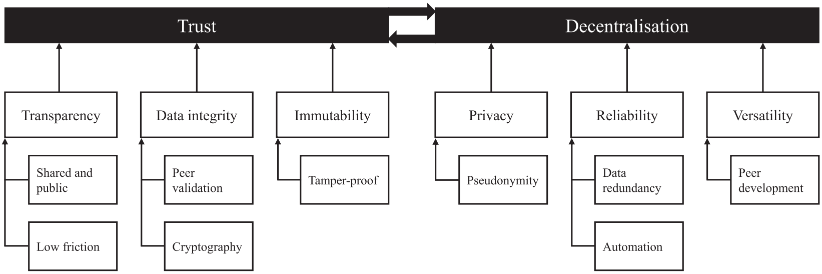

Fig. 10.1 Characteristics of blockchain (Adapted from Seebacher and Schüritz [2017])

Beck et al. 2018). But blockchain is not just a technological innovation. By providing a valid alternative to traditional trusted intermediaries, it also carries philosophical, cultural, and ideological underpinnings that have to be taken into account (Mougayar 2016). For this reason, Mougayar (2016) proposes to integrate the technical definition with a business definition and a legal definition. From a business point of view, blockchain can be defined as a peer-to-peer exchange network for transferring value, while, from a legal perspective, it can be defined as a technology to validate transactions.

Blockchain has two main characteristics (Fig. 10.1). First, it brings trust where there is none (Beck et al. 2016; Rosati et al. 2016; Tapscott and Tapscott 2016; Glaser 2017). In fact, blockchain-based systems ensure higher transparency by making information available to all network participants, but they also leverage cryptography and peer validation of transactions to ensure data integrity and record immutability (Böhme et al. 2015; Sun et al. 2016). Second, blockchain-based systems are fully distributed. Users' privacy is protected by using pseudonyms while the system's reliability is ensured by storing a copy of the database in every node (Böhme et al. 2015; Beck et al. 2016; Weber et al. 2016). These two key characteristics of blockchain are ultimately interconnected as mechanisms to build trust are needed for creating a decentralised network, and decentralisation provides the means for users to get involved in the network by establishing the basis for a consensus mechanism (Seebacher and Schüritz 2017).

Users' ability to read and submit transactions to a blockchain depends on their access to transactions. There are different "flavours" of

Table 10.1 Types of blockchain (Adapted from Beck et al. [2018])

	Access to transaction validation	
Access to transactions	*Permissioned*	*Permissionless*
Public	All nodes can read and submit transactions. Only authorised nodes can validate transactions—e.g. Ripple	All nodes can read, submit and validate transactions—e.g. Bitcoin
Private	Only authorised nodes can read, submit and validate transactions—e.g. R3 Corda	Not applicable

blockchain (Table 10.1). In a public (permissionless) blockchain, every node can read and submit (validate) transactions while in a private (permissioned) blockchain only authorised nodes can (Peters and Panayi 2016).

Regardless of the type of blockchain, there are some key features that are common (although to different extents) to all of them (Mougayar 2016):

- Distributed network: the adoption of a blockchain removes all centralised entities and distributes access to all of the participants (i.e. nodes) in the network. In other words, all participants in the network, and not a specific one, can verify the transactions. Miners are key actors in this distributed network as they work to solve the computational problems that allow to create, verify, and securely store transactions.
- Cryptography: it enables parties to maintain the privacy of the information they send to each other. Blockchain uses Public Key Infrastructure (PKI) mechanisms to execute transactions. Each blockchain user has a public key and a private key. In order to complete a transaction, a sender needs to know the public key of the receiver who can decrypt the message by using its own private key. Every transaction is stored in a block, which has a unique fingerprint (i.e. hash) that ensures the authentication of the transaction source.
- Timestamp: every transaction that occurs on the blockchain is timestamped and no one is able to change it once it has been recorded.

Blockchain is mostly known for its ability to process monetary and financial transactions. However, it can also ensure that transactions comply with specific rules parties have agreed upon in the form of "smart contracts" (Tschorsch and Scheuermann 2016; Risius and Spohrer 2017). Beck and Müller-Bloch (2017) refer to blockchains supporting this kind of applications as "blockchain 2.0".

Despite all the hype around blockchain, it is still a nascent technology and there are technical, non-technical, and regulatory challenges to overcome in order to foster adoption. Extant academic research has focused on technical aspects of blockchain (Yli-Huumo et al. 2016; Risius and Spohrer 2017) but a number of issues, such as efficiency, latency, throughput, scalability, security, and systems integration still need to be (partially) addressed (Yli-Huumo et al. 2016). Security issues represent real concerns for financial institutions as they store and exchange highly sensitive information about their customers and operate under strict regulations. In addition, the new European General Data Protection Regulation[1] (GDPR) now requires organisations to obtain specific consent from their clients to use their private information. With permissionless public blockchains, it is difficult to control who accesses the blockchain. As such, financial institutions are more likely to adopt a private or permissioned blockchain than a public blockchain (Fink 2017). However, due to smaller number of participants (i.e. nodes), private or permissioned blockchains are more vulnerable to 51-percent attacks[2] (Peters and Panayi 2016; Yli-Huumo et al. 2016). Further research is arguably needed in this space in order to increase technology adoption in the financial sector.

