DISTRIBUTED LEDGER TECHNOLOGY *in securities clearing and settlement: Some issues*

MARK MANNING, MAXWELL SUTTON and JUSTIN ZHU, Reserve Bank of Australia

This paper explores the potential role of DLT in securities markets, using the equity market as an example. The paper discusses potential benefits and costs, drawing out limitations and challenges in the adoption of the new technology, as well as regulatory considerations. Despite the heightened interest in DLT, the paper concludes that the likely path is incremental adoption of the technology rather than wholesale replacement of the existing infrastructure. An earlier version of this paper was presented at the 21st Melbourne Money and Finance Conference.

There is currently extensive interest in distributed ledger technology (DLT) and its potential application in financial markets. The industry is investing heavily in research and development, either independently or in consortia, to identify use cases and develop workable prototypes of the technology.

Securities markets are a particular area of focus, due to the scope for efficiency gains in existing practices that are often characterised by multiple layers of intermediation and reconciliation. It is anticipated that DLT could reduce back-office processing costs by facilitating anticipatory reconciliation, and potentially (near) real-time settlement.

Background on distributed ledger technology

A distributed ledger is a way of storing information, and recording changes to that information, in a distributed fashion rather than relying solely on a trusted central party. In practical terms, a distributed ledger aims to provide transparency of information to multiple parties in a way that preserves a high level of security and operational resilience. Key features of the technology are:

> *Distribution:* The ledger is 'distributed' since it is replicated at each node connected to the network. In an unrestricted application, each of the nodes would have an identical copy of the agreed latest version of the ledger and would be able to access the history of every transaction made through the network.

> *Blockchain:* The ledger comprises 'blocks' of information, linked together in chronological order to form a 'blockchain' that represents accumulated transactions at a particular point in time. Cryptography is used to underpin the integrity of the ledger and to ensure that it can be relied upon as a single source of truth. Parties that wish to conduct transactions could do so using a digital signature that authenticates a transaction, so that it can be recognised as valid by the network but cannot be used by another party without the cryptographic information.

> C*onsensus:* A 'consensus' protocol or algorithm is applied to validate new transactions added to the ledger and to ensure the robustness of the ledger to any attempts to subvert the network.

Application of distributed ledger technology in clearing and settlement

The use of DLT in financial markets has emerged only relatively recently. In the past year, a small number of financial market infrastructure (FMI) providers and market operators have either launched applications of DLT or announced concrete proposals for its application. In October 2015, for instance, NASDAQ announced a new trading platform underpinned by a private distributed ledger, Linq, for the issuance of shares by private companies. The first issuance of shares on this platform was conducted in December. In Australia, ASX announced in

January 2016 that it would be working jointly with a technology vendor, Digital Asset Holdings, to develop a replacement for its equity clearing and settlement system based on DLT. And, in April, Computershare announced a joint venture with SETL to develop share ownership registries using DLT.

Beyond the various initiatives that have either been launched or announced, many other market participants are actively exploring a wide range of potential uses for the technology, including to support trading and post-trade functions. There are a number of drivers behind the growing interest in distributed ledger applications in financial markets. Some of the often-cited benefits of the technology include:

- *Data integrity:* Distributed ledgers allow the transfer of value between parties without the need for a central party to verify and facilitate each transaction. Potentially, this would enhance integrity since, unlike traditionally centralised records — which can be modified unilaterally by the central party — a distributed ledger with appropriate cryptographic protections cannot be changed without coordinated action from a sufficient number of colluding nodes. This would allow parties that do not necessarily trust each other to rely on the ledger without the need for a central party.
- *Access to information:* Since the distributed ledger acts as a single source of truth, it could provide users with timely and direct access to reliable information. Potentially, this could in turn: reduce reliance on intermediaries; streamline back-office processes (including reconciliation); minimise disputes and remediation; and improve institutions' access to information for risk management and planning purposes. And, for regulators, the ledger could provide a consolidated audit trail, with detailed histories of transactions that could potentially also be analysed for supervisory purposes, compliance monitoring and systemic risk assessment, including in a crisis.
- *Settlement lags:* A widely discussed benefit of the technology for financial markets is the potential to reduce settlement timeframes, from several days to close to real time. The potential for increased settlement speed derives from the existence of an immutable record of securities ownership that can be accessed and maintained using DLT. Protocols could potentially be developed that would permit a transaction to proceed only once it has been confirmed (by interrogating the ledger) that the transacting parties have in place the securities and funds required to complete the transaction. The move to such a reduced settlement time could substantially shrink the role of central counterparties (CCPs) in the equities market and reduce capital committed to the settlement process.
- *Disintermediation:* For exchange-traded securities, there are a number of intermediaries in the existing post-trade environment, including CCPs, central securities depositories (CSDs), clearing and settlement participants, other agents such as brokers and custodians. Interactions among these intermediaries under the existing post-trade arrangement are complex (Appendix 1) and reconciliations between the intermediaries are required. Depending on how DLT is adopted within a market, disintermediation could occur, with some intermediaries displaced or their roles fundamentally transformed. There are, however, natural limits to the transformative impact of this technology. For instance, distributed ledgers do not currently have the capability to replace some of the functions of FMIs — particularly those requiring discretion or judgement; for example, it is unlikely that they could manage the replacement cost guarantee or default management functions of a CCP.
- *Operational resilience:* Implementation of DLT could enhance resilience to either a physical disruption or a cyber-attack. Depending on the extent to which write access to the ledger is distributed, multiple iterations of the ledger could offer improved redundancy; an outage at one node does not pose the same risks as an outage for a centralised system. Similarly, from the perspective of resilience to a cyber-attack, a distributed ledger would potentially be much harder to subvert, since an attacker would have to overwhelm a majority of the network, rather than just the central party that manages the network. However, the additional security may be lessened by the fact that a distributed ledger may have a larger attack surface, as it has more access points for potential subversion.

- *Smart contracts:* So-called smart contracts are contracts written in computer code rather than legal language, which are executed automatically when certain conditions are met. The use of distributed ledgers in conjunction with smart contracts could enable the automation of certain events in a contract's life-cycle (e.g. payment of a dividend or delivery of collateral). Some applications of smart contracts may require human intervention, which could be handled by suspending execution and waiting for an adjudication. This 'process orchestration' could support a wide range of legal contracts, particularly if more routine legal contracts could be standardised. The use of smart contracts introduces new risks, as it may be impossible to ensure that all anticipated events are identified and dealt with. As the decentralised autonomous organisation (DAO) attack discussed below shows, smart contract code may also be taken advantage of in unforeseen ways.

Challenges in adoption

As noted, the application of DLT in financial markets could be transformative in many respects, including in its implications for the roles of financial intermediaries and FMI providers, the nature of financial contracts, and the execution of core back-office processes. The application of such technology could also require changes to underpinning regulation (see below).

There are, however, many challenges in the transition to a new market structure supported by DLT. For instance, DLT will need to interoperate with existing FMIs, at least during the transition period and address the risks and challenges associated with transforming intermediary functions and post-trade business processes that have evolved over many years. These risks are in addition to the technical challenges associated with applying the technology itself (ESMA 2016). It is therefore likely that the technology will be adopted only incrementally, and at least initially in a way that preserves many existing functions, processes and business models. This view is shared by Mainelli and Milne (2016), who conclude from an industry-wide survey that the initial applications of DLT will be 'based on piecemeal developments'.

A possible adoption path for the technology is outlined below.

Ledgers are likely to be 'permissioned', with limited distribution

Trust is paramount in financial markets. Therefore, there may be a natural reticence among financial institutions to adopt an entirely identity-agnostic model, such as the model used in Bitcoin. Rather, many applications in financial markets will most likely involve private 'permissioned' ledgers, whereby access to the network is granted only subject to an institution meeting certain standards or criteria. A similar conclusion is reached by Pinna and Ruttenberg (2016) and Mainelli and Milne (2016).

Particularly in clearing and settlement, it is likely that the operators of the existing FMIs will maintain control of their functions and administration of their networks, and retain ownership of associated data in accordance with their rulebooks. An important implication of this is that the cryptographic protocols required to validate new entries to the ledger can be less resource-intensive than in a trustless public network. This may help to ensure that the technology can meet the demanding throughput capacity requirements of a wholesale financial market. Another implication is that the central entity controlling the network can remain a clear 'focal point' for regulation and supervision, with such activities potentially able to continue to occur within existing frameworks and according to existing processes.

