Cross-Border Settlement Systems: Blockchain Models Involving Central Bank Money
Xiaohang Zhao, Haici Zhang, Kevin Rutter, Clark Thompson, Clemens Wan
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Cross-Border Settlement Systems: Blockchain Models Involving Central Bank Money

Xiaohang Zhao, Haici Zhang, Kevin Rutter, Clark Thompson, Clemens Wan*

January 22, 2018

Abstract

Multiple central banks have conducted experiments with blockchain for domestic settlement between commercial banks. While progress has been made on domestic interbank settlement, there is not a clear approach for cross-border settlement. Today, interbank payments between currency zones require correspondent banking relationships, Continuous Linked Settlement (CLS) accounts, or a combination of both. This paper discusses several options that involve distributed ledger technology (DLT). The first group of models would heavily involve central banks, the second group involve a trusted third party and a more passive role for central banks. The models are evaluated based on monetary supply implications, impact on liquidity management for commercial banks, settlement risk, credit risk, and complexity for central banks. This preliminary exploration intends to inform future work with international payments.

1 Introduction

Several central banks have developed prototypes for domestic interbank settlement systems using distributed ledger technology (DLT). The early phases of these projects were proof-of-concept experiments that explored opportunities for DLT to improve the existing centralized Large Value Payment System (LVPS) or Real-time Gross Settlement (RTGS) infrastructure. Major aspects of Project Ubin and Jasper are listed in Appendix A. The Hong Kong Monetary Authority also recently completed a first phase of a third project with R3. Current and future phases of these projects are expanding to new applications.

RTGS systems are largely efficient from advanced economy central banks’ perspective. These systems involve near-instant book-entry adjustments between commercial bank settlement accounts at the central bank. However, DLT may provide gains for different stakeholders across:

- Liquidity management for commercial banks

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*Xiaohang and Haici are graduate students at the University of Delaware. Thanks to Paul Laux and Adam Jason Fleischhacker for their help with the paper. The corresponding author for this working paper is Kevin Rutter (Kevin.rutter@r3.com). The models and analysis that follows is preliminary.

1. All blockchains are distributed ledgers, but not all distributed ledgers “batch” information together into a chain of blocks. For simplicity the term blockchain and distributed ledger technology are used interchangeably in this paper.

2. These include Project Ubin in Singapore and Project Jasper in Canada.

3. Since the adoption of DLT will depend on the confidence of market players, project teams assessed the degree to which the DLT systems would meet the Principles for Financial Market Infrastructures (PFMI) prescribed by the Bank for International Settlements.

4. With Project Jasper and Ubin, similar design choices were made to minimize the monetary supply impact. Both projects represented money as tokens (depository receipts) redeemable for existing central bank reserves. Whereas central bank reserves are themselves interest rate remunerating, the depository receipts in the prototype were not.

• Expanded access to digital central bank money for new groups (such as corporates, retail)\(^6\)
• Delivery versus payment\(^7\)
• Underdeveloped interbank settlement infrastructure in developing economies
• Resiliency (avoiding a central point of failure), back-up systems
• Cross-border interbank settlement

This paper focuses on the last point, cross-border settlements between commercial banks.\(^8\) Cross-border payments are an area with many pain points across stakeholders.\(^9\)

First, the paper surveys the major methods of cross-border settlement as it works today, through correspondent banking and Continuous Linked Settlement (CLS). Cross-border settlement involves the exchange of one for another currency in pairs through foreign exchange (FX) transactions.

Second, the paper reviews possible designs for large value cross-border payment platforms with DLT. Several of these options do not necessarily have to be implemented by using a distributed or decentralized payment network. Some are implementable with more traditional or centralized technologies. Still, they may benefit from the flattened and transparent structure induced by peer to peer transactions along with decentralized data storage and validation.

Certain options require deep involvement and participation from central banks (in some cases in roles the central banks do not perform today), while others would allow the central banks to have a more passive role. The paper first reviews models with central banks as active participants, and second reviews models using trusted third parties instead of central banks. For each option, the components of the method, the actions undertaken, and conceptual evaluations of the method are presented. A final section summarizes the findings and suggests areas for further experimentation or implementation.

2 Existing Settlement Options

In this section we begin with a brief description of the concepts around cross-border settlement. Then, we look at settlement through correspondent banking and CLS. This sets the stage for the following sections, which build upon this context to examine the models.

Cross-border Settlement

A foreign exchange transaction is the bidirectional payment of a currency pair. A central concern for the settlement of a FX transaction is the risk of having one currency leg irrevocably paid out while not finalizing the receipt of the other currency leg.