Non-technical challenges, instead, are mostly related to (a) building up innovation legitimacy (Lynn et al. 2018), (b) understanding the determinants of users' adoption, (c) measuring the value generated by blockchain investments, and (d) assessing potential impacts on society (Risius and Spohrer 2017). Finally, regulatory challenges mostly arise from the distributed nature of blockchain applications which, by definition, can span across multiple jurisdictions, with responsibilities for system maintenance are shared among all network participants (Yeoh 2017).

[1] See https://gdpr-info.eu/ for further details.

[2] "The ability of someone controlling a majority of network hash rate to revise transaction history and prevent new transactions from confirming" (Bitcoin.org 2018).

10.3 Payments and Remittance

Departing from cryptocurrencies, here we mainly focus on interbank and cross-border payments which are often processed by intermediary clearing firms. These processes require a series of complicated processes including bookkeeping and transactions and balance reconciliations across multiple financial institutions[3] (Guo and Liang 2016). The result is a long and time-consuming process which often translates in delays in payments settlement and additional costs. Cross-border payments totalled $27.7 trillion in the first quarter of 2017 (BIS 2017), and represent 20% of total transaction volumes in the payments industry and 50% of the revenues (McKinsey 2016). Notwithstanding the scale, 43% of the capital transferred is lost in transaction costs (Guo and Liang 2016).

Beside the actual transaction cost, the time delay between payment initiation and settlement creates a risk for the parties involved; this is mostly related to the risk default of the counterparty and to fluctuations of the foreign currency whose value is determined by market rules (Bott and Milkau 2017). By enabling peer-to-peer payments and by offering 24/7 settlements, blockchain can reduce transaction costs and risk while bringing (almost) real-time settlements and increased transparency and traceability (Buitenhek 2016). Given these undeniable benefits, it is not surprising that both central banks and private institutions have started looking at blockchain-based applications for payments (Bott and Milkau 2017).

Inefficient payments processing is a business as much as an ethical problem. In fact, cross-border multi-currency payments are not only associated with business transactions; remittance also accounts for a significant amount of cross-border money transfers. According to recent World Bank estimates, international remittance totalled $585 billion in 2017, 7.32% of which was lost in transfer fees (World Bank 2017). In addition, 39% of the world's population, mostly comprised of the population in developing countries, does not have a bank account making it very hard for the receiver to actually collect the money being transferred (Mesropyan 2016). In this context, thoughtful combinations of blockchain systems and mobile technologies could potentially put billions back

[3] See, for example, Park (2016) for more details on the current cross-border payment settlement process.

into the pockets of families in developing countries therefore reducing (at least partially) the gap with richer countries.

10.4 Credit and Lending

Credit and lending is another area where blockchain can significantly change current operations. Other chapters in this book discuss peer-to-peer lending (Chapter 2) and crowdfunding (Chapter 1), two well-established innovations in the FinTech landscape with significant growth rates. Despite the attention they receive today, these practices are essentially as old as commerce; the main difference is that they were traditionally based on informal and interpersonal trust relationships. Peer-to-peer platforms have essentially found a way to reduce information asymmetry and formalise the relationship between parties therefore increasing trust between the two sides of the market, and, of course, to profit from their intermediation role. As a technology enabling peer-to-peer "trust-free" transactions, blockchain can replace both traditional (e.g. banks, credit unions) and new intermediaries (e.g. peer-to-peer lending platforms) therefore lowering transaction costs of lending and business financing (Larios-Hernández 2017). A typical example is the adoption of blockchain-based tokens to enable disintermediated crowdfunding campaigns also known as Initial Coin Offerings[4] (ICOs) (see, among others, Rohr and Wright 2017; Adhami et al. 2018; Catalini and Gans 2018; Chen 2018; Howell et al. 2018). Despite all the attention these blockchain-enabled peer-to-peer systems are receiving from investors, regulators, and the media, the volume of capital that goes through these channels still represents a tiny portion of the overall credit/lending market. As Hawlitschek et al. (2018) suggest, these systems still struggle in crossing users' "trust frontier". The authors further suggest that a widespread adoption of these systems depends on the development of trusted interfaces.

In the context of credit and lending, blockchain could also be leveraged to improve lenders' decision-making. Risk assessment of potential borrowers (be it a company or an individual) is usually based on the historical records of financial transactions. Data availability and quality, however, pose significant challenges to the validity and robustness of

[4] This topic is discussed in more details in the previous chapter.

credit score models (Abdou and Pointon 2011). These issues are particularly pronounced when potential borrowers are small- and medium-sized businesses or individuals for which information is rarely publicly and/or readily available (Thomas et al. 2017). This ultimately results in inefficient capital allocation (Jacobson and Roszbach 2003) and lost growth opportunities (Beck and Demirguc-Kunt 2006).