One challenge with permissioned ledgers is to set access criteria that provide for effective competition on the one hand, while adhering to appropriate standards of safety and security on the other. Such a trade-off is, however, already addressed in existing regulatory standards for FMIs (CPSS–IOSCO 2012). The impact of permissioned ledgers on competition in the provision of clearing and settlement services will also need to be considered.

Applications are likely to work 'with' rather than 'against' the prevailing operating environment

The current network of intermediaries involved in the existing post-trade network has evolved over many years. These institutions and their roles and functions are well established and firmly embedded in existing post trade processes. Unravelling, transforming or replacing this structure would therefore be a substantial challenge. The promise of compelling benefits would be necessary to justify the cost of effecting such changes. Furthermore, the distribution of costs and benefits will be uneven, which may result in vested interests seeking to slow the pace of change (DTCC 2016). However, economic incentives such as back-office savings and potential capital reduction could accelerate some aspects of the transition.

Similar challenges have been observed in other market-change contexts. For instance, a study commissioned by the DTCC on shortening the settlement cycle identified such difficulties and also concluded that regulators would need to play an important role in facilitating and supporting any such change (BCG 2012). In addition, the study noted that a seamless transition would require testing by individual institutions and on an industry-wide basis.

Even if the introduction of DLT did succeed in fundamentally reshaping the post-trade structure, full disintermediation would seem unlikely. The barriers of cost, risk and technical expertise requirements may provide a disincentive for end investors to operate their own ledgers. Instead, they would most likely rely on ledger service providers, who would provide the service to multiple users to achieve economies of scale. Therefore, intermediary roles would be transformed rather than eliminated.

Another factor potentially slowing the pace of change is some parties' reluctance to adopt the new technology before an industry standard protocol has been agreed. While there are opposing views, a number of parties have argued in favour of either a single global protocol or interoperable protocols. In rolling out the technology, parties operating different technologies are likely to need to consider the merits of interoperability so as to avoid fragmentation. While this can potentially slow the pace of innovation, it can avoid remediation ex post to reconfigure to a common standard. Central infrastructure providers can also help to promote a common standard ex ante. Currently, there are a number of industry standard setting initiatives underway.

Even if the introduction of DLT did succeed in fundamentally reshaping the post-trade structure, full disintermediation would seem unlikely. The barriers of cost, risk and technical expertise requirements may provide a disincentive for end investors to operate their own ledgers. Instead, they would most likely rely on ledger service providers, who would provide the service to multiple users to achieve economies of scale. Therefore, intermediary roles would be transformed rather than eliminated.

A full transition to real-time settlement is unlikely in the near term

As noted, DLT offers the potential for a substantially shorter settlement cycle. However, a number of challenges may need to be overcome in the transition to a near real-time settlement model:

> *Industry-wide coordination/changes in market practice:* Imposing changes in market practice often presents a significant barrier to the adoption of new practices or technologies. Many markets, including Australia, have only recently shortened the settlement cycle to T+2, or will shortly do so. This process required a long lead time and significant industry consultation and coordination, for each market. In light of this experience, further progress in shortening the settlement cycle is more likely to occur incrementally, rather than via a single disruptive change. One possible path may initially be to offer market participants a choice between alternative settlement cycles. Since differential pricing of trades settling on different timeframes would be undesirable, it may be preferable for any such choice to be exercised only after trade execution, rather than at the point of trade. This would, however, require securities borrowing and lending to meet delivery requirements if an institution did not have the securities in place to meet a shorter settlement timeframe (see below).

- > *Liquidity impact:* Close consideration would need to be given to the liquidity impact of near real-time settlement. Batch settlement processes in many securities settlement facilities, whereby sales and purchases are settled simultaneously at the end of the settlement cycle, generate significant netting and liquidity efficiencies. Depending on the particular settlement model applied, the liquidity required to support settlement under such arrangements is often a very small fraction of the gross obligations. Near real-time settlement would require participants to meet the gross obligations of their activity as each trade is settled, ensuring also that liquidity was available at the point of trade. Liquidity would of course continue to be recycled — an institution could fund securities purchases with funds received from its securities sales — but for a given institution the liquidity efficiency of the settlement process will depend on the particular timing and sequence of its securities purchases and sales.
- > *Availability of securities and cash at the time of trade:* Ensuring that securities and cash are in place at the time of trade may present a challenge, especially for market makers and investors using overseas custodians. A move to real-time settlement may therefore require changes and enhancements to the functioning of the securities lending market. A report on shortening the settlement cycle in the US identified similar issues, suggesting that such a move could increase the incidence of failed trades (PricewaterhouseCoopers 2015). Trade management processes might therefore need to be re-evaluated and possibly automated to minimise failed trades and adequately handle failures in this new environment.

