Project Jasper: Are Distributed Wholesale Payment Systems Feasible Yet?

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- Distributed ledger technology (DLT)—most commonly known as the foundation of Bitcoin—offers a fundamentally different way to conduct and track financial transactions. Researchers are investigating its usefulness in all corners of the financial system.
- Project Jasper is a proof of concept of a DLT-based wholesale payment system. The experiment provided significant insights into the relative strengths and weaknesses of using DLT for financial market infrastructures.
- For critical financial market infrastructures, such as wholesale payment systems, current versions of DLT may not provide an overall net benefit relative to current centralized systems. Recent versions of DLT have, however, made advances compared with initial cryptocurrency applications of DLT.
- Benefits for the financial system of a DLT-based wholesale payment system could likely arise from its interaction with a larger DLT ecosystem of financial market infrastructures, potentially including cross-border transactions.

Introduction

Financial technology (fintech) is defined as financial innovation enabled by technology that could result in new business models, applications, processes or products and that has an associated material effect on financial markets and institutions or the provision of financial services.[3]

One such innovation with significant potential is distributed ledger technology (DLT), or blockchain, as a common variant of it is known (**Box 1**). DLT, introduced with the cryptocurrency Bitcoin in 2008 (Nakamoto 2008), enables the secure validation and recording of transactions. A distributed ledger is a database shared between multiple parties. It allows those parties

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3 See Schindler (forthcoming) for a discussion of the drivers of fintech.

Box 1

What Is a Distributed Ledger System?

Distributed ledger technology became popular following the introduction of the cryptocurrency Bitcoin in 2009. A bitcoin (lower case b) is a digital token that represents a digital money. Bitcoin (upper case B) is a system to transfer bitcoins between people. This is done via a ledger of transactions that is visible to all and maintained by a distributed system of "miners" who operate computers that are nodes on the system. These nodes update the ledger with new transactions as they are made. The ledger is designed as a series of blocks of transactions linked together using cryptography. This ledger is known as a blockchain.

This system was a breakthrough because it demonstrated a way to maintain a ledger of information between parties in such a way that (i) no one oversees the system and (ii) the ledger can be credibly updated and agreed upon by members of the Bitcoin system even though no one trusts any other member to act honestly.

This "trustless" updating of a distributed ledger is achieved by having miners compete to win the right to validate blocks of transactions by solving a difficult mathematical puzzle. The first miner who completes a new puzzle broadcasts the block and solution to all the other miners and in return "mines" new bitcoins created with that block. Although the problem miners work on is difficult to solve, it is easy to verify. Once the other nodes have seen and verified a new solution, the new block is added to the chain, the transactions in the block are considered settled and miners begin mining a new set of transactions. The way nodes come to agreement about the new block is called a consensus mechanism, and the puzzle is the proof of work (PoW).

While the Bitcoin system has proven to be quite resilient, a number of aspects undermine its suitability for financial market infrastructures: (i) all transactions are visible to everyone, which may, for example, violate banking laws and put certain parties involved in transactions at a disadvantage; (ii) PoW is very costly in terms of time and energy and its benefits are not typically needed in trusted environments; and (iii) the system is open to anyone who would like to join and participants are anonymous.

To address these issues, financial technology companies have been developing alternatives to the Bitcoin system. These new distributed ledger systems allow access only to a restricted set of trusted counterparties. In some systems the consensus mechanism is replaced by other methods to reach agreement. In the Corda platform used in Phase 2 of Project Jasper, this is done via a notary node that is trusted by everyone and replaces the PoW function. Finally, these systems dispense with the concept of a blockchain and replace it with a ledger that is still distributed among the nodes, but where each node has access only to necessary data. This affords less transparency across the system and allows more privacy for participants.

to execute mutually agreed-upon transactions and achieve consensus on changes to the database. In this way, it ensures consistency between parties. The key feature of a distributed ledger is that authorized parties, through the use of a consensus mechanism, share identical versions of the data without the need for a central database or central administrator.[4]

A more general-purpose DLT platform called Ethereum was launched in 2013. It allows any type of digital asset to be defined, created and traded. It also enables smart contracts, which allow a DLT to execute the terms of a contract automatically, providing more functionality than simply transferring one specific type of asset (Buterin 2013). These developments sparked tremendous interest from the financial sector. The shared nature of the underlying ledger can offer a number of potential benefits, including process and cost efficiencies, resilience and interoperability. However, there are also a number of challenges in adapting DLT to financial sector applications, including the speed of transacting, achieving finality of the transactions, and privacy. Recent fintech companies have developed more general DLT systems, such as Corda[5] by R3, to meet the needs of the financial sector.