In order to overcome these limitations, financial institutions have started looking at using "alternative data" in their models such as mobile-phone information, psychometric testing, social media activity, or ecommerce transactions (McEvoy 2014). However, collecting, aggregating, and integrating data from different sources can be challenging and require specialist skills that financial companies do not always have in-house. The growing demand for this kind of service has led to the emergence of data marketplaces (Stahl et al. 2014). Data marketplaces usually offer a wide range of capabilities, such as data gathering, aggregation, integration, processing, enrichment, etc. (Roman and Gatti 2016). When it comes to credit scoring, data marketplaces can represent a common point of entry for perspective lenders and borrowers through which information is exchanged securely (Roman and Gatti 2016). Data marketplaces are essentially centralised systems, therefore require different stakeholders to trust a third-party managing their data. This may prove to be particularly challenging for very sensitive and potentially valuable data like those used for credit scoring. In this context, blockchain can be leveraged to create disintermediated trusted data marketplaces that securely connect together information providers, perspective borrowers and lenders, and guarantees data provenance and data integrity (Roman and Gatti 2016). Blockchain-enabled systems have therefore the potential to improve the credit scoring processes, therefore lowering default rates and providing undoubted economic benefits (Byströrm 2016).

10.5 Trading and Settlements

Chapter 8 in this book is dedicated to recent advancements in trading technology. Even though trade execution time has been brought down to milliseconds, post-trade settlement is still a lengthy and redundant process that spans over multiple days. Two-day (T+2) or three-day (T+3) settlement is still the industry standard but more complex transactions like syndicated loans can take up to three weeks (Chiu and

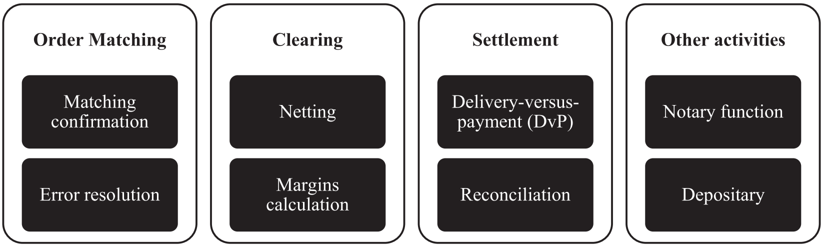

Fig. 10.2 Typical post-trade activities

Koeppl 2018). Figure 10.2 provides a brief summary of typical post-trade activities.[5]

As per payments, long settlement time and inefficient processes generate considerable costs and risk for the counterparties involved in a transaction. According to Broadridge (2015), industry spends $6 billion to $9 billion per year in core and ancillaries post-trade activities for standardised asset classes like equities and fixed income, but these figures go up to $24 billion when including more sophisticated asset classes and over-the-counter (OTC) markets.

Benos et al. (2017) argue that blockchain may impact the post-trade cycle in six ways:

- Reducing reconciliation and data management costs: the adoption of blockchain technology would allow the creation of a distributed, shared and synchronised database of security ownership. As such, it can simplify and automate most post-trade processes and significantly reduce the need for reconciliation. Mainelli and Milne (2016) estimate a potential 50% reduction for this kind of transaction costs.
- Flexible settlement times: intermediaries currently have at least a full day to prepare the settlement and borrow securities or cash as needed, therefore managing their own liquidity. A T+0 (same-day) settlement, although desirable from a risk management perspective, would also require intermediaries to borrow cash or securities in advance, therefore increasing liquidity risk. In this context, flexible

[5] See AFME (2015) for more details.

settlement times appear more desirable in a blockchain environment, and could be implemented via smart contracts therefore creating benefits for all market participants. Khapko and Zoican (2018) demonstrate that a combination of flexible or short settlement cycles, coupled with option-like penalties for failures-to-deliver, would discipline competition on securities lending markets and improve market quality.

- Automated clearing: in a blockchain environment, when a trade is agreed the calculation of obligations (i.e. netting) could happen automatically and simultaneously therefore reducing the need for a clearing agent.
- Direct ownership: in the current market settings, investors are not always the owners of the securities they trade. There is indeed a chain of custodians who hold securities and act as intermediaries between issuers and investors. This creates implications for shareholder rights (Micheler 2015; Van der Elst and Lafarre 2018). When securities are issued in the form of (or can be transformed into) digital tokens, blockchain could facilitate direct ownership and increase transparency in the market, therefore enabling peer-to-peer trading.
- Traceability and transparency: blockchain is an "append-only" database. In other words, records cannot be deleted or altered once they have been stored in a block. This provides full traceability of transactions. The ledger is also shared among network participants, therefore increasing transparency. However, as Malinova and Park (2017) point out, investors often prefer privacy over transparency even when the latter may be socially desirable. Building on this point, the authors propose a blockchain-based market setting, which maximises social welfare, while protecting investors' privacy.
- Security and resilience: being a decentralised system, a blockchain does not have a single point of failure. As such, it is more resilient to cyberattacks and not subject to cybersecurity-related downtimes to the same degree.

