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Abstract

This paper is an examination of adoption of distributed ledgers in financial services. We review more than one hundred initiatives and a large practitioner literature, considering fourteen areas of application and seven case studies, in order to provide both a conceptual analysis of these technologies and to review their current and prospective adoption in financial services. There are several component technologies applied in distributed ledger, many offering substantial commercial and operational benefits even applied outside of a distributed ledger and best viewed as part of the broader picture of ongoing digitalization of financial services using various data technologies. Our findings suggest that decision makers can take a pragmatic approach to distributed ledgers, not be concerned about this technology upending their business but be open to cross industry co-operation where this is strategically justified and to then adopt what works to improve outcomes for customers and other stakeholders. Overall, distributed ledgers and crypto assets, are really a distraction from the wider and more important issues of ongoing digitisation and automation of financial services. Data sharing and cross industry co-operation – as well as well as enlightened public policy to promote adoption of new technologies, competition and prudential and systemic safety – are crucial to this digital revolution. This does not depend on widespread adoption of distributed ledgers.

Keywords

JEL Classification

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Evolution or revolution?
Distributed ledger technologies in financial services

Anil Savio Kavuri[1] and Alistair Milne[2]

(There are two versions of this paper: a short summary report of 16 pages plus references; the full research report of 121 pages plus references[3].)

Abstract

This paper is an examination of adoption of distributed ledgers in financial services. We review more than one hundred initiatives and a large practitioner literature, considering fourteen areas of application and seven case studies, in order to provide both a conceptual analysis of these technologies and to review their current and prospective adoption in financial services. There are several component technologies applied in distributed ledger, many offering substantial commercial and operational benefits even applied outside of a distributed ledger and best viewed as part of the broader picture of ongoing digitalization of financial services using various data technologies. Our findings suggest that decision makers can take a pragmatic approach to distributed ledgers, not be concerned about this technology upending their business but be open to cross industry co-operation where this is strategically justified and to then adopt what works to improve outcomes for customers and other stakeholders. Overall, distributed ledgers and crypto assets, are really a distraction from the wider and more important issues of ongoing digitisation and automation of financial services. Data sharing and cross industry co-operation – as well as well as enlightened public policy to promote adoption of new technologies, competition and prudential and systemic safety – are crucial to this digital revolution. This does not depend on widespread adoption of distributed ledgers.

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[3] The full research report can be found at https://cama.crawford.anu.edu.au/sites/default/files/uploads/cama_crawford_anu_edu_au/2020-01/dlt_evolution_or_revolution_final_jan_2020_-_manuscript.pdf

Executive Summary

Overview: Over the course of the last twelve months we have conducted an in-depth analysis of the adoption and potential impact of distributed ledger (DL) technologies in financial services. Our detailed evidence and analysis are reported in an eighty-page version of this report, accompanied by a further sixty pages of appendices and references. This summary report compiles our key insights and principal supporting evidence. It is aimed especially at practitioners in the financial service industry and the public sector who are not specialists in distributed ledger technologies and would like to understand our findings about the application of DL in financial services, without closely reading our full report.

Analysis: Our analysis is both conceptual and empirical. We conducted an extensive review of literature: on distributed ledgers, on their practical application and also on the newly emerged 'ecosystem' of crypto assets that are exchanged using distributed ledger technologies. We reviewed over one hundred announced initiatives with financial application. We examined fourteen specific areas of application for DL in financial services. We looked in more detail at seven prominent case studies.

Insights: We obtained twelve principal insights from our investigations:

1. There is much confusion about DL. We describe this as a 'Tower of Babel' because the same words are so often used with widely different meanings and differences in understanding which we try to elucidate. In particular, "distributed ledger" or "distributed ledger technologies" have several interpretations. We offer some definitions, corresponding to the most established usages but these are far from universally accepted. Our definition of distributed ledger is one in which data is shared with a complete record of past data and without any centralised institutional control. (Section 2).
2. There are many (we distinguish nine) technologies used in the distributed ledger, with every practical application of DL being different. To achieve the benefits of DL, users can select the relevant technological elements for their particular use case. Often these technologies can be employed using a conventional database design that is not (under our definition) a DL at all. (Section 2)
3. Although DLs vary substantially, they all are databases involving some degree of decentralization. This decentralization is though not a simple either/ or decision. DLs used in mainstream financial services are never fully decentralized. Various aspects of the ledger are centralised or decentralized to various degrees. (Section 2)
4. In none of our fourteen areas of application in financial services has there yet been widespread adoption. There are five particularly promising areas of potential application where we judge sharing of data in standardised form, using distributed ledger technologies, is most likely to emerge: (i) Recording ownership and transaction in illiquid assets; (ii) Funds allocation in investment management; (iii) Derivatives operations and clearing; (iv) Trade Finance; and (v) International payments. Even here though lack of co-ordination still holds back the development of shared data solutions (Section 3).
5. Our case studies focus on seven examples where DL applications are near commercial implementation on a large scale. These are almost all incremental improvements to

existing processes, making clear that adoption of DL is an evolution not a disruptive revolution (Section 3).