4 For an overview of DLT and the policy issues surrounding it, refer to CPMI (2017). For a technical but accessible introduction to some of the concepts in this article, refer to Narayanan et al. (2016).

5 Corda is an open-source distributed ledger platform designed to record, manage and automate legal agreements between businesses.

Financial sector participants are interested in this distributed ledger technology for several reasons. It has the potential to reduce back-office costs by automating various settlement processes. It can increase the reliability and traceability of information stored in the ledger, since the consensus mechanism puts limits on who can change records and how they can change them. Finally, with decentralized processes, settlement of transactions could be faster—reduced to hours or minutes instead of days.

One area of interest has been the potential implications of DLT for financial market infrastructures (FMIs). FMIs act as the trusted third party between financial institutions, tracking and recording transactions in centralized ledgers. Operators of FMIs, participants and central banks are all interested in the efficiencies and opportunities that a DLT-based system could provide relative to current centralized systems. As a result, many recent DLT advancements have focused on ways for traditional operators of centralized systems to realize the benefits of DLT while mitigating its disadvantages. For example, a common trend has been toward creating DLT systems that restrict access to a group of trusted entities. This contrasts with open arrangements like Bitcoin, where any entity can participate. To date, central banks have implemented DLT only in proofs of concept, and further examination of potential DLT applications can be expected.

One of the areas being investigated is the possible application of DLT to wholesale payment systems. Canada's existing wholesale payment system is the Large Value Transfer System (LVTS), operated by Payments Canada. The LVTS processes an average of $175 billion in payments each business day. It has been designated a systemically important FMI and is overseen by the Bank of Canada in accordance with the Principles for Financial Market Infrastructure (PFMIs).[6]

Wholesale payment systems make sense as an early potential application of DLT because they are relatively simple. They are also critical for financial stability. It is therefore important that overseers, like the Bank of Canada, understand how the use of DLT could change the way centralized systems are structured and operate, whether a DLT system could meet existing international standards, and any potential implications for payment system policy.

In 2016, Payments Canada, along with the Bank of Canada, R3 and Canadian commercial banks that are members of the R3 consortium, initiated an experimental project, code-named Project Jasper, to explore a DLT-based wholesale payment system.[7] The immediate goal of Project Jasper was to build a proof-of-concept system (with no intention of advancing to a production-level system) that leveraged a settlement asset issued and controlled by a central bank. In the first phase (Phase 1), participants built a settlement capability on an Ethereum platform and demonstrated its ability to exchange a settlement asset between participants. The second phase (Phase 2), built on a Corda platform, incorporated a liquidity-saving mechanism (LSM) that allows participants to coordinate their payments to reduce liquidity needs. As part of Phase 2, the participants are preparing a longer white paper, to be published by the end of June 2017, outlining the detailed technical and policy implications of the work.

6 The PFMIs are a set of international standards for systemically important payment systems established by the Bank for International Settlements (CPSS-IOSCO 2012).

7 R3 is an international consortium of large banks with the goal of investigating and developing applications of DLT for the financial sector. Participating Canadian members are BMO Bank of Montreal, Canadian Imperial Bank of Commerce, HSBC, National Bank of Canada, Royal Bank of Canada, Scotiabank and TD Canada Trust. These seven institutions are also members of Payments Canada, and they are all participants in the LVTS.

One of the main lessons from this experiment is that the versions of distributed ledger currently available may not provide an overall net benefit when compared with existing centralized systems for interbank payments. Core wholesale payment systems function quite efficiently. There may, however, be net benefits for the broader group of payment system participants and the entire financial system from a DLT-based wholesale payment system in terms of savings from reduced back-office reconciliation and improved interaction with a larger DLT ecosystem of financial market infrastructures. Below is a high-level overview of the project and the preliminary findings.

Key Features of Project Jasper

Project Jasper provided vital insights into how a central bank and participating financial institutions can complete interbank payments on a distributed ledger.[8] The project also offered an understanding of the functioning of a wholesale payment system using different DLT platforms and how modern payment system features, such as queues, could be incorporated to increase efficiency by reducing collateral needs. Finally, developing a working prototype improved awareness of potential risks associated with DLT-based systems and how they can be mitigated.