The possibility that a counterparty might fail to deliver a payment is called settlement risk. Settlement risk has four major components: credit risk, liquidity risk, operational risk and business risk (Manning, Nier, and Schanz 2009). Because settlement risk usually boils down to credit risk, known as Herstatt risk in the FX context, only credit risk will be discussed in this section.

The longer time a FX transaction takes, the riskier it will be. The standard FX transaction takes more than 2 days to settle. The reason is that there often exists a significant time zone difference between the two involved currency jurisdictions. To settle each currency leg, the funds must be

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\(^6\)The Riksbank’s e-krona project is examining routes for expanding digital central bank money to the general population. Phase 1 of Project LionRock with the HKMA (forthcoming paper) examined expanding digital central bank money to corporates.

\(^7\)Project Jasper Phase 3 is examining securities settlement.

\(^8\)It should be emphasized that this paper only discusses the trades among banks rather than the trades between banks and their customers. Without loss of generality, the paper also assumes spot FX transactions. See Eun and Resnick (2014), chapter 5, for a definition of the FX interbank market.

\(^9\)See the speech, Fintech and Cross-Border Payments for more information on some of the shortcomings. Despite these pain points, there are still substantial barriers that make reforming international wholesale payments a difficult task. For example, given the global systemic importance of international payments, any solutions would have to be extremely operationally mature and also avoid unintended consequences.
transferred through the relevant domestic payment system. The operating hours of these payment systems are different across international time zones.

The core settlement step occurs when money is exchanged in relevant payment systems by updating four accounts: the due from and due to account of currency X as well as the due from and due to account of currency Y for the respective banks. For example, Table 1 shows the core settlement step of Figure 1, in the next section. This paper focuses on the core settlement step in central bank money.

<table>
<thead>
<tr>
<th></th>
<th>Due from account</th>
<th>Due to account</th>
</tr>
</thead>
<tbody>
<tr>
<td>Currency X</td>
<td>Bank A</td>
<td>Bank B's correspondent</td>
</tr>
<tr>
<td>Currency Y</td>
<td>Bank B</td>
<td>Bank A's correspondent</td>
</tr>
</tbody>
</table>

### Correspondent Banking

Traditionally, cross-border transactions have been settled in a decentralized way through a correspondent banking relationship. In one example, two banks are each members of their local LVPS, but do not have direct access to the LVPS of the foreign currency they are trading for. Figure 1 shows this example for a Japanese Bank (A) buying Canadian Dollars from a Canadian Bank (B). Both banks have to maintain a correspondent banking relationship with another participating bank that has a domestic presence that can receive payments on their behalf and execute subsequent payment instructions.

![Figure 1: Correspondent Banking](Source: Miller and Northcott (2002))

It is also possible that neither bank has direct access to the LVPS of foreign currency. For example, Bank A could be in London, but holds Japanese yen (JPY) through a correspondent bank in Japan while Bank B could be in Zurich but holds Canadian dollars (CAD) through a correspondent bank in Canada (Mägerle and Maurer 2009). In this example, the payment made by Bank A may stem from a credit line offered by its correspondent bank. In other words, if allowed by the arrangement of the correspondent banking relationship, Bank A could have an overdraft in its nostro account. Consequently, it is the correspondent bank which pays central bank money and therefore is directly exposed to credit risk.

The correspondent banking approach to settling cross-border transactions introduces credit risk because the delivery of the currency being sold is not conditional on the final receipt of the currency.

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10 A special case is that Bank A and Bank B have the same correspondent bank that operates subsidiaries in both currency jurisdictions (Arjani 2007). Consequently, the correspondent bank could update its book by crediting and debiting the client accounts and no fund transfer through LVPS is required. However, as long as the crediting and debiting operations are not synchronized, settlement risk still exists.

11 Bank A’s nostro account refers to the subaccount held by Bank A in its correspondent bank.
being purchased. Each counterparty may take a credit exposure up to the principal value of the trade and the potential loss may exceed its capital.

**Continuous Linked Settlement (CLS)**

To reduce the credit risk from correspondent banking, major players in the FX market jointly created a payment-versus-payment (PvP) mechanism called Continuous Linked Settlement (CLS).\(^{12}\)

In a business day, CLS links the gross settlement of all the possible currency pairs that can be formed by its membership by batch-processing FX transactions during a time window that all the domestic LVPS\(^{13}\) of the supported currencies are open.

Using CLS, the settlement of payment obligations is separated from the actual fund flow. Each settlement member holds a single multi-currency account at CLS and submits its payment instructions resulting from FX transactions to CLS before a settlement day starts (i.e., no later than 00:00 CET) via SWIFT messages.