6. DL is just one way of digitizing shared business processes. Harmonizing business processes through data sharing and standardisation is important to delivering the full benefits of digitization. Adoption of DL is not though necessarily the best way of achieving this harmonization. (Section 4)
7. Start with the problem not the solution. Good technology management requires first identifying a clearly defined operational problem and then determining the best solution (whether DL or other form of digitisation). Starting with the technology, as many proponents of DL do, and then searching for operational problems that it might solve typically leads to sub-optimal technology choices. (Section 4)
8. Adoption of DL, as in our narrow definition of a database with a complete record of past data and without centralised institutional control, is justified when shared multiparty governance of data and data access is of primary importance. When this is not the case then a more conventional database design will be more appropriate (though this will often still be labelled 'DL' if it makes some use of DL technologies). (Section 4)
9. Garbage in – garbage out. The collective effort to adopt a distributed ledger can support automation and improve operational efficiency; but they are not a 'magic bullet' for solving underlying data problems. Specifically, DL does *not* create trust in data (the claim that DL is a 'trust machine' is a widespread fallacy). Trust in DL data depends on trust in the original external source of the data. (Section 4)
10. Government intervention to promote or require adoption of DL or other digitisation in financial services will sometimes be justified. Further supporting public initiative to solve identity challenges may also be justified. (Section 5)
11. Radical change in financial services based on DL technologies is still feasible, and may be desirable, but only if government led.
12. Current focus on distributed ledgers and blockchain is misplaced; it is a distraction from the practical steps required on the road to digital transformation.

1 Introduction to summary research report

This report is a summary of a year-long investigation of the adoption of distributed ledgers (DL) in financial services and their potential future impact.[4] This investigation is both conceptual and empirical. We discuss the distinguishing features of DL. We have reviewed more than one hundred DL initiatives and fourteen areas of application in financial services and prepared more detailed case studies of seven leading commercial applications. We describe the benefits and costs of implementing DL technologies. We examine the role of public policy in adoption of these new technologies.

The full longer version of this research is being published alongside this short version.

This summary report and the full report are both structured as follows. Section 2 discusses basic concepts and component DL technologies. Section 3 investigates applications in financial services including our seven case studies. Section 4 examines the benefits and costs of adopting DL technologies. Section 5 considers public policy issues. Section 6 concludes. Here in this summary report we also provide 12 insights drawn from our research.

2 Distributed ledgers: basic concepts and component technologies

The section discusses the key concepts of DL and the technologies they employ. We begin with our first main insight, about the key concepts of DL:

INSIGHT 1: **There is much confusion about DL. We describe this as a 'Tower of Babel' because the same words are so often used with widely different meanings and differences in understanding which we try to elucidate. In particular, "distributed ledger" or "distributed ledger technologies" have several interpretations. We offer some definitions, corresponding to the most established usages but these are far from universally accepted. Our definition of distributed ledger is one in which data is shared with a complete record of past data and without any centralised institutional control.**

From our extensive review, it is clear that there is little agreement on the meanings of either DL or DLT. Discussion of DL at industry conferences, in consultancy and practitioner analyses and in online fora is a 'Tower of Babel' with many mutually incompatible languages using the same words to describe essentially different data solutions. In particular, we notice wide-spread reference to "Distributed Ledger Technology" in the singular, which is a quite meaningless usage because distributed ledgers are combinations of several technologies used in varying combinations, not a single technology. We refer to "Distributed Ledger Technologies" or DLT in the plural, to refer to all the technologies employed in implementing the many variants of Distributed Ledger or DL.

We then offer the following definition, reflecting the strictest interpretation of DL.

[4] There is so much activity of this kind that we have not been able to cover all current developments, for example Facebook's Libra project, announced in June of 2019, is not covered in this report.

DEFINITION 1: (not universally accepted) A distributed ledger (DL) is a database of cryptographically-secured time-ordered immutable data records, with multiple operators storing and independently updating their own copies of the database and multiple users reading and proposing the addition of new data records.[5]

This definition is consistent with many widely accepted applications of DL, but for several reasons we cannot claimed that is universally accepted. First, in many applications in financial services described as DL, there is in fact a single operator not multiple operators (for examples see some of our seven case studies below). Second, while cryptographic security is always essential, a complete time-ordered immutable set of data records is not always employed.[6] Third the rights to add new data may be quite limited. In short it is possible for a solution described as a 'distributed ledger' to be a cryptographically-secured but otherwise quite conventional database.[7]

We distinguish distributed ledgers from their component technologies, as follows:

DEFINITION 2: Distributed ledger technologies (DLT) are the range of component technologies employed in distributed ledgers, delivered in a number of software environments.