Benos et al. (2017) also highlight a number of challenges to overcome before blockchain goes mainstream in the area of clearing and settlement. These are mostly related to (1) interaction between the digital and the physical world (e.g. current legacy assets held by custodians), (2) legal and regulatory limitations (e.g. proof of ownership), and (3) technology readiness (e.g. scalability and throughput). A number of initiatives have been undertaken to overcome regulatory barriers (Van der Elst and Laferre 2018). For example, the State of Delaware explicitly reference the use of blockchain technology in Section 224[6] of the general corporation law (DGCL) on July 21, 2017. Also, there are ongoing efforts from multiple stakeholders aiming to enhance blockchain performance and reliability (Yli-Huumo et al. 2016; Higgins 2018; Chiu and Koeppl 2018), which suggest that it will not be long before blockchain-based applications start moving from the proof-of-concept stage to the production stage. For example, the European Central Bank and the Central Bank of Japan have already conducted a first study to evaluate the possibility of using blockchain for real-time gross settlements that are crucial in conducting monetary policy (ECB 2017).

10.6 Compliance

Regulation is becoming increasingly burdensome in financial services. In order to increase investor protection and to prevent financial crime, post-crisis regulatory changes have dramatically increased the amount of reporting and compliance requirements for all the actors involved in the industry. Banks spent almost $100 billion for compliance in 2016 (McDowell 2017) and the overall expenditure is growing year-by-year (Thomson Reuters 2018). Regulatory technology (RegTech[7]) may be a way to reduce these costs and so financial services are investing a significant amount of resources in this direction (Spezzati 2017).

In this section, we will focus on three main regulatory frameworks: (1) the EU Markets in Financial Instruments Directive (MiFID II[8]) and the corresponding US Dodd–Frank Wall Street Reform and Consumer

[6] "Any records administered by or on behalf of the corporation in the regular course of its business, including its stock ledger, books of account, and minute books, may be kept on, or by means of, or be in the form of, any information storage device, method, or 1 or more electronic networks or databases (including 1 or more distributed electronic networks or databases) […]" (Delaware General Corporation Law—Section 224).

[7] Chapter 6 covers this topic in more details.

[8] https://ec.europa.eu/info/business-economy-euro/banking-and-finance/financial-markets/securities-markets/investment-services-and-regulated-markets-markets-financial-instruments-directive-mifid_en.

Protection Act,[9] (2) Know Your Customer (KYC) and Anti-Money Laundering (AML) regulation, and (3) financial reporting standards (IFRS/IAS). Blockchain can help financial companies and regulators in handling compliance requirements across all these areas. MiFID II and the Dodd-Frank have been enacted in response to the global financial crisis with the main objective of increasing transparency in the financial markets and strengthening investor protection (Black 2010; Prorokowski 2015). Both regulations require financial firms to keep track of all interactions related to every single transaction. Comprehensive, traceable and time-stamped reporting is essential to comply with these regulations and this is where blockchain may represent a valuable solution. For example, Sheridan (2017) argues that a publicly available blockchain can be an effective solution to effectively communicate equivalence decisions under MiFID II; this would represent a single source of truth for identifying third-party countries that are allowed to conduct financial business in the EU. Similarly, a distributed ledger can be used by different regulators to uniformly record firm-by-firm authorisations and permissions.

Processes for KYC/AML compliance are particularly redundant. Financial institutions are required to onboard their customers before conducting any business activity with them in order to avoid working with/for customers involved in illegal activities (Ruce 2011). The onboarding process consists of an exchange of documents and information between a financial institution and the perspective customer. Even though most of the documents required for onboarding customers are standardised, the overall process has to be repeated by each institution for each customer with which it wants to interact. Secure and reliable information sharing could eliminate redundancies therefore making the process more efficient and improving customer experience (Moyano and Ross 2017). Moyano and Ross (2017) propose a system architecture for a distributed ledger through which financial institutions can verify the result of standardised KYC tasks that have already been conducted for a specific customer. Such a system would lower the cost associated with KYC processes without compromising participants' security and privacy.

Financial reporting quality is historically a key concern for regulators. Even though this applies to every industry, the financial sector has traditionally received special attention in this respect due to the key enabling

[9] https://www.govtrack.us/congress/bills/111/hr4173/text.

role that it plays in the economy. Standard setters are continuously trying to increase the transparency and accuracy of financial statements, and to unify financial reporting practices across multiple jurisdictions (Barth et al. 2008). There is still limited evidence of blockchain applications for financial reporting purposes (Dai and Vasarhelyi 2017) and some contrasting opinions in the literature (Coyne and McMickle 2017). However, some characteristics of the blockchain like data integrity, (almost) real-time updates, instant sharing of necessary information, and programmable and automatic controls may represent the basis for a new financial reporting ecosystem (Dai and Vasarhelyi 2017). Dai and Vasarhelyi (2017) present a first example of a blockchain-enabled triple-entry accounting information system, which may represent a step forward towards real continuous auditing. In a similar vein, Wang and Kogan (2018) propose a prototype of a blockchain-based transaction processing system for real-time accounting that leverages zero-knowledge proofs to find a trade-off between transparency and confidentiality. This kind of financial reporting systems could prove to be particularly suitable for the financial sector where every transaction has to be recorded and where traceability and records' immutability are extremely important to prevent fraud. Furthermore, auditors and regulators may be able to access financial records in real time if needed, therefore increasing transparency and timely interventions where needed.