During this procedure, the settlement member accumulates short positions in currencies for which it is an overall seller and long positions in currencies for which it is an overall buyer. Assuming that all trades related to a settlement member will be settled, an overall balance will be calculated by CLS for each currency at 00:00 CET and is provided as the initial pay-in schedule or liquidity required to the settlement member, who sends central bank reserves to the CLS settlement account. Between 00:00 CET and 06:30 CET, further liquidity saving actions may be taken by members by submitting in-out swap instructions.\(^{14}\) From 06:30 CET, a revised pay-in schedule is calculated and then the settlement and funding cycle will last from 07:00 CET to 12:00 CET. While the settlement process usually ends by 09:00 CET, the pay-in and pay-out process goes on continuously. Figure 2 summarizes the operational timeline of CLS.

![Figure 2: CLS Operational Timeline (CET)](source: Mägerle and Maurer (2009))

To settle a trade, relevant accounts of counterparties are credited and debited on the book of CLS. Consider the following example.\(^{15}\) Suppose both Bank A and Bank B have accounts in the relevant LVPS and are settlement members of CLS. Bank A buys dollars from Bank B with pounds and the agreed exchange rate is $2/£. The amount for trade is 1 million pounds and 2 million dollars. To further simplify analysis, assume that this is the only transaction that CLS will settle in a day. The net positions of Bank A and Bank B in currency USD and GBP are reported in Table 2.

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\(^{12}\)The presentation here is based on Annex 4 of CPSS (2008) and Bordo et al. (2016). Also, see Mägerle and Maurer (2009) for a brief introduction on the topic.

\(^{13}\)These LVPS are typically Real Time Gross Settlement Systems (RTGS).

\(^{14}\)When two members have reverse positions in two currencies, they can swap their positions in CLS while swapping back outside of CLS later and thus in effect reduce their obligation (right) to pay to CLS (receive from CLS) in a settlement day. Although the reverse swap is usually settled through the traditional correspondent banking channel and therefore re-introduces credit risk, it pushes the liquidity constraint to a future date. For example, member A has a net short position in currency X (amount \( -A_X \)) but a net long position in currency Y (amount \( +A_Y \)) while member B has the opposite position (amount \( -B_X \) and \( -B_Y \)). Then the liquidity saving A and B could get today by doing an in-out swap will be at most min \( (A_X, B_X) \) in currency X for A and at most min \( (A_Y, B_Y) \) in currency Y for B.

\(^{15}\)Cited in Bordo et al. (2016), chap. 13.
To settle the trade, Bank A and Bank B do not need to have fully funded accounts at CLS. In fact, CLS will divide the pay-in process into five tranches (each lasting for one hour) so the liquidity need will be spread out across the funding cycle. However, the settlement in CLS is still on a gross basis. Consequently, CLS allows a member to have intra-day overdrafts. For our simple case, suppose Bank A and Bank B put 10% of their trade amount into their CLS accounts as “collateral” or initial pay-ins. The balance sheets of Bank A, Bank B and CLS before and after settlement are reported in Table 3.

Table 3: Balance Sheets Before and After Settlement

<table>
<thead>
<tr>
<th>Before</th>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$2M due from Bank B +£0.1M due from CLS -£0.1M CB Funds</td>
<td>+£1M due to Bank B</td>
</tr>
<tr>
<td>B</td>
<td>+£1M due from Bank A +£0.2M due from CLS -£0.2M CB Funds</td>
<td>+£2M due to Bank A</td>
</tr>
<tr>
<td>CLS</td>
<td>+£0.1M CB Funds +£0.2M CB Funds</td>
<td>+£0.1M from Bank A +£0.2M from Bank B</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
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<th>Assets</th>
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</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>+£2M due from CLS -£0.1M CB Funds</td>
<td>+£0.9M Overdraft at CLS</td>
</tr>
<tr>
<td>B</td>
<td>+£1M due from CLS -£0.2M CB Funds</td>
<td>+£1.8M Overdraft at CLS</td>
</tr>
<tr>
<td>CLS</td>
<td>+£0.1M CB Funds +£0.2M CB Funds</td>
<td>-£0.9M from Bank A +£2M from Bank A +£1M from Bank B +£1.8M from Bank B</td>
</tr>
</tbody>
</table>

Source: Bordo et al. 2016, pp. 599, Table 13.2A, 13.2B

The above example has several implications when thousands of transactions are settled through CLS. The first is that a trade is settled in the sense that obligations due to and due from counterparties will be undertaken by CLS. Because settlement is on a gross basis while fund flowing is on a net basis, CLS is “forced” to allow members to have overdrafts at some currency subaccounts if the overall balance across all currencies after conversion into USD is positive.