There are several such software environments including the open source Hyperledger Fabric, variants of the Ethereum software, the smart contracts language DAML supported by Digital Asset and the Corda solution of the R3 consortium. These can all support secure data sharing solutions that would be relatively difficult to implement using conventional database software. The reason, though, for calling them all distributed ledger technologies seems to be more about persuading company boards to agree to substantial expenditures on new technology. They are less about providing a precise description of what is being done.

2.1 The component technologies used in distributed ledgers

INSIGHT 2: **There are many (we distinguish nine) technologies used in the distributed ledger, with every practical application of DL being different. To achieve the benefits of distributed ledger, users can select the relevant technological elements for their particular use case. Often these can then be employed using a conventional database design that is not (under our definition) a DL at all.**

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[5] This definition emphasizes that distributed ledgers are databases and focuses attention on rights for reading and updating of records and on data integrity and security. It also acknowledges a critical distinguishing feature: the presence of multiple operators. The innovations of distributed ledger innovations are thus both providing a complete record of past data and also reducing centralized institutional control. However, in the permissioned versions of DL which are required for application in mainstream financial services (see later discussion) some degree of institutional control over participation is still required.

[6] Note that immutability (i.e. the permanency of records which cannot be changed once added to the DL) is a consequence of time-ordering combined with completeness of data records. Once an entry is accepted on the ledger it is never subsequently changed or removed. The only possible updating is appending new ledger entries.

[7] We are careful to avoid using the even more confusing term 'blockchain' which we believe, to avoid confusion, should apply only to unpermissioned ledgers secured using proof of work to establish consensus on blocks of data appended to the ledger e.g. the Bitcoin blockchain. Blockchain though has become extensively used as a vaguely defined buzzword indicating secure sharing of data.

Distributed ledgers combine a range of cryptographic and other techniques.[8] We distinguish nine component technological elements (Table 1).

The first four elements of table 1 are core functions. Arguably the benefits obtained from these functions are the reasons for the interest in distributed ledgers. Users though can select or combine any of these core technological elements in pursuit of the benefits of DL.

The two supporting elements are both required. This also requires a choice on whether the ledger permissioned or unpermissioned:

- a permissioned ledger is one in which operators and users must confirm their real-world identities and obtain permission to join the network.
- an unpermissioned ledger is one in which anyone can join the network of users without having to provide a real-world identity (for example the Bitcoin blockchain).

In order to comply with law and regulation all applications of distributed ledger technologies in mainstream financial services have to be permissioned. This in turn requires some form of institutionalised governance, at a minimum controlling permission for joining the network.

Table 1: the nine elements sometimes used in distributed ledgers

	Core functionality (required under Definition 1)
1.	Multiple, identical, copies of a computer-readable database
2.	Multiple operators responsible for updating the ledger, no central operator
3.	Complete time-ordered immutable records containing the entire data history
4.	Individually specified rights for reading and for instructing changes to the ledger allocated amongst multiple users (essential)
	Supporting technology
5.	Synchronization (or a ‘consensus mechanism’) avoiding inconsistent versions of the ledger.
6.	Identification of users and operators through public cryptographic keys, linked as required in the design of the ledger to real-world identities (essential)
	Additional technological elements
7.	The possibility (not a requirement) of a ledger specific asset ‘owned’ by users
8.	Incorporation of extra-ledger information in ledger entries or user keys
9.	Potential for algorithmic updating of the ledger based on its current state (what are often referred to as ‘smart contracts’).

2.2 How the technologies are combined: the database ‘stack’

INSIGHT 3: **Although distributed ledgers vary substantially, they are all shared databases involving some degree of decentralization. This decentralization is though not a simple either/ or decision. Distributed ledgers used in mainstream financial services are never fully decentralized. Various aspects of the ledger are centralised or decentralized to various degrees.**

[8] Some insight can be obtained from comparing DL with the technologies of the internet and the world wide web (see for example Ito, Narula, and Ali 2017). The internet is also supported by a combination of technologies. The difference is that the core elements of distributed ledger can also be implemented separately.

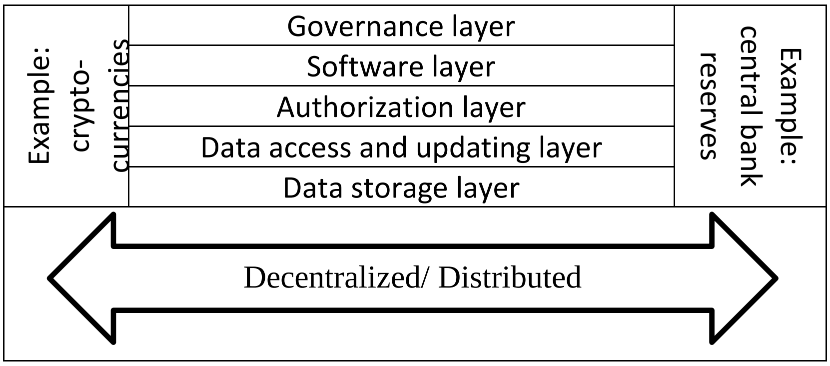
To understand how the composite technologies can be combined in DL, we distinguish five different layers of the DL 'stack' (Figure 1). Firstly, note that this 'stack' applies also to conventional databases. Secondly, the degree to which a particular layer is centralized and whether the database is a DL or a conventional database is less important than the services it provides and the security it offers.