Policy considerations

Current regulatory standards for FMIs are designed to be technology agnostic. However, since the application of DLT could introduce significant changes to the way markets operate, regulators will have to assess whether any aspects of the current regulatory framework need to be changed.

More incremental adoption of the new technology in market practices would be less likely to require material regulatory changes. With more transformative change, consideration might need to be given to matters such as the definition of particular clearing and settlement activities, roles of intermediaries, access and privacy. For instance, questions would need to be addressed about the participants' rights of access to data held on distributed ledgers and their ability to develop new products and revenue streams based on these data.

Given the systemic importance of FMIs, a core focus of regulation, supervision and oversight is stability. Widespread adoption of the technology would require careful consideration of certain aspects including:

- > *Security and consensus:* Appropriate governance and risk management of all nodes participating in the ledger are critical. In some consensus models, certain nodes would play a role as validators of transactions. To preserve trust in the system, such nodes would need to be subject to appropriate oversight. Indeed, without such oversight and other controls and incentives, there could be potential for fraudulent activity.
- > *Settlement arrangements:* Since any transaction written to the ledger is immutable, there would need to be clarity as to the point after which payments or transfer instructions cannot be revoked, and after which any erroneous transactions would need to be reversed by offsetting transfer instructions. Another important aspect is how the cash leg of a settlement would be supported in a distributed ledger system. While most of the focus on DLT has been on the securities leg of transactions, the cash leg is just as important and would require work to ensure linking of the two parts (Pinna and Ruttenberg 2016).
- > *Operational performance and resilience:* A settlement system based on DLT would need to meet established performance standards around throughput capacity, scalability and availability. Furthermore, in transitioning from a centralised system to a distributed system, there may be changes in a FMI's vulnerability to either physical or cyber disruptions, which would need to be understood and potentially addressed through revisions to relevant physical and information security policies and governance arrangements (ESMA 2016).
- > *Smart contracts:* The potential self-executing nature of smart contracts could be a source of financial stability risk, particularly if hard coded algorithms were to replace human judgement in unusual or volatile market conditions. Proponents of smart contracts assert that such risks could be managed within the algorithm, for example by programming in thresholds beyond

which execution requires manual intervention. Furthermore, in the clearing and settlement context, it is currently expected that the application of smart contracts would be restricted to the execution of non-discretionary actions already provided for in the operator's rulebook. The recent transfer of funds from the Ethereum DAO entity, by an unknown actor exploiting a loophole in a contract, highlights the need for greater consideration of the vulnerabilities that smart contracts could create in a DLT system (Waters 2016).

Closing remarks

As noted, we are at an early stage in the emergence of this technology. Its potential transformative impact is yet to be revealed. There are many challenges in the transition to its large-scale adoption, including the difficulty of unravelling the existing structure and firmly embedded business processes. Economic incentives, including those arising from back-office savings and capital reduction, could nevertheless accelerate some aspects of the transition.

Recognising the potential policy implications should this technology be widely adopted, regulators around the world are watching very closely and engaging very actively in the debate — both within their respective jurisdictions and internationally.

As noted, we are at an early stage in the emergence of this technology. Its potential transformative impact is yet to be revealed. There are many challenges in the transition to its large-scale adoption, including the difficulty of unravelling the existing structure and firmly embedded business processes. Economic incentives, including those arising from back-office savings and capital reduction, could nevertheless accelerate some aspects of the transition.