Otherwise, the sequence of settlement would be hard to arrange. Most of the time, an overdraft will be offset either by later settlements or through pay-in fund flows. However, a large overdraft is still risky because of the possibility of default. So CLS puts limits on the negative position one can hold per currency.

CLS allows its members to have temporary negative balances for more than one currency subaccount at the same time. Given that the net balance due to a FX transaction should always be zero when calculated using the agreed exchange rate, and that FX transactions are settled on a gross basis, one may wonder how an overall balance could become negative.

There are two possible reasons for a negative balance. First, the exchange rates used by CLS to compute the overall balance are generally different from the exchange rates specified by the associated FX contracts. In the case that someone fails to deliver the sold currency, it is the obligation of CLS to pay out the desired currency. CLS will do this by selling other currencies held by the default member to some liquidity providers at the spot exchange rate. To protect itself
from the potential loss due to exchange rate fluctuations, CLS will use the spot exchange rate on
the settlement day plus a haircut when calculating the overall balance.

The second reason is that both the pay-in and pay-out take place during the settlement process.
Assuming that no new settlements occur, it is possible that at a given time point, CLS pays more
than it receives from a member. Consequently, the existing overall balance can go negative when
the decrease outweighs the increase.

A transaction can be settled only if the negative positions that result from it do not exceed the
respective limits for both counterparties and that the overall balance after the settlement
remains positive. If any of the conditions are not satisfied, the transaction will be pushed back
to the queue and retried later. As stated before, the overall balance depends on the pay-in and
pay-out history. Whether a trade can be settled not only depends on but also influences this overall
balance, so the planned pay-in and pay-out schedule should be dynamically adjusted according to
the behavior of settlement members.

CLS saves members liquidity because actual fund movement is based on the net balance, assuming
all trades are settled. The netting calculation is done as if members are doing multilateral netting.
However, CLS is not a multilateral netting arrangement because transactions are settled individ-
ually. The actual fund flow will change if some transactions fail to settle because the involved
members do not pay CLS in time.

Members do not hold overnight positions at CLS. By the end of a settlement day, for any member,
all currency accounts should have zero balances. By centralizing the settlement of FX transactions,
the payments of currency legs related to a transaction are synchronized on the book of CLS. As
a result, liquidity saving features are offered based on a centralized netting calculation of the pay-in
schedule.

In addition, CLS provides a market maker feature. When one party drops out from a transaction
due to a default, the transaction can still be settled using standby lines of credit maintained by
CLS with liquidity providers for each supported currency.

CLS has provided significant improvements to cross-border interbank settlement since being founded
in 2002. It serves as an anchor technology in the modern financial world and has streamlined inter-
bank payments internationally. However, it does have a few limitations. First, it must operate
in a time window when all involved LVPS are open. For a specific transaction, settlement can be
faster, in theory, if the LVPS are geographically close. Second, CLS has strict requirements about
what currency can be settled through the system and who can become a member. In other words,
CLS at this time has somewhat restricted access.

Some of the following options in section 3 or 4 could complement existing CLS services or similarly
complement correspondent banking. Some of the following options may be carried out most effec-
tively by partnering with existing industry players, as significant barriers exist for implementing
changes to international wholesale payments.

3 Intermediate Cryptocurrencies in Context

Public cryptocurrencies like Bitcoin and Ethereum allow remote peer-to-peer transfer of electronic
value in the absence of trust between the counterparties. An intermediate cryptocurrency within
this paper’s context only circulates in the interbank market, accessible solely to financial institu-
tions. In other words, given the purpose of this paper, this type of intermediate cryptocurrency is
rooted in the wholesale segment of the payment system. This is in contrast to Fedcoin, which is a
concept for facilitating retail payments (Garratt 2016).16

16See Garratt (2016) for a further comparison between Fedcoin and CAD-coin. The property of “publicly accessible”
digital central bank money entails consequences beyond the scope of this research. The rough idea is that if
households and firms were given access to central bank accounts, commercial banks’ dominant role as providers
of credit and payment services could be undermined. As a risk-free, interest-bearing asset, a central bank issued
cryptocurrency for the retail rail may become preferable to bank deposits (and even paper currency, presuming
anonymity concerns were addressed), encouraging households and firms to convert their bank traditional deposits
into new cryptocurrency deposits. There are various proposed designs to account for this, such as account limits,
daily transaction maximums, and interest rate adjustments.
CAD-coin is a kind of domestic central bank-issued solution for wholesale payments, originally explored in Project Jasper. CAD-coin had the restriction that it could only be used to settle obligations between participants of the LVPS of a specific currency jurisdiction. With CAD-coin’s structure, if either counterparty does not have access to the LVPS, then a correspondent banking structure would need to be introduced.