Insight 3 can be understood from Figure 1. As can be seen, it is spectrum of possible outcomes and some parts can be decentralized or distributed while others remain centralized.

A few further points are relevant to this centralization/ decentralization decision:

- Degree of centralization. Conventional databases have a single operator and a centralized data storage layer. A DL, strictly defined according to our Definition 1, has many operators and no central master copy of a distributed ledger.
- Commercial applications using permissioned ledgers have relatively few operators, so the data storage layer is only partially decentralized. Partial decentralization is also possible within other layers.
- Conventional databases are either controlled by a single institution or have a corporate governance framework overseeing the decisions of a single operator. An appropriately designed DL using shared software automates some of these institutional processes.

Figure 1: the database 'stack' showing the 5 layers of distributed ledgers and conventional databases[9]



9 This figure extends the distinction of (Rauchs et al. 2018, esp Section 4.1.4) between the data, network and protocol layers of distributed ledgers. Their data layer are the records held on the ledger. We divide their network layer into two: the authorization layer and the data access and updating layer. We also divide their protocol layer into two, distinguishing the software controlling the participation and data processing layers and a governance layer operating outside the software. A governance layer is needed since not every ledger action can be fully software controlled (e.g. agreement on participation or software changes).

3 Applications of distributed ledgers in financial services

3.1 Fourteen areas of application

Our long report provides detailed discussion of the opportunities for employing DL technologies in fourteen different areas of financial services. Table 2 below summarises these fourteen areas of application we have reviewed.

Table 2: potential financial services applications of distributed ledgers

Application area	Summary Assessment
A Asset ownership and management	
1. Equity ownership and transactions	Some limited DL opportunities
2. Bond ownership and transfers	Some limited DL opportunities
3. Illiquid assets: syndicated loans and asset backed securities	More substantial opportunity for DL in both ownership and transactions
4. Funds allocation by asset managers	Complex operations: DL may help.
B Trading and derivatives	
5. Derivative exposures and clearing	Helping overcome complexity through data sharing, DL useful but multiple operators not required.
6. Collateral and default management	Promising initiatives, potential application of DL, but multiple operators not required.
7. Money and forex markets	Limited application of DL to foreign exchange post trade processing.
8. Metals and commodity markets and trading	Similar picture as in many other areas: limited niche application.
C Corporate financial services	
9. Trade finance	Many initiatives, strong case for data sharing using DL, but unclear any will achieve critical mass.
10. Corporate supply chains	Opportunities for digitisation, sharing of data using DL can be important but multiple operators not required.
11. Insurance and reinsurance	Many opportunities for digitisation, few require data sharing using DL.
12. International payments	Shared ledgers including DL are facilitating information flow, unclear if multiple operators are required.
D Regulatory oversight	
13. Client on-boarding & KYC/AML	A critical area but main issue is agreed standardized identity solutions, could then be supported using DL.
14. Regulatory reporting	Main concern is standardisation to support automated reporting and to allow supervisors direct view of underlying data; some limited potential for DL.

The analysis of these fourteen areas supports the following insight.

INSIGHT 4: **In none of our fourteen areas of financial services application has there yet been widespread adoption. There are five particularly promising areas of potential application, where we judge sharing of data in standardised form, using distributed ledger technologies, is most likely to emerge: (i) Recording ownership and transaction in illiquid assets; (ii) Funds allocation in investment management; (iii) OTC derivatives operations; (iv) Trade finance; and (v) International payments. Even here though lack of co-ordination still holds back the development of shared data solutions.**

We find no widespread adoption of DL within any of these areas. There are though some promising more specific applications, especially in the following:

- Recording ownership and transaction in illiquid assets
- Funds allocation in investment management.
- OTC derivatives operations
- Trade finance
- International payments.

Currently, transaction operations in relatively infrequently traded assets (e.g. syndicated loan participations, structured credit securities) are slow and cumbersome and could be conducted more efficiently using shared ledgers.

The administration of funds under management is opaque and complex and DL could help address particular difficulties, such as implementing corporate actions for ultimate owners and allocation of the proceeds of shared market transactions amongst funds.

Derivatives operations continue to require substantial manual operations, because of lack of standardisation and inconsistencies between the systems of different firms. Here there is substantial opportunity for standardisation of data, in turn supporting the use of 'smart contracts' (i.e. automated contract execution) and more timely and accurate risk assessment.

There are numerous inefficiencies in trade finance that could be addressed by DL. Currently, trade finance is paper-based, fragmented and labour intensive.

DL can make international payments more transparent giving, clients and customers much more complete visibility of their international payment transactions.