10.7 Conclusion and Avenues for Future Research

This chapter provides an overview of blockchain technology and of the extant literature on its potential applications and implications for the financial sector. Despite all the hype and all the promises around blockchain technology, it still remains an early-stage technology; the number of potential use cases is getting larger and larger but very few of them have made their way to the market. This is particularly the case for financial services where conservatism and regulatory requirements represent significant challenges for innovation.

Blockchain is, in essence, a technological innovation. Thus, perhaps unsurprisingly, most of the research so far comes from computer science domain. Even though pure technical aspects of blockchain go beyond the scope of this chapter, it is worth to briefly mention some existing technical challenges that also represent opportunities for research. First of all, integrating existing legacy systems with blockchain is still a very difficult task; it would be naïve to think that organisations will get rid of existing systems to move to blockchain-based systems. Therefore, integration/migration patterns have to be identified in order to streamline adoption. The trade-off between security, performance, and sustainability is another topic that is widely discussed. In relation to this, different combinations of block sizes and encryption and consensus mechanisms are being explored; different combinations are likely to be more suitable for some applications but not for others, hence the need for a contingency approach to this issue.

Although there are a number of question marks around blockchain as a technology, the number of technical studies is arguably growing fast (Yli-Huumo et al. 2016). The same cannot be said for organisational and business-related research (Risius and Spohrer 2017). In a conservative, heavily regulated and profit-driven sector like financial services, reducing the uncertainty around implementation outcomes, and increasing regulatory and community acceptance are likely to play a critical role in fostering blockchain adoption. We identify at least two ways to reduce uncertainty: (1) in-depth investigations of different use cases: as Risius and Spohrer (2017) also point out the number of business case studies is still very limited; (2) a suitability framework for blockchain applications: not all applications or all organisations may benefit from blockchain adoption, therefore a suitability framework like the one proposed by Misra and Mondal (2011) for cloud computing applications may represent a useful "reality check" for organisations. Building legitimacy around blockchain is extremely important in this context in order to increase regulatory and community (i.e. customers, employees, investors, and other stakeholders) acceptance (Rosati et al. 2016; Lynn et al. 2018). While Lynn et al. (2018) offer a first approach to this matter, further research is needed to gain a deep understanding of how blockchain legitimacy is changing over time, and if and how organisations are proactively trying to build it across multiple audiences (i.e. stakeholders). Regulators indeed have mostly taken a "wait and see" position on blockchain so far but they would be more likely to incentivise the adoption of a technology that is welcomed by multiple stakeholders. Finally, creating an analytical framework for measuring the value generated by blockchain investments may be extremely useful for building business cases for blockchain adoption. This is particularly relevant for financial services where financial resources are usually available but are allocated based on the return they are expected to generate. In this context being able to assess and quantify, with reasonable certainty, the impact of blockchain technology over the short and long term likely facilitates management buy-in.

This chapter has provided an overview of potential blockchain applications for the financial services sector and discussed related academic literature. As blockchain has the potential to automate many financial operations, it can generate significant gains in efficiency across the entire sector. For some intermediaries like brokers, clearing, and settlement houses though, those efficiency gains will result in lower revenues. The advent of blockchain technology poses significant challenges for these actors, who must radically reconsider their value propositions in order to stay in business. However, blockchain still remains at an early stage of development and the extent of changes it can generate in the financial sector is contingent to overcoming its current technical limitations and to increasing the acceptance of different stakeholders. A more collaborative approach to research across different academic disciplines and industry could be particularly fruitful in this context to advance the technology and realise its full potential.

References

Abdou, H. A., & Pointon, J. (2011). Credit scoring, statistical techniques and evaluation criteria: A review of the literature. *Intelligent Systems in Accounting, Finance and Management, 18*(2–3), 59–88.

Adhami, S., Giudici, G., & Martinazzi, S. (2018). Why do businesses go crypto? An empirical analysis of initial coin offerings. *Journal of Economics and Business*, forthcoming.

AFME. (2015). *Post trade explained—The role of post-trade services in the financial sector*. Available at: https://www.afme.eu/globalassets/downloads/publications/afme-post-trade-explained.pdf. Last accessed 10 August 2018.

Bank for International Settlements (BIS). (2017). *BIS international banking statistics at end-March 2017*. Available at: https://www.bis.org/statistics/rppb1707.pdf. Last accessed 15 August 2018.

Barth, M. E., Landsman, W. R., & Lang, M. H. (2008). International accounting standards and accounting quality. *Journal of Accounting Research, 46*(3), 467–498.

Batiz-Lazo, B. (2009). Emergence and evolution of ATM networks in the UK, 1967–2000. *Business History, 51*(1), 1–27.

Beck, R., Avital, M., Rossi, M., & Thatcher, J. B. (2017). Blockchain technology in business and information systems research. *Business & Information Systems Engineering, 59*(6), 381–384.

Beck, T., & Demirguc-Kunt, A. (2006). Small and medium-size enterprises: Access to finance as a growth constraint. *Journal of Banking and Finance, 30*(11), 2931–2943.