This definition of intermediate cryptocurrency within this paper has an extra dimension compared with Project Jasper’s CAD-coin. While still specific to the interbank payment market, an intermediate cryptocurrency in this section’s context can flow freely across borders. The ledger where the intermediate cryptocurrency is issued should be open access such that worldwide financial institutions can hold accounts on it. In other words, the underlying ledger where the asset is issued and kept track of must achieve a global scope by relaxing the requirements about who can join the ledger. Ideally, settling an FX transaction with the generic structure “Currency A->Intermediate cryptocurrency->Currency B”, efficiency would be gained on the payment leg of the intermediate cryptocurrency since the digital asset can flow directly from the sender’s account to the receiver’s account.

Features of the Intermediate Cryptocurrency

This approach has several fundamental requirements. First, it should be widely-adopted. Unlike the domestic depository receipt models, an intermediate cryptocurrency should be honored as a valid settlement asset across multiple currency jurisdictions at least. Some examples would be universally accessible.

Second, it should have a stable market value. An intermediate cryptocurrency issued by a central bank should be pegged and convertible with the fiat currency issued by the central bank at par. The value of the cryptocurrency would be solidly supported by the value of the corresponding domestic fiat currency. The cryptocurrency also inherits the popularity from domestic money and would fit better with existing market infrastructures.

Public cryptocurrencies like bitcoin and ether are not backed by assets have no inherent value from assets held in a third party - as is the case with central or commercial bank money - but only speculative (market) value. This contributes to high volatility and hence the potential risk of loss during the “cash out” procedure when exchanging the cryptocurrency with fiat currencies (Koning 2017). This problem is worse if there is a time difference between the settlements of the two payment legs. An intermediate cryptocurrency should have stable market value to fulfill the function of value storage and facilitate value transfer across currency zones.

Third, it ideally should have deep liquidity. As both the volume and value of transactions are large through the cross-border wholesale payment system (Higginson 2016), there should be large and fluctuating demand for converting between the intermediate cryptocurrency and desired local currencies, which requires the existence of market makers to provide sufficient liquidity.

4 Central Bank Issuer Models

The three models below assume active involvement of central banks. The first model involves central banks issuing their own cryptocurrencies. The second model involves central banks coordinating to issue a dual-registered cryptocurrency for a specific currency pair. The third model involves credit lines.

Option 1: Central Bank-issued Intermediate Cryptocurrency

For this approach, the fiat currency issued by the central bank should be widely recognized as a foreign reserve by worldwide central banks. In other words, the fiat currency should be one of the major currencies.
Description of the model

The general picture of this option in the context of Royal Bank of Canada (RBC) buying Singapore Dollars (SGD) from Credit Suisse (CS) with Canadian Dollars (CAD) is illustrated by Figure 3. In the figure, banks first show their FX interest. Then, exchange providers or brokers match the indication of interest (IOI) and return a quote. The accepted quote is executed, and then legs are settled through omnibus accounts.

The price between a cryptocurrency pair is set by market makers (dealers) or by matched book transactions through a centralized exchange. The currency symbols there represent intermediate cryptocurrencies (which might be constructed as a bi-directional pair with set exchange rates, such a crypto representing buy SGD/ sell CAD at a given rate) rather than the original fiat currencies.

RBC can exchange value with CS directly using the intermediate cryptocurrency. Or it can achieve capital efficiency by holding a single cryptocurrency and by converting it to other currencies contingently.

Evaluation

This approach entails high legal risk and places a large burden on central banks because it requires the ledger to be opened to global financial institutions, in a different way than global financial institutions are connected today.

Different currency jurisdictions may have their own data confidentiality and regulation requirements which may be incompatible with others. However, because each of the major currencies has the potential to be represented as an intermediate cryptocurrency, the network effect will be maximized if these intermediate cryptocurrencies are all issued on a common ledger.

This model assumes that the intermediate cryptocurrencies are all issued on an interoperable, common ledger. With a common ledger, the need for interledger operations is effectively eliminated. The more currencies (asset) that are issued on an interoperable ledger, the less likely a given cryptocurrency needs to be converted to off-ledger assets.

Option 2: Cross-registered Intermediate Cryptocurrency

Option 1 assumes the counterparty for the FX transaction can be easily found and then provides a solution to the core settlement step. For currency pairs that are not heavily traded, the counterparty of a desired trade may not be easy to find. Option 2 tries to mitigate this problem by considering an alternative settlement asset: a depository receipt that can be circulated both in currency jurisdiction X and Y. It should be mentioned that option 2 diverges away from the core settlement step by directly targeting the demands of settling international trade, which is often the purpose of conducting FX transactions.
The depository receipt model involves having the tokens being exchanged backed by collateral held at a third party, in this case the third parties are respective central banks.\textsuperscript{17} Within this approach, a Canadian dollar depository receipt (DR) or a Singapore dollar depository receipt (DR) is a receipt conveying title to a net balance of central bank-issued money payable on redemption by the central bank.