3.2 Seven case studies

Table 3 summarizes our seven case studies and the information we have obtained on them:

Table 3: Summary of our seven case studies

Initiative	***Launch***	***Expected Full deployment***	***Supporting Technology***	***Digital ledger on our Definition 1?***
Digital Asset and ASX collaboration on CHESS replacement	2015	March – April 2021	DAML (smart contracts)	No
ISDA's common domain model CDM implemented using Digital Asset DAML	2016	2019	DAML (smart contracts)	No
DTCC's Trade Information Warehouse DLT re-platforming	2016	Q4 2019	Hyperledger Fabric	No
Utility Settlement Coin (USC) now renamed as Fnality.	2015	Live 'as soon as possible' (2020?)	Clearmatics platform (permissioned Ethereum)	Yes, permissioned
SETL IZNES platform for Investment funds transactions	2017	Live 2018 full uptake 2020+	SETL ledger platform	Yes, permissioned
J.P. Morgan Interbank Information Network (IIN)	2017	Network expanding, live in 2019	Quora (permissioned Ethereum)	No
Ripplenet suite of products (xCurrent and xRapid recently rebranded as RippleNet, and xVia rebranded as On Demand Liquidity)	2013	Ongoing	Own platform	Yes, hybrid

Note: these cases illustrate the range of possibilities when using the component DL technologies listed in Table 1. Not all are consistent with Definition 1. Several (e.g. those of ASX, ISDA, and J.P. Morgan) have a single operator rather than multiple operators. Only ASX and ISDA make important use of smart contracts. The DTCC and J.P. Morgan networks are focused on information sharing not transfer of ownership.

INSIGHT 5: **Our case studies focus on seven examples where DL applications are near commercial implementation on large scale. These are almost all incremental improvements to existing processes, making clear that adoption of DL is an evolution not a disruptive revolution.**

We have analysed seven of the most prominent applications of DL in financial services. These are the few projects that we have identified operating on large scale and close to commercial implementation.[10] We are not seeking to promote these initiatives. We think some are more promising than others and not all will succeed. But we do believe that these seven cases give a good overview of the range of DL solutions and of their potential applications.

[10] These are not all current applications reaching commercial scale. There other vendor solutions, for example some of those already discussed in the five most promising areas of application that are already commercially implemented. These seven all have potential as very widely used data sharing solutions using some form of DL.

In 2015 ASX's Cash Equities Clearing and Settlement started working with Digital Asset to develop solutions for the Australian market utilizing Distributed Ledger Technology (Digital Asset, 2016). The initial focus was on fully replacing ASX's twenty-year-old system for post-trade clearing and settlement. Market participants will use Digital Asset's DAML (Digital Asset Modelling Language) SDK to construct applications for the new system. DAML is "smart contract-like" language and tools.[11]

ISDA Common Domain Model is the first industry solution to try to standardize the representation of derivatives trade events and processes. (ISDA 2019). ISDA proposed the Common Domain Model in May, 2018 and within a year has already obtained support from R3, Axoni, Goldman Sachs and Barclays. (Coindesk 2019b).

DTCC entered the test phase of relaunching Trade Information Warehouse (TIW) on DL and cloud in November, 2018. (DTCC 2018). The firm is looking to go live on the service in Q4 2019.[12]

Fnality supports a digital asset known as Utility Settlement Coin or USC (Coindesk 2019a). This is an asset-backed digital cash instrument implemented on DL. USC was started 4 years ago in 2015 with UBS and Clearmatics.[13] Fnality's blockchain architecture is a private permissioned version of Ethereum called Autonity (Coindesk 2019a). Fnality is described in the June 2017 press release that announced their public launch as follows "The focus for Fnality is … to create a regulated network of distributed Financial Market Infrastructures (dFMIs) to support global exchange of value transactions. Initially, five currencies are in scope: CAD, EUR, GBP, JPY & USD…. with convertibility into fiat currency at par guaranteed at all times." (Fnality, 2019).

SETL is a London based institutional payment and settlement infrastructure provider. Citi and Credit Agricole Investment Bank, Computershare, S2iEM and Deloitte are shareholders in the company. SETL was launched in July 2015 to deploy a multi-asset, multi-currency institutional payment and settlements infrastructure based on blockchain technology[14.] IZNES is a pan-European record-keeping platform for EU mutual funds utilizing SETL's a proprietary permissioned distributed ledger solution.[15] IZNES went live in March, 2019 and now has over €1bn of assets registered on its platform.