Beck, R., Czepluch, J. S., Lollike, N., & Malone, S. O. (2016). Blockchain—The gateway to trust-free cryptographic transactions. *24th European Conference on Information Systems (ECIS 2016)*. Istanbul, Turkey.

Beck, R., & Müller-Bloch, C. (2017). Blockchain as radical innovation: A framework for engaging with distributed ledgers. In *Proceedings of the 50th Hawaii International Conference on System Sciences.* Waikoloa Village.

Beck, R., Müller-Bloch, C., & King, J. L. (2018). Governance in the blockchain economy: A framework and research agenda. *Journal of the Association for Information Systems.*

Benos, E., Garratt, R., & Gurrola-Perez, P. (2017). The economics of distributed ledger technology for securities settlement. Available at SSRN: https://ssrn.com/abstract=3023779.

Bitcoin.org. (2018). *51% attack, majority hash rate attack*. Available at: https://bitcoin.org/en/glossary/51-percent-attack. Last accessed 29 August 2018.

Black, B. (2010). How to improve retail investor protection after the Dodd-Frank Wall Street Reform and Consumer Protection Act. *University of Pennsylvania Journal of Business Law, 13,* 59–106.

Böhme, R., Christin, N., Edelman, B., & Moore, T. (2015). Bitcoin: Economics, technology, and governance. *Journal of Economic Perspectives, 29*(2), 213–238.

Bott, J., & Milkau, U. (2017). Central bank money and blockchain: A payments perspective. *Journal of Payments Strategy & Systems, 11*(2), 145–157.

Broadridge. (2015). *Charting a path to a post-trade utility. How mutualized trade processing can reduce costs and help rebuild global bank ROE.* Broadridge White Paper. Available at: http://www.broadridge.com/broadridge-insights/Charting-a-Path-to-a-Post-Trade-Utility.html. Last accessed 10 August 2018.

Buitenhek, M. (2016). Understanding and applying blockchain technology in banking: Evolution or revolution? *Journal of Digital Banking, 1*(2), 111–119.

Byström, H. (2016). *Blockchains, real-time accounting and the future of credit risk modeling.* Department of Economics, Lund University. Available at: https://project.nek.lu.se/publications/workpap/papers/wp16_4.pdf. Last accessed 16 August 2018.

Capgemini Consulting. (2016). *Smart contracts in financial services: Getting from hype to reality.* Available at: https://www.capgemini.com/consulting/resources/blockchain-smart-contracts/. Last accessed 9 August 2018.

Catalini, C., & Gans, J. S. (2018). *Initial coin offerings and the value of crypto tokens* (No. w24418). National Bureau of Economic Research.

Chen, Y. (2018). Blockchain tokens and the potential democratization of entrepreneurship and innovation. *Business Horizons, 61*(4), 567–575.

Chiu, J., & Koeppl, T. V. (2018). Blockchain-based settlement for asset trading. Available at SSRN: https://ssrn.com/abstract=3203917.

Coyne, J. G., & McMickle, P. L. (2017). Can blockchains serve an accounting purpose? *Journal of Emerging Technologies in Accounting, 14*(2), 101–111.

Dai, J., & Vasarhelyi, M. A. (2017). Toward blockchain-based accounting and assurance. *Journal of Information Systems, 31*(3), 5–21.

Das, P., Verburg, R., Verbraeck, A., & Bonebakker, L. (2018). Barriers to innovation within large financial services firms: An in-depth study into disruptive and radical innovation projects at a bank. *European Journal of Innovation Management, 21*(1), 96–112.

Desai, F. (2015). *The evolution of Fintech*. Forbes. Available at: https://www.forbes.com/sites/falgunidesai/2015/12/13/the-evolution-of-fintech/#343661ff7175. Last accessed 9 August 2018.

European Central Bank. (2017). *Payment systems: Liquidity saving mechanisms in a distributed ledger environment*. Available at: https://www.ecb.europa.eu/pub/pdf/other/ecb.stella_project_report_september_2017.pdf. Last accessed 29 August 2018.

Fink, M. (2017). *Blockchains and data protections in the European Union* (Max Planck Institute for Innovation and Competition Research Paper 18(01)). Available at SSRN: https://ssrn.com/abstract=3080322.

Gardner, J. A. (2011). *Innovation and the future proof bank: A practical guide to doing different business-as-usual*. Chichester: Wiley.

Glaser, F. (2017). *Pervasive decentralisation of digital infrastructures: A framework for blockchain enabled system and use case analysis*. 50th Hawaii International Conference on System Sciences (HICSS 2017), Waikoloa, HI, USA.

Gomber, P., Kauffman, R. J., Parker, C., & Weber, B. W. (2018). On the fintech revolution: Interpreting the forces of innovation, disruption, and transformation in financial services. *Journal of Management Information Systems, 35*(1), 220–265.

Guo, Y., & Liang, C. (2016). Blockchain application and outlook in the banking industry. *Financial Innovation, 2*(1), 24.

Hawlitschek, F., Notheisen, B., & Teubner, T. (2018). The limits of trust-free systems: A literature review on blockchain technology and trust in the sharing economy. *Electronic Commerce Research and Applications, 29*, 50–63.