The first key challenge in developing Project Jasper was establishing how to transfer value. The PFMIs require that an FMI settle in central bank money whenever practical and available. This usually means settling using accounts at the central bank. To do this, the concept of a digital depository receipt (DDR) was used to represent Bank of Canada deposits. A DDR is a digital representation of currency that is issued by the Bank of Canada; it could be one approach for a wider use of central bank money in the future (Garratt 2017). DDRs are issued in the system by the Bank of Canada and are backed one for one by cash pledged to the Bank by participants. The exchange of DDRs for central bank money means there is no increase in money circulating in the banking system.

The DDRs are used by participants in the system to exchange and settle interbank payments. The processing cycle of Project Jasper achieved ultimate settlement finality on the books of the Bank of Canada after exchanging DDRs with the Bank of Canada for Canadian dollars transferred into their respective settlement accounts. For all intents and purposes, these DDRs functioned as cash in the system.

The second key challenge was how to most efficiently settle payments with the minimum amount of DDRs or liquidity. Historically, interbank payments were settled using systems that conduct end-of-day netting between participants. But as volumes and values increased in these systems, central banks became concerned about the risks inherent in netting. In response, most central banks have opted for the implementation of real-time gross settlement (RTGS) systems (see Bech and Hobijn 2007). With RTGS, payments are processed individually, immediately and with finality throughout the day. Phase 1 of Project Jasper was implemented as a pure RTGS system with every individual payment on the ledger being prefunded by DDRs in the participant's wallet.

RTGS systems eliminate settlement risk at the cost of an increased need for liquidity. Liquidity demands on RTGS systems can be enormous, given the large values that are settled in these systems—typically up to one-fifth of a

8 Further information about work on e-money at the Bank of Canada can be found on the Bank's e-money page.

country's gross domestic product on a daily basis. To make RTGS systems less liquidity-demanding, operators around the world have implemented LSMs.[9] The most effective LSMs are those that support settlement by periodically matching offsetting payments that have been submitted to a central payments queue and settling only the net obligations.[10] However, offsetting algorithms cause delay in settlement, which is unacceptable for some types of payment. Banks therefore need a way to make these time-critical payments. Phase 2 of Project Jasper explored the possibility of giving banks the choice of entering payments for immediate settlement or into a queue for netting and deferred settlement. Project Jasper appears to be the first public instance of implementing an LSM algorithm on a distributed ledger platform.

Technical Aspects of Project Jasper

The rise of Bitcoin spurred the interest of FMI developers in DLT. Bitcoin uses a proof-of-work (PoW) protocol that provides decentralized validation of transactions. PoW protocols are designed to deter a participant from taking over an open DLT system and double-spending or rewriting the ledger. This is done by requiring costly work from each node verifying transactions. This protocol can be very computationally expensive, however, and requires some level of transparency of all transactions. On the Bitcoin blockchain, for example, all the identities of participants are masked, but all transactions are visible to everybody. This expense and transparency stem from the anonymous and open nature of DLTs such as Bitcoin.

In Phase 1 of Project Jasper, the system was built on the Ethereum platform, which uses a PoW consensus protocol. The public version of Ethereum is an unrestricted system that shares a full copy of the ledger with all participants; Jasper used a version that shared the ledger among R3 members only. In a closed, private network, like a wholesale payment system, PoW protocols are neither necessary nor desired. Restricting access to trusted counterparties enables developers of DLT protocols to use alternative efficient protocols to perform the validation and recording functions.

The Corda platform on which Phase 2 of Project Jasper is built uses a notary function instead of PoW. A key feature of Corda is that updates to the ledger are achieved through two functions: a validation function and a uniqueness function.[11] The validation function, performed by the parties involved in the transaction, ensures that all details of the transaction are correct and that the sender has the required funds. The uniqueness function is performed by a notary. For the Project Jasper system, this is the Bank of Canada. In this role as notary the Bank has access to the entire ledger so that it can verify that the funds involved in a transaction are available.

Liquidity-saving mechanisms in Project Jasper

The Jasper LSM is a payment queue with periodic multilateral payment netting. Conceptually, the way it works is quite simple. If a bank has a non-urgent payment, the payment can be put in a holding queue. After the bank

9 In the early 1990s approximately 3 per cent of the largest payment systems in the world used liquidity-saving features; by 2005 this proportion had risen to 32 per cent (Bech, Preisig and Soramäki 2008). This trend has continued, and nearly all major payment systems now use some form of LSM.