Traditionally, international trades often involve paying or receiving funds denominated in foreign currencies. In the context of bilateral trading, cross-registered depository receipts (CRDR) may eliminate the need of currency exchange and hence eliminate the need for finding a counterparty to do the currency exchange, eliminating the thin markets problem.

**Description of the model**

A CRDR is a DR that is issued by CB X/CB Y at par with currency X/currency Y but honored by CB Y/CB X at a fixed predetermined rate. For example, 1 unit of CRDR issued by CB X can be purchased from and sold to CB X at par. It can also be redeemed at CB Y any time before expiration for \( E_0 \) amount of currency Y. \( E_0 \) is the spot exchange rate when the CRDR is issued. Let \( t_0 \) be the time of issuance and \( t_1 \) be the time of expiration. Suppose a total amount of \( Q_0 \) units of CRDR are issued at \( t_0 \) and \( Q_1 \) units are received by CB Y at \( t_1 \). To retire the CRDRs from circulation, CB Y sends the \( Q_1 \) units of CRDR back to and gets paid with \( Q_1 E_0 \) units of currency Y by CB X. At the same time, CB X recalls the rest CRDRs still in circulation by repurchasing them with currency X at par. The arrangement so far implies that there would be two kinds of CRDR. CRDR issued by CB X and CRDR issued by CB Y. Denote them by CRDR\_X and CRDR\_Y respectively. Although subsequent analysis focuses on the lifecycle of CRDR\_X, the same analysis also applies to CRDR\_Y.

Table 8 describes the change of the balance sheet of CB X between issuance and expiration. There are several points to notice.

1. Redeeming CRDR\_X into currency Y can be regarded as CB Y’s increasing monetary supply backed by foreign asset CRDR\_X.

2. CB X needs to consume its foreign reserve to repurchase the CRDR received by CB Y. The operation is financed by liquidating the assets used to back up the original deposits from CRDR. It is assumed that the asset is transferred to CB Y through FX transactions in an implicit way. This assumption is an abstraction from real world operations to avoid introducing the balance sheets of FX dealers and brokers. This repurchase operation reveals the FX risk undertook by CB X because the exchange rate at which the foreign reserve is gained may not be the same with the exchange rate at which the CRDR is issued.

3. The aggregate size of CB X and CB Y should remain roughly the same before the issuance and after the expiration of CRDR\_X. The implication is that CRDR\_X holder’s action of redeeming CRDR\_X into currency Y causes a shrinkage of the balance sheet of CB X as well as an expansion of the balance sheet of CB Y with in an approximately equivalent size. The difference is caused by FX fluctuation.

\textsuperscript{17}With Project Jasper, a settlement cycle starts with participants’ pledging cash collateral into a special pooled account held by the Bank of Canada to redeem an equal amount of a central bank-issued digital asset, CAD-coin, that can be circulated to the distributed ledger. Two banks can then send payments to each other with CAD-coin in real time to meet their payment obligations that they have agreed to settle on DLT. Alternatively, a bank may also “cash out” its holding CAD-coins by converting them back into CAD with BOC.
One major advantage of using CRDR as the settlement asset for bilateral trading is that CRDR can flow freely across the border of the two involved currency jurisdictions. As a result, the settlement procedure fits better to the typical design framework assumed by DLT. In the best case, only one ledger of CRDR will be involved for a single trade if the CRDR itself is used as the settlement asset, which allows the settlement to be finalized in real time.

A commercial bank can prepare for the uncertain demand of a foreign currency by holding enough amount of CRDR linked to the foreign currency. But the invested fund remains its ability in settling domestic obligations denominated in local currency. As a result, the liquidity requirement for daily operation is reduced. It should be mentioned that the benefits also apply to any entity which has the need to maintain balance in multiple currencies.

As illustrated in the previous analysis, a currency jurisdiction may undergo passive monetary supply shrinkage or expansion due to the honored dual redeemability of the CRDR issued by itself.
or the other central bank. For example, issuing CRDR_\(X\) may cause a shrinkage of the domestic supply of currency \(X\) while an expansion of the domestic supply of currency \(Y\) if the CRDR_\(X\) holder decides to redeem a positive amount at \(CB\ Y\). Although in theory this fluctuation can be offset by issuing enough amount of CRDR_\(Y\), it is hard to predict what amount will be proper. In other words, the imbalance of cross-border transactions will be reflected as an instability of monetary supply.