Higgins, S. (2018). *Method and system for net settlement by use of cryptographic promissory notes issued on a blockchain* (U.S. Patent Application No. 15/342). 463.

Howell, S. T., Niessner, M., & Yermack, D. (2018). *Initial coin offerings: Financing growth with cryptocurrency token sales* (No. w24774). National Bureau of Economic Research.

International Data Corporation (IDC). (2012). *IDC predictions 2012: Competing for 2020* (IDC #231720).

Jacobson, T., & Roszbach, K. (2003). Bank lending policy, credit scoring and value-at-risk. *Journal of Banking & Finance, 27*(4), 615–633.

Khapko, M., & Zoican, M. (2018). *Smart settlement. Society for Financial Studies (SFS) Cavalcade, 2017* (EFA 2017 Mannheim Meetings Paper; Rotman School of Management Working Paper No. 2881331; Swedish House of Finance Research Paper No. 17-4). Available at SSRN: https://ssrn.com/abstract=2881331.

Larios-Hernández, G. J. (2017). Blockchain entrepreneurship opportunity in the practices of the unbanked. *Business Horizons, 60*(6), 865–874.

Luftenegger, E., Angelov, S., van der Linden, E., & Grefen, P. (2010). *The state of the art of innovation-driven business models in the financial services industry* (Beta Report). Eindhoven University of Technology.

Lynn, T., Rosati, P., & Fox, G. (2018). *Legitimizing #Blockchain: An empirical analysis of firm level social media messaging on Twitter*. 26th European Conference on Information Systems (ECIS 2018).

Mackenzie, A. (2015). The fintech revolution. *London Business School Review, 26*(3), 50–53.

Mainelli, M., & Milne, A. (2016). *The impact and potential of blockchain on the securities transaction lifecycle* (SWIFT Institute Working Paper No. 2015-007).

Malinova, K., & Park, A. (2017). *Market design with blockchain technology*. Available at SSRN: https://ssrn.com/abstract=2785626.

McDowell, H. (2017). *Banks spent close to $100 billion on compliance last year*. Available at: https://www.thetradenews.com/banks-spent-close-to-100-billion-on-compliance-last-year/. Last accessed 10 August 2018.

McEvoy, M. J. (2014). *Enabling financial inclusion through "alternative data"*. Bentonville, AR: Mastercard Advisors.

McKinsey & Co. (2016). *Global payments 2016: Strong fundamentals despite uncertain times.* Available at: https://www.mckinsey.com/~/media/McKinsey/Industries/Financial%20Services/Our%20Insights/A%20mixed%202015%20for%20the%20global%20payments%20industry/Global-Payments-2016.ashx. Last accessed 9 August 2018.

Mesropyan, E. (2016). *39% of the world's population does not have a bank account*. Available at: https://gomedici.com/39-of-the-worlds-population-does-not-have-a-bank-account/. Last accessed 9 August 2018.

Michel, S. (2014). Financial services and innovation. In T. Harrison & H. Estelami (Eds.), *The Routledge companion to financial services marketing* (p. 191). Abingdon: Routledge.

Micheler, E. (2015, November). Custody chains and asset values. Why crypto-securities are worth contemplating. *Cambridge Law Journal, 74*(3), 505–533.

Misra, S. C., & Mondal, A. (2011). Identification of a company's suitability for the adoption of cloud computing and modelling its corresponding Return on Investment. *Mathematical and Computer Modelling, 53*(3–4), 504–521.

Mougayar, W. (2016). *The business blockchain: Promise, practice and application of the next internet technology*. New Jersey: Wiley.
Moyano, J. P., & Ross, O. (2017). KYC optimization using distributed ledger technology. *Business & Information Systems Engineering, 59*(6), 411–423.
Nakamoto, S. (2008). *Bitcoin: A peer-to-peer electronic cash system*. Available at: https://bitcoin.org/bitcoin.pdf
Park, Y. (2016). *The inefficiencies of cross-border payments: How current forces are shaping the future*. Available at: http://euro.ecom.cmu.edu/resources/elibrary/epay/crossborder.pdf. Last accessed 15 August 2018.
Peters, G. W., & Panayi, E. (2016). Understanding modern banking ledgers through blockchain technologies: Future of transaction processing and smart contracts on the internet of money. In P. Tasca, T. Aste, L. Pelizzon, & N. Perony (Eds.), *Banking beyond banks and money* (pp. 239–278). Cham: Springer.
Prorokowski, L. (2015). MiFID II compliance—Are we ready? *Journal of Financial Regulation and Compliance, 23*(2), 196–206.
Risius, M., & Spohrer, K. (2017). A blockchain research framework. *Business & Information Systems Engineering, 59*(6), 385–409.
Rohr, J., and Wright, A. (2017). *Blockchain-based token sales, initial coin offerings, and the democratization of public capital markets* (Cardozo Legal Studies Research Paper No. 527; University of Tennessee Legal Studies Research Paper No. 338). Available at SSRN: https://ssrn.com/abstract=3048104 or http://dx.doi.org/10.2139/ssrn.3048104.
Roman, D., & Gatti, S. (2016, August). Towards a reference architecture for trusted data marketplaces: The credit scoring perspective. In *Open and Big Data (OBD), International Conference on IEEE* (pp. 95–101).
Rosati, P., Nair, B., & Lynn, T. (2016). #Bitcoin vs #blockchain: An exploratory study on the Bitcoin and blockchain discourse on Twitter. In *Proceedings of the 7th European Business Research Conference*.
Rosati, P., & Paulsson, V. (2017). Development of accounting information systems over time. In M. Quinn & E. Strauss (Eds.), *The Routledge companion to accounting information systems* (pp. 13–23). Abingdon: Routledge.
Ruce, P. J. (2011). Anti-money laundering: The challenges of know your customer legislation for private bankers and the hidden benefits for relationship management (the bright side of knowing your customer). *Banking Law Journal, 128*, 548–564.
Santander. (2015). *The Fintech 2.0 paper: Rebooting financial services*. Available at: https://www.finextra.com/finextra-downloads/newsdocs/the%20fintech%202%200%20paper.pdf. Last accessed 9 August 2018.
Seebacher, S., & Schüritz, R. (2017). Blockchain technology as an enabler of service systems: A structured literature review. In *International Conference on Exploring Services Science* (pp. 12–23). Cham: Springer.