J.P. Morgan's blockchain-based cross-border payment product, the Interbank Information Network (IIN), began development in 2017.[16] As of 22 April 2019 IIN had grown to over 220 financial institutions.[17] John Hunter, J.P. Morgan's head of clearing in a recent article in the Financial Times (Financial Times 2019) suggests that the aim of IIN is to address a wide range of issues that could require manual interventions in payments.[18]

Ripple's goal is to use these new technologies to provide alternative mechanisms of international payment, reducing the substantial costs and inefficiencies of current conventional systems. It is,

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[11] An advantage of DAML over some smart contract platforms is that written agreements through DAML can remain private and do not have to be shared across multiple nodes in a network (Computerworld 2018).
[12] TIW currently automates the record keeping, lifecycle events, and payment management for $10 trillion of cleared and bilateral credit derivatives.
[13](UBS 2016)
[14] (SeTL 2018)
[15](Siliconangle 2017)
[16] Announced in (JP Morgan 2017, 2018).
[17] See (Noonan 2019)
[18] These include erros in account number, routing code or other aspects of the transaction Quoted in (Noonan 2019).

though, a little difficult to understand exactly how their solutions deliver these benefits. The more widely used functions of RippleNet seem to provide a useful alternative payments messaging service to current conventional systems. This offers alternative means for underlying transfer of value, at least where payments flows are offsetting and naturally net out. The more advanced On Demand Liquidity service using their cryptocurrency XRP for foreign exchange is more confusing, since moving from bilateral (e.g. $ to Rupiah) to trilateral ($ to XRP to Rupiah) would seem on the face of it to absorb rather than provide liquidity to customers. It is also unclear how they replace the role of correspondent banks in accessing central bank money in foreign jurisdictions, and the number of commercial bank users appears to fall some way short of the number experimenting with J.P. Morgan's IIN or using SWIFT's gpi.

4 Distributed ledgers: the adoption decision

This section discusses the adoption of distributed ledgers.

4.1 The benefits and costs of DL adoption

Adoption is a cost-benefit decision. Table 4 lists the main benefits and costs associated with DL, as revealed by the detailed analysis of our longer report. Focusing first on the benefits, we highlight the following points:

- DLs are just one implementation of modern information, communication and data technologies that might be used to realize the benefits listed in Table 4. The underlying source of these benefits is digitisation not DL and DL is not necessary for most of these benefits.
- The key underlying benefits of digitisation are data management, from sharing data either in a single system or between systems; or, if data is not shared, from standardisation of data to allow automated interaction of different systems.
- One DL myth is that these new technologies achieve efficiency in processing, with for example DLT providing "through put" efficiency gains by eliminating hierarchies of financial intermediation. This is putting the cart before the horse. The simplification of hierarchies of financial intermediation may support greater efficiency of processing, but this is delivered by the structural change itself not by the supporting database technology. It is a secondary question whether such change is best implemented using DLT.
- Some DL benefits are achievable with existing technologies and conventional database design. For example, low-cost rapid execution of financial transactions with immediate finality for trades in major securities markets is possible without employing any DL technologies. The reason this has not happened is that market participants prefer delayed settlement (T+2), allowing them to acquire cash or securities for settlement only when they decide to hold a trading position overnight, rather than having to preposition cash and securities before every trade (Mainelli and Milne 2016). Delayed settlement is a feature not a bug.

Table 4: the benefits and costs of DL adoption in financial services

Benefits
• Data management benefits from shared common data
• Low cost rapid execution of financial transactions with immediate finality;
• Reduced uncertainty through automated pre-commitment to payments or other asset transfers through 'smart contracts';
• Removal or simplification of layers of financial intermediation, leading to increased competition and lower charges to final customers;
• Overall reduction in transaction costs, supporting innovation in financial services and promoting financial inclusion.
Additional Social Benefits
• Improved regulatory oversight as data is moved onto distributed ledgers
• Reduced systemic risk from failure of centralized institutions
Private Costs
• Reengineering of business processes in order to participate in the ledger • Costs of governance: both the costs of participation in governance and the potential costs of being obliged to comply with adverse collective decisions • Falling business margins as new competitors take advantage of the transparency of the ledger to compete in core business activities

Note. The costs listed in this table do not include the high resource costs and slow speed of confirming transactions in cryptocurrency ledgers. The table is designed for assessing commercial applications where real world identities are known. As a result, the operational inefficiencies of 'proof of work' in cryptocurrency ledgers – which arise because real world identities are unknown – do not need to be considered.

Turning to the costs and the adoption decision, we highlight the following further points:

- Adoption of a DL requires participation in collective governance of the ledger. Concern about the cost of this participation and about loss of control may lead to a non-DL solution for digitisation being preferred over a DL solution.
- The fall in business margins resulting from increased transparency (whether from sharing of data on a single ledger or agreeing to common data standards) can be a major disincentive to adoption of DL or other forms of digitisation. As a result established market participants may resist these innovations.
- Even when established market participants perceive benefits from adoption of DL or other forms of digitisation, the costs of reengineering their business processes may outweigh these benefits.
- Additional social benefits, of no direct relevance to individual firms, may justify a public policy intervention to force adoption of DL or other digitisation.

4.2 Do we need distributed ledgers to provide these benefits?

With this background, we now turn to some further insights:

INSIGHT 6: **DL is just one way of digitizing shared business processes. Harmonizing business processes through data sharing and standardisation is important to delivering the full benefits**

of digitization. Adoption of DL is not though necessarily the best way of achieving this harmonization.