There are also other risk implications. First, credit risk is eliminated because central banks rarely default. Second, the holder of CRDR is exempted from foreign exchange risk because the exchange rate is fixed. However, the FX risk is transferred to central banks. The hedging cost of CBs should be priced as a premium of CRDR. Third, this model may not scale up well since each pair of CBs needs to honor two CRDRs.

However, the above arrangement inevitably introduces an arbitrage opportunity for a CRDR holder. To nullify this simple arbitrage strategy, either the circulation period should be limited to short term or the redemption with foreign currency should be restrictive, say, only at the time of expiration. It should be emphasized that as long as commercial banks recognize CRDR itself as a valid settlement asset, when CRDR can be redeemed should not undermine its efficiency in the aspects of settlement speed and liquidity saving and other benefits mentioned above.

Another salient feature of this model distinguishing it is that value exchange activities using CRDR as the settlement assets are conducted in a decentralized way. Although technically it is possible for a central bank to keep track of every unit of CRDR it has issued, this model does not forbid anonymity.

One other interesting extension is the potential to extend this model to involve multiple central banks (beyond having just two dual-register).

**Option 3: Central Bank Bilateral Credit Line**

In this model the central banks of the two jurisdictions where either a one-directional or a bidirectional payment flow is occurred use credit lines. The central banks act like gateways for cross-border transactions as well as foreign exchange brokers. Central banks are not likely to take on risk in the payment system, which greatly reduces the likelihood of this approach being adopted. Still, this option is evaluated for completeness.

Continuing with the participants discussed in option 2, RBC wants to buy SGD from CS with CAD.

**Figure 5: Central Bank Bilateral Credit Line Model**
Description of the Model

1. RBC deposits CAD at BOC and gets an equivalent amount of CAD DR on the book of BOC. CS deposits SGD at MAS and gets an equivalent amount of SGD DR on the book of MAS. RBC and CS negotiate a rate to exchange CAD DR and SGD DR, so that RBC will buy SGD DR from CS with CAD DR. Note that the underlying assets being exchanged are deposit receipts of the corresponding fiat currencies rather than the fiat currencies themselves. However, to keep the narrative succinct, the suffix “DR” for “deposit receipt” is dropped thereafter.

2. RBC instructs BOC to pay CS in CAD while CS instructs MAS to pay BOC in SGD. Because CS is in MAS’s jurisdiction and RBC is in BOC’s jurisdiction, the ultimate payment must be routed from MAS to CS and from BOC to RBC. As a result, the next step is to let BOC instruct MAS to pay CS in CAD and let MAS instruct BOC to pay RBC in SGD. This is done by allowing BOC and MAS to establish bilateral credit lines with each other.

3. Suppose that BOC and MAS have agreed upon the exchange rate for the bilateral credit line as 1 CAD is equivalent with E SGD. If BOC grants 1 million credits denominated in CAD to MAS, then MAS should grant E million credits denominated in SGD to BOC.

4. BOC instructs MAS to pay CS on behalf of RBC by allowing MAS to draw upon its credit line denominated in CAD. Because MAS consumes its credit in order to make payment on behalf of RBC, and BOC has received RBC’s payment denominated in CAD, the used credits are expected to be restored in the future when BOC transfers what it receives from RBC to MAS. RBC receives its desired currency in the form of central bank credits, i.e., an IOU from MAS pledging the same amount of SGD. Because the credits are endorsed by the central bank, the settlement of the payment leg from CS to RBC denominated in SGD can be regarded as finalized. And the resulted SGD credits can be used to clear other obligations of RBC. The same procedure also applies to the payment flow from CS to RBC.

5. Whenever a breach occurs in either direction of the credit line, the central bank which exhausted its credit may recover its credit balance by selling its local currency and buying the target currency which it owes to the other central bank. Alternatively, the two central banks may negotiate whether they should jointly increase the credit limits for both direction or just increase the limit for the breached direction temporarily.