10 The liquidity savings from offsetting algorithms arise from the fact that liquidity is needed only for the net difference between payments to allow settlement. Suppose Bank A needs to make a payment to Bank B for a value of $100, and Bank B needs to make a payment to Bank A for a value of $90. The amount of liquidity required to settle these two payments, if they were entered into a queue operating an offsetting algorithm, would be $10. In contrast, without an LSM, the liquidity requirement to settle these two payments would be at least $100.

11 See the non-technical Corda white paper.

submits a notification of the payment to the queue, the submitted payment waits with other queued payments until the beginning of a matching cycle. The queue is then locked temporarily while an algorithm combines all the submitted payments, determines each bank's net obligations and assesses each bank's liquidity position.[12]

A payment queue is inherently centralized. A key challenge was implementing it in a DLT system, rather than using traditional account-based centralized ledger systems. These technical issues introduced significant complexity and served to highlight the challenges inherent in building decentralized systems that rely on some level of centralized control or centralized information.

The innovative solution developed in Project Jasper was the incorporation of an "inhale/exhale" routine onto the Corda platform. Before the matching cycle begins, banks may submit payments to the queue. However, these payments do not immediately go through the two-stage validation and uniqueness process necessary to add a transaction to the ledger in the Corda system. Instead, the payment instructions sit in the queue until the matching cycle begins. At that point, a sequence of events occurs. First, during the "inhale" phase, a notification is sent to all banks participating in the matching cycle requesting that they send DDR to the Bank of Canada. Each of these individual payments is then validated and added to the ledger. Then, in the "exhale" phase, the matching algorithm determines a subset of payments to clear, on a net basis, given available funds. The Bank of Canada sends DDR payments back to all participating banks equal to the amounts they contributed, plus or minus any money they are owed or owe following the completion of the matching algorithm.

To illustrate, suppose that only two banks, A and B, place payments to each other in the queue with values equal to $100 and $90, respectively. In addition, each bank sent $15 to the queue as part of the inhale phase. After netting the two payments, the algorithm would charge $10 to Bank A and credit $10 to Bank B. Given their initial contributions from the inhale phase, this would mean the exhale phase payments are $5 to Bank A and $25 to Bank B.

These transactions are then validated and added to the ledger. Payments not matched by the algorithm remain in the queue. At this point a new matching cycle begins. Banks are free to enter or remove payments from the queue until the end of the next matching cycle, and the process continues to repeat.

Efficiency and Financial Stability Risks of Project Jasper

The efficiency and financial stability risks of Project Jasper were evaluated through the lens of the PFMIs that apply to the operation of a wholesale payment system. Of these, only those relevant to a proof-of-concept system were considered. Principles that would apply only to a production-level FMI—such as those relating primarily to governance and legal aspects—were excluded.[13] Thus, the examined principles can be grouped in terms of the risks they address: credit and liquidity risk, settlement risk and operational risk.

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12 The design is similar to the LSM added to the United Kingdom's wholesale payment system, the Clearing House Automated Payment System (CHAPS), in April 2013. In CHAPS, the time between each matching cycle is two minutes and payments are frozen for 20 seconds during each matching cycle while the matching algorithm runs. The United Kingdom reports liquidity savings of around 20 per cent (Davey and Gray 2014).

13 Other legal questions outside of the PFMIs, such as anti-money laundering requirements, were also excluded.

Credit and liquidity risk

The Jasper platforms were designed without credit risk because all payments represent a claim on deposits at the central bank—a riskless asset. Participants transfer cash to the Bank of Canada, through the LVTS, which then creates DDRs that can be exchanged on the distributed ledger platform. Overall, nothing in the proof-of-concept design was identified to be fundamentally incompatible with the credit-risk principle.

As outlined above, Project Jasper incorporated an LSM that imitated the functionality of existing RTGS systems to mitigate liquidity risk, the risk that a participant would have insufficient DDRs to make a payment. The performance of Jasper's LSM is currently being tested using simulated data. While it is too early to predict the results of these simulations, we can report that to date we see no evidence that implementing the LSM on a distributed ledger would change its use or performance relative to a centralized system. The LSM would likely generate liquidity savings similar to existing LSMs.

Settlement risk

Settlement is defined as the irrevocable and unconditional transfer of an asset. Defining the conditions under which settlement is final is foundational to financial stability.