INSIGHT 7: **Start with the problem not the solution. Good technology management requires first identifying a clearly defined operational problem and then determining the best solution (whether this is a DL or other form of digitisation). Starting with the technology, as many proponents of DL do, and then searching for operational problems that it might solve typically leads to sub-optimal technology choices.**

Both these insights follow immediately from our discussion of Table 4.

4.3 A key benefit of DL: shared multiparty governance of data and data access

INSIGHT 8: **Adoption of DL, as in our narrow definition of a database with a complete record of past data and without centralised institutional control, is justified when shared multiparty governance of data and data access is of primary importance. When this is not the case then a more conventional database design will be more appropriate. This could still be labelled 'DL' if it makes some use of DL technologies.**

In support of this insight, consider the following quotation, from IBM, usefully highlighting some key issues when considering the adoption of a distributed ledger solution:

"There are four key questions in evaluating the need for blockchain [or distributed ledger]; they can uncover how closely your use case aligns with the purpose and value proposition of blockchain itself.

"1. Does the solution require trusted data to be shared across multiple parties without a central authority?
"2. Are assets being transferred between parties?
"3. Is there a need for privacy among participants in the current business network?
"4. Is there the need for greater trust inside the current business network?" (IBM 2018 pg 9)

We broadly agree with IBM that these are key questions about the adoption of DL – narrowly defined as in our Definition 1 – for digitisation of operational processes. Our analysis above suggests though some qualifications:

(i) Even if trusted data must be shared (IBM's question 1) it must still be asked if this is best done with or without a central authority or repository. A key question here is governance (the top layer of our database 'stack' shown in Figure 1): are the additional costs of shared governance arrangements justified?
(ii) We already have many systems for recording and transferring of financial and other assets (IBM's question 2). So here, the key question is whether these already exist and whether the costs of introducing a distributed ledger sufficiently improves these systems.
(iii) Privacy (IBM's question 3) can already be achieved in conventional databases using modern tools of cryptographic security. This is not itself a reason for using a distributed ledger.
(iv) Trust in data (IBM's question 4) may be achieved more directly, using other approaches, promoting open data access, greater technical standardisation and automated data exchange.

4.4 Challenges of Data Management

INSIGHT 9: **Garbage in – garbage out. The collective effort to adopt a distributed ledger can support automation and improve operational efficiency; but they are not a 'magic bullet' for solving underlying data problems. Specifically, DL does *not* create trust in data (the claim that DL is a 'trust machine' is a widespread fallacy). Trust in DL data depends on trust in the original external source of the data**.

Our full report provides an extended discussion of the all too familiar and all too often messy challenges of data management and the relevance of DL to address these challenges. This is one of the most overhyped aspects of DL technologies. Commentators have made unrealistic claims such as "Distributed ledger is a truth machine". The reality is much more mundane. Apart from the rare exceptional case of totally closed systems such as blockchains for transfer of cryptocurrencies, data on DLs has to be imported via external data interfaces. This is true of all the fourteen areas of financial services applications we review.

5 DL, digitisation and public policy

We complete our report with a brief public policy discussion. This leads to two insights on adoption and the potential for radical reform based on DLT. We also consider the legal and regulatory treatment of crypto assets, but we have little new to add here to extensive current discussion.

5.1 They legal and regulatory treatment of crypto assets

Our full report offers a brief discussion of the legal and regulatory treatment of crypto assets, the newly emerging class of financial assets based on cryptographically secured recording of ownership and execution of transactions (of which cryptocurrencies, stable coins and ICOs are examples). They are held on unpermissioned distributed ledgers and traded on crypto exchanges, raising legal and regulatory concerns.

We predict that eventually, over the next decade or two, most crypto assets will be eventually traded within the regulatory perimeter, in order to comply with investor protection and other regulation, and as a result will become effectively indistinguishable from conventional assets. Their only distinguishing feature will be that ownership is recorded on a distributed ledger rather than in a conventional database. This will require "permissioned" ownership to replace the current "unpermissioned" ownership and the 'crypto' and 'conventional' assets spaces will merge. At the same time, it is likely that there will continue to be a distinct class of unregulated crypto assets that will continue as a fringe asset outside of the mainstream and some residual trading between the regulated crypto and unregulated crypto spaces.

5.2 Encouraging adoption

INSIGHT 10: **Government intervention to promote or require adoption of DL or other digitisation in financial services will sometimes be justified. Further supporting public initiative to solve identity challenges may also be justified.**

This insight is based on Table 3 above, listing the costs and benefits of DL and other forms of digitisation of financial services operations. There are three main justifications for government intervention promoting adoption of these technologies:

- Co-ordination. Even where private enterprises benefit from technological innovation, they may struggle to co-ordinate on a solution (often, as illustrated in our review of DL in trade finance, more than one solution emerges and none achieve critical mass).
- Vested interest. Transparency of DL and other digitisations may often reduce the profit margins of incumbent firms, who will therefore resist adoption.
- The decisions of private firms do not take into account social benefits (see Table 3).