Sheridan, I. (2017). MiFID II in the context of financial technology and regulatory technology. *Capital Markets Law Journal, 12*(4), 417–427.

Spezzati, S. (2017). *Banks are spending $20 Billion on compliance tech ahead of MiFID*. Available at: https://www.bloomberg.com/news/articles/2017-11-29/banks-are-spending-20-billion-on-compliance-tech-as-mifid-looms. Last accessed 10 August 2018.

Stahl, F., Schomm, F., & Vossen, G. (2014). Data marketplaces: An emerging species. In H.-M. Haav, A. Kalja, & T. Robal (Eds.), *Databases and information systems VIII* (pp. 145–158). Amsterdam: IOS Press.

Sun, J., Yan, J., & Zhang, K. Z. (2016). Blockchain-based sharing services: What blockchain technology can contribute to smart cities. *Financial Innovation, 2*(1), 2–26.

Tapscott, D., and Tapscott, A. (2016). The impact of the blockchain goes beyond financial services. *Harvard Business Review*. Retrieved May 25, 2017, from https://hbr.org/2016/05/the-impact-of-the-blockchain-goes-beyond-financial-services.

Terrell, E. (2010). *History of the American and NASDAQ stock exchanges*. In Library of Congress–Business Reference Services.

Thomas, L., Crook, J., & Edelman, D. (2017). *Credit scoring and its applications* (Vol. 2). Philadelphia: SIAM.

Thomson Reuters. (2018). *Cost of compliance 2018*. Available at: https://risk.thomsonreuters.com/content/dam/openweb/documents/pdf/risk/report/cost-of-compliance-special-report-2018.pdf. Last accessed 10 August 2018.

Tschorsch, F., & Scheuermann, B. (2016). Bitcoin and beyond: A technical survey on decentralized digital currencies. *IEEE Communications Surveys & Tutorials, 18*(3), 2084–2123.

Yeoh, P. (2017). Regulatory issues in blockchain technology. *Journal of Financial Regulation and Compliance, 25*(2), 196–208.

Yli-Huumo, J., Ko, D., Choi, S., Park, S., & Smolander, K. (2016). Where is current research on blockchain technology?—A systematic review. *PLoS ONE, 11*(10), e0163477.

Van der Elst, C., & Lafarre, A. (2018, July 24). *Blockchain and smart contracting for the shareholder community* (European Corporate Governance Institute (ECGI)—Law Working Paper No. 412/2018). Available at SSRN: https://ssrn.com/abstract=3219146.

Wang, Y., & Kogan, A. (2018). Designing confidentiality-preserving blockchain-based transaction processing systems. *International Journal of Accounting Information Systems, 30*, 1–18.

Weber, I., Xu, X., Riveret, R., Governatori, G., Ponomarev, A., & Mendling, J. (2016). Untrusted business process monitoring and execution using blockchain. In *International Conference on Business Process Management* (pp. 329–347). Cham: Springer.

World Bank. (2017). *The cost of sending remittances: June 2017*. Available at: http://www.worldbank.org/en/news/infographic/2017/06/15/the-cost-of-sending-remittances-june-2017. Last accessed 9 August 2018.

World Economic Forum (WEF). (2013). *The role of financial services in society—A multistakeholder compact*. Available at: http://www3.weforum.org/docs/WEF_FS_RoleFinancialServicesSociety_Report_2013.pdf. Last accessed 9 August 2018.

World Economic Forum (WEF). (2016). *The role of financial services in society—Understanding the impact of technology-enabled innovation on financial stability*. Available at: http://www3.weforum.org/docs/WEF_FS_RoleFinancialServicesSociety_Stability_Tech_Recommendations_2016.pdf. Last accessed 9 August 2018.

Wright, A., & De Filippi, P. (2015). *Decentralized blockchain technology and the rise of lex cryptographia*. Available at SSRN: 2580664.