Two aspects related to settlement finality are relevant to the application of DLTs like Project Jasper: operational settlement—or the certainty of the process by which a decentralized ledger is updated—and legal settlement, which is how settlement finality is defined in relevant system rules and associated laws.

To ensure legal settlement finality, Project Jasper was structured so that a transfer of DDR was equivalent to a full and irrevocable transfer of the underlying claim on central bank deposits. This design feature relates to the issuance of DDR and is therefore independent of the platforms upon which Jasper was built.

In contrast, to ensure operational settlement finality, issues related to the underlying technology of the DLT platforms used would need to be resolved. In the case of Ethereum, a PoW consensus mechanism is used to validate payments. But PoW settlement is probabilistic. The payment is therefore never fully settled because there is always a small probability that the payment could be reversed. Settlement becomes increasingly certain as the recorded transaction becomes more immutable over time, but it never reaches the point of being irrevocable. In the Corda platform, the role of a trusted notary would, in theory, eliminate this uncertainty because transactions could not be revoked once completed. However, this system has not been stress tested, and thus some risk may still be associated with settlement finality.

Overall, the move from Ethereum to Corda reduces settlement risk and improves the likelihood that a production system would comply with the settlement-risk principle. However, a final assessment requires further testing.

Operational risk

Resilience, security and scalability are the core operational risk considerations in wholesale payment systems. Given that Project Jasper is not a production-level platform, a detailed assessment of all of these operational risks was not possible. That said, the focus of Jasper was on resilience and scalability.

In terms of resilience, a key question was whether a DLT-based wholesale payment platform could provide more cost-effective resilience by having no single point of failure. Phase 1 of Project Jasper demonstrated a lower cost for high availability[14] because the nodes operated by all of the participants essentially served to back each other up insofar as their shared data were concerned. This guaranteed high availability without extra risk-proofing of each node. However, once additional functionality, such as an LSM, is added to the system, the susceptibility to a single point of failure can return. Resilience must therefore be carefully considered in the implementation design, for three reasons.

First, additional technology components—such as key, identity and system access management—are currently based on centralized models and the assumption of single trusted operators (there are early-stage attempts to devise distributed versions of these). Thus, these important components suffer from the same typical challenges associated with a single point of failure that existing centralized systems face. For example, the digital keys are bound to individual participants and are used to prove these participants' right to perform transactions on specific assets; any operator of a blockchain node needs to have system components to store its digital keys securely and not share them with others in the network. Thus, system components that store digital keys should be made highly available to avoid single point-of-failure risk and backed up for disaster recovery since this information cannot be recovered from another participant's node.

Second, the single-point-of-failure comparison of DLT systems with existing systems can be taken a step further with a notary system, such as Corda. Unlike PoW, participants' individual nodes must be operational to send or receive payments, reducing the resilience of the system. The Corda DLT platform examined in Project Jasper partitions data so that each participant's node has access to and maintains only a subset of that data. While this approach resolves data privacy issues, it introduces significant challenges for data replication across the network.[15] Unlike public blockchain schemes, where all nodes have a copy of the exact same database (e.g., Jasper Phase 1), these restricted systems have a point of failure at every node; that is, each node requires data replication and archiving to ensure business continuity, rather than each node providing resilience to the system, as in the case with the Ethereum blockchain.

Third, a single point of failure is more likely in a notary system, where nodes are relatively more specialized than they are in a PoW system. In Phase 2 of Project Jasper, the role of notary in Corda is performed by the Bank of Canada, so an outage at the Bank would prevent any processing of payments. This is important because it highlights that operational resilience is related to the function being performed by each node.

An overall evaluation suggests that, when compared with both centralized platforms and an open DLT platform, restricted distributed ledger schemes may decrease operational resilience if they are not carefully designed. This need for operational resilience may make Jasper Phase 2, based on Corda, more expensive than the current centralized system in terms of meeting the PFMIs. In Jasper Phase 2, it is therefore likely that each participant would have to invest in a high-availability node to reduce the chance of an outage.

14 A payment system is said to be highly available if it operates a very high percentage of the time it is supposed to, for example, 99.99 per cent of the time.

15 It is important to note that Corda queues pending requests to nodes as part of the design, so that when a participant with an outage is back, online transactions may still be processed.