This is not to argue that governments should take a lead in designing and implementing digital technological solutions. But they may require private firms to develop technology solutions (Open -Banking in the UK is an example) and they may incentivise co-ordination and adoption by committing to require adoption of a (possibly flawed) public sector designed solution if private firms do not design and implement something better themselves.

Government or regulatory policy decisions to promote adoption cannot be taken lightly. They involve substantial costs for private firms and therefore must be justified by a careful weighing of benefits against and costs. They will also still often require substantial political support in order to overcome industry lobbying against their implementation.

One aspect of digitisation where public policy intervention is most clearly justified is in supporting identity solutions for customers, clients and participants in financial markets. Standardised identity is a key part of digital automation of financial processes. But this is a classic public good: non-rival (an identity solution used in one situation can be used in many) and dominated by fixed costs (a heavy investment in establishing and using the solution so inefficient to have many competing solutions). An emerging market example is the promotion of the Aadhar identity scheme in India. Achieving consensus on effective national or global identity systems is though a considerable technical and political challenge.

5.3 Radical reform?

INSIGHT 11: **Radical change in financial services based on DL technologies is still feasible, and may be desirable, but only if government led.**

As revealed by our case studies, the practical implementation of DL and other related digital technologies in financial services is proving to be an incremental evolution of existing processes not a radical change.

This does not mean that radical change in financial services operations using DL and related data technologies is not possible. It does mean that such radical change will require public sector action: to redesign the supporting institutional and operational architecture and to get private sector firms and households to adopt the necessary technological innovations.[19]

Two examples illustrate this point.

[19] Another possible route to radical change might be non-traditional crypto-based investment instruments e.g. ICOs slowly gaining traction for retail investors and eventually displacing more conventional approaches. In our judgement this is unlikely to happen. As discussed in the long version of our report, we such crypto assets must for adoption evolve to become fully regulated and indistinguishable from mainstream equity and debt securities.

1) Modern distributed ledger technologies could allow all managed investment funds to operate on a 'wallet' basis, in which individual investors would directly participate in the ownership of securities. As discussed in our full report, such a development could support greater operational efficiency, greater competition in currently high margin provision of asset management and support fuller engagement of shareholders in corporate governance. However there seem to be considerable vested interests who would incur costs and lose revenue and therefore will resist such change without public sector intervention.

2) Another possibility would be to use these technologies for addressing systemic risk in banking and financial markets. Commercial banks could be required to maintain all deposit accounts offering rights of withdrawal on a shared ledger, with deposits on the ledger backed by claims on central bank money (a modern version of proposals going back to the 1930s of ending the possibility of bank runs through '100 per-cent' reserved banking).[20] Similarly central counterparties could be replaced by smart-contract based ledger in which any failure to meet a contractual financial obligation (whether delivery of cash or securities) is met by a collectively programmed real time re-allocation of funds and securities.

These may sound far-fetched, involving as they do a complete re-engineering of current banking and financial market operations. But they are no more radical than the visions of change proposed by crypto-assets enthusiasts and would go a long way to ending once and for all the threat of systemic financial crisis.

6 Conclusion

This short report summarises the findings from an extensive (140 page) examination of current and future applications of distributed ledgers (DLs) in financial service. The study includes a conceptual analysis of these technologies; an examination of more than one hundred initiatives and seven case studies; a discussion of the balance of benefits and costs in the adoption decision; and assessment of the role of public policy.

Much commentary about DL has focused on the so-called 'Gartner hype cycle' which predicts that all technologies go through an initial period of disenchantment before achieving ultimate success. Our view is different – we think that interest in DL/ blockchain will fade over the next decade or two. There will by then be widespread use of the underlying component technologies for data sharing and process automation – but hardly anyone will still be talking about distributed ledger or blockchain at all. We summarise this in one final insight.

INSIGHT 12: **Current focus on distributed ledger or blockchain is misplaced, a distraction from the practical steps required on the road to digital transformation.**

Our message here is that distributed ledgers (DL or as many rather loosely call them 'blockchains') are not well-defined solutions for sharing of data and automation of operations in financial services. DL means different things in almost every application context. A focus on DL, rather than on the business problems they may solve, limits understanding of how new technologies will actually transform operations in financial services. The focus should instead be on the operational and business problems themselves; and how they can best be addressed using the range of new

[20] This would be an extremely radical implementation of central bank issue of digital currency (CBDC), requiring all transactions to be conducted using the CBDC. The practical implementation of CBDC being currently considered by a number of central banks worldwide is much less radical than this.

available technologies for cryptographic security, control of access to permanently stored data and for the 'smart' automated fulfilment of financial contracts. The resulting digitisation of operational processes will transform financial services and other business and public services over the years ahead. Whether these implementations are called 'DL' and the extent to which they are provided by todays leading DL technology consortia and vendors is not so important.

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