Appendix 1

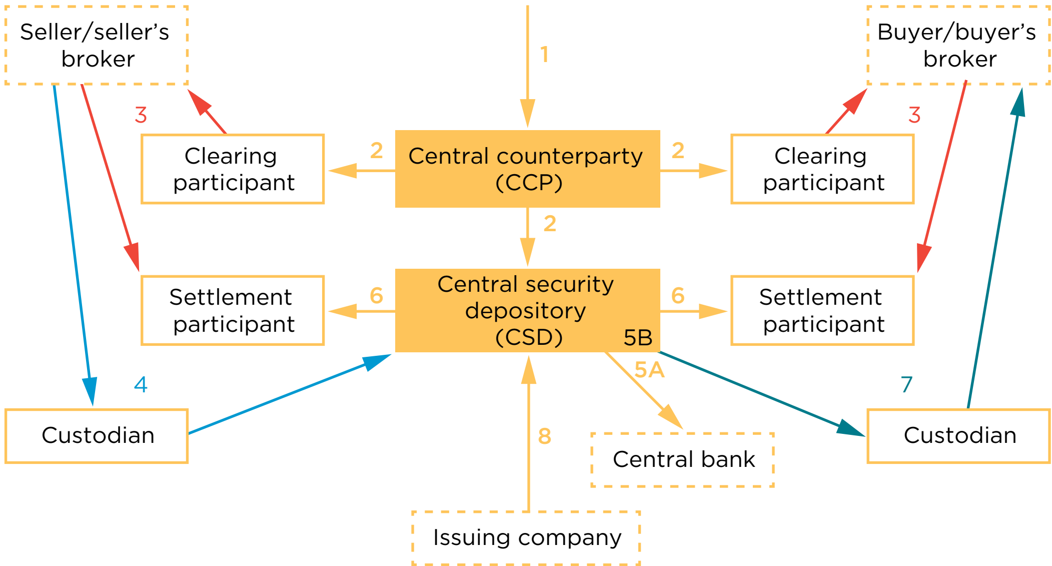
Background on post-trade processing in the equity market

Existing post-trade arrangements involve layers of intermediation and reconciliation (Figure 1). Some of these could be eliminated or transformed by the introduction of distributed ledger technology.

To settle an exchange-traded equity transaction, the current process generally consists of the following steps:

1. The details of a trade are submitted to the CCP which reconciles orders and performs novation and netting.
2. Both *clearing participants* are notified of the trade including information on security payment/receipt and funds payment/receipt. The CSD is also notified of the trade.
3. The *clearing participants* inform their respective customers/brokers of their obligations and the customers/brokers instruct their *settlement participants*.
4. The seller (or its broker) submits an instruction for the securities to be transferred from its *custodian* to the *settlement participant's* account at the CSD.
5 a. On the settlement date, funds are transferred across accounts at the central bank.
   b. Securities are transferred (simultaneously, i.e. on a delivery-versus-payment (DvP) basis) from the seller *settlement participant's* account at the CSD to the buyer *settlement participant's* account at the CSD.
6. Both *settlement participants* receive confirmation of the completion of the DvP transfer.
7. The purchased securities are transferred from the buyer *settlement participant's* CSD account to the buyer's *custodian*.
8. When new securities are issued, the securities are added to a CSD when they are ready to be traded.

Figure 1: Current post-trading process in the equity market



Acknowledgements

We would like to thank Andrew Alexandratos, Louise Carter, David Emery, Steve Gallagher, Jenny Hancock, Bharat Patel, Tony Richards and Kaz Tsukamoto for their helpful comments and suggestions.

References

Boston Consulting Group (BCG) 2012, 'Cost benefit analysis of shortening the settlement cycle', prepared by the Boston Consulting Group, commissioned by the Depository Trust and Clearing Corporation.

Committee on Payment and Settlement Systems (CPSS) and International Organization of Securities Commissions (IOSCO) 2012, *Principles for Financial Market Infrastructures*, Bank for International Settlements, April.

Depository Trust and Clearing Corporation (DTCC) 2016, 'Embracing disruption: Tapping the potential of distributed ledgers to improve the post trade landscape', *DTCC White Paper*.

European Securities and Markets Authority (ESMA) 2016, 'The distributed ledger technology applied to securities markets', *ESMA Discussion Paper*, no. 2016/773.

Mainelli, M and Milne, A 2016, 'The impact and potential of blockchain on the securities transaction lifecycle', *SWIFT Institute Working Paper*, no. 2015–007.

Pinna, A and Ruttenberg, W 2016, 'Distributed ledger technologies in securities post-trading', *ECB Occasional Paper Series*, no. 172.

PricewaterhouseCoopers 2015, 'Shortening the settlement cycle: The move to T+2', PwC Report.

Waters, R 2016, '"Ether" brought to Earth by theft of $50m in cryptocurrency', *Financial Times*, 18 June.