Another key aspect of operational risk in the PFMIs is scalability. Currently, the LVTS processes 32,000 transactions daily, with a peak throughput of roughly 10 transactions per second. In DLT arrangements, there is a computational cost to distributing functionality. In PoW platforms like Ethereum, there is limited capacity to scale. In Phase 1 this was approximately 14 transactions per second because Ethereum was designed for the public Internet, where speed limitations would challenge information flow between nodes. While this speed is sufficient to process current daily LVTS volumes, it could create future peak volume constraints, such as in times of market stress or volatility. In contrast, scalability would not be a constraint in the Corda platform because Corda does not have a consensus method based on a fixed time and requires only nodes of the involved parties and a notary to verify transactions.

Transparency and Privacy

A fundamental requirement for a wholesale payment system is the need for participants to keep their transactions private from parties not involved in the transaction. This is necessary to prevent other participants from being able to take advantage of this information. A participant's clients may also prefer or require this privacy. By implication, PoW systems are ill-suited for these types of large-value systems because they operate under the assumption that all transactions in the system are, at a certain level, publicly observable.

In contrast, notary-based DLT systems, such as Corda, permit increased privacy because a trusted third party (e.g., the Bank of Canada) helps validate all transactions. But the lack of transparency in the Corda system implies that no node in the system, with the possible exception of the notary, has all the information. Therefore, if the information at one or more nodes is corrupted, it may not be possible to reconstruct the entire network since even the notary does not have a full copy of the ledger. This creates the need for backups of individual nodes and a loss of the economies of scale associated with centralized systems. Further, it raises the question of whether the proposed operational-resilience benefits of DLT are possible under the constraint that transactions remain private.

Conclusion

Project Jasper enabled a better understanding of the roles and responsibilities of the operator of a DLT wholesale payment system, its participants and the central bank. In a DLT framework, the operator's role would likely be closer to that of a rule maker or standard setter rather than a traditional IT infrastructure operator. DLT has implications for the roles of operators as well as for how the PFMIs should be applied or revised. It may be necessary at some point to update the PFMIs to include principles outlining regulatory authorities' requirements for structuring a DLT for a market infrastructure.

In addition, the work on Project Jasper has allowed the stakeholders of the wholesale payment system to jointly develop the platform. Both private and public sector partners learned a great deal about the technical aspects of DLT from the project. They found this improved their mutual recognition of the complexity of the processes involved and cultivated collaboration to overcome technical obstacles. It also allowed for a comprehensive comparison of different DLT technologies from all perspectives (i.e., overseer, operator and participant).

A pure stand-alone DLT wholesale payment system is unlikely to match the net benefits of a centralized wholesale payment system. This is because some parts of a viable wholesale payment system are inherently centralized, such as the LSM discussed above. This added complexity could lead to further operational risk when compared with current centralized systems.

Instead, the benefits of a DLT-based wholesale payment system likely lie in its interaction with the broader FMI ecosystem. Such benefits may be obtained by integrating other assets on the same ledger as payments—which could greatly simplify collateral pledging and asset sales—reaping economies of scope and reducing costs to participants by integrating back-office systems.

Cost savings or efficiency gains may also be possible sector-wide. This could occur if a DLT-based core interbank payment system can serve as the basis for other DLT systems to improve clearing and settlement across a range of financial assets. For example, exchange-traded assets already clear and settle through safe and efficient systems. But gains would be possible if these systems could be integrated by having cash on the same ledger as payments to settle the cash leg of each transaction. Over-the-counter markets (for stocks, bonds and derivatives), syndicated loans and trade finance are much more decentralized systems with long settlement times. These could be significantly improved using a DLT-based platform if they could be integrated with a core wholesale payment system, resulting in the transfer of cash payments using central bank money.

Distributed ledger platforms offer potential cost savings by lowering the costs of reconciliation. If a DLT-based system allows banks to validate their transactions at the very beginning, it could reduce back-office reconciliation work and potentially achieve major cost savings for the financial sector. These cost savings depend on the nature of the DLTs: a PoW system like Ethereum, for example, would be relatively more expensive to operate because of the computational cost of the consensus mechanism.

Project Jasper has provided valuable insights to all the parties involved. Several paths could be explored further. One possible future extension could be to think about how to pledge general collateral instead of cash collateral to the Bank of Canada. Another would be to explore the potential integration between Project Jasper and other types of DLTs, either domestically or internationally. This could help determine potential efficiency increases from better connections, improved automation of cross-border payments or the ability to settle multiple assets (e.g., bonds or money market instruments) on the same ledger.

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