The above actions are summarized in Figure 5. Table 6 illustrates the balance sheet changes for the two central banks corresponding to the actions are below.
Table 6: Balance Sheet Changes for BOC and MAS (action by action)

<table>
<thead>
<tr>
<th>Action 3 – credit line is established</th>
<th>BOC</th>
<th>Setup credit limit from MAS in SGD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MAS</td>
<td>Setup credit limit from BOC in CAD</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Action 1</th>
<th>BOC</th>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+ CAD</td>
<td>+ deposit from RBC in CAD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ SGD</td>
<td>+ deposit from CS in SGD</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Action 2 and 4</th>
<th>BOC</th>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBC initiates payment – credit line of CAD is consumed</td>
<td>+ IOU from MAS in CAD</td>
<td>+ IOU to MAS in CAD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ IOU from RBC in CAD</td>
<td>+ IOU to CS in CAD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ IOU from BOC in CAD</td>
<td>+ deposit from CS in CAD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- IOU to CS in CAD</td>
<td>+ deposit from CS in CAD</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Action 3</th>
<th>BOC</th>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS initiates payment – credit line in SGD is consumed</td>
<td>+ IOU from CS in SGD</td>
<td>+ IOU to RBC in SGD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ IOU from MAS in SGD</td>
<td>+ IOU to MAS in SGD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ IOU from BOC in CAD</td>
<td>+ deposit from BOC in SGD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- IOU to RBC in SGD</td>
<td>+ deposit from RBC in SGD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- IOU to BOC in SGD</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Action 4</th>
<th>BOC</th>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBC redeems central bank credits</td>
<td>- IOU from MAS in SGD</td>
<td>- deposit from RBC in SGD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- SGD</td>
<td>- IOU to BOC in SGD</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Action 5</th>
<th>BOC</th>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS redeems central bank credits</td>
<td>- CAD</td>
<td>- IOU to MAS in SGD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- IOU from BOC in CAD</td>
<td>- deposit from CS in SGD</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Action 6</th>
<th>BOC</th>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credit line in SGD is restored</td>
<td>- IOU from CS in SGD</td>
<td>- IOU to MAS in SGD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- IOU from BOC in SGD</td>
<td>- deposit from CS in SGD</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Action 7</th>
<th>BOC</th>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credit line in CAD is restored</td>
<td>- IOU from MAS in CAD</td>
<td>- deposit from BOC in CAD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- IOU from RBC in CAD</td>
<td>- IOU to BOC in CAD</td>
<td></td>
</tr>
</tbody>
</table>

Evaluation

Because in this model central banks act as gateways of cross-border transactions, they would be capable of seeing every transaction passing through them. What’s more, they could also accept or reject transactions under their own judgement. In other words, this model would provide central banks with a powerful tool for implementing policies regarding cross-border transactions.

There also could be settlement risk implications. Consider the payment leg from RBC to CS denominated in CAD. As long as neither direction of the credit line is breached, the two payment legs can be settled jointly in real time if both the LVPS of CAD and the LVPS of SGD are online. More specifically, because CS receives its purchased currency from MAS rather than through its correspondent bank in the other jurisdiction, any delay due to moving funds inside the correspondent network is eliminated. In addition, because it is central banks’ obligation to make sure the funds for exchange are in place before initiating any payment, CS will never instruct MAS to pay RBC without receiving the fund ready message from BOC. Consequently, both the length and the magnitude of RBC’s and CS’s exposure to settlement risk are reduced to almost zero. Nevertheless, the central banks may take too much of the burden in this approach. They need to manage the credit risk in case of default as well as the FX risk when restoring the credit line.

In this model, both central banks and commercial banks may face liquidity risks. On one hand, a commercial bank needs to pledge the fund in advance of a payment. To safeguard against settlement risk, the commercial bank needs to wait until its counterparty has also pledged the currency to
exchange. Therefore, the commercial bank suffers from liquidity risk to the magnitude of the pledged funds. Although the prefunding constraint can be relaxed by allowing the commercial bank to draw overdrafts with its central bank, the relaxation will have the consequence of temporarily increasing the monetary supply. On the other hand, a central bank may need to restore the breached credit line by infilling a certain amount of foreign currency which either comes from its existing foreign reserve or from the FX market. It is possible the central bank fails to finance itself through either source. Besides, liquidity saving allowed by a set of bilateral netting models is generally no greater than a unified multilateral netting model.

Any model that requires a large number of bilateral relationships will have operational complexity. The model may not scale up because each pair of central banks need to negotiate and maintain a bilateral credit line. Suppose there are n jurisdictions, then in total there would be n(n-1)/2 bilateral credit lines.

An issue with the above design is that it is unclear how the legal framework should be settled to incentivize MAS to pay for a bank of BOC or to encourage BOC to pay for a bank of MAS. Another issue is related to how RBC/CS can redeem its SGD/CAD credits. Although the model suggests that a commercial bank could access foreign currency directly through its central banks, it may take a while to figure out the associated legal terms. The sub-option “Alternative Bilateral Credit Line Model” is aimed to resolve these issues.

Sub-Option 3.1: Alternative Central Bank Bilateral Credit Line Model

One variation on the bilateral credit line model has central banks acting as super correspondents instead of using credit lines. Two central banks hold accounts with each other at the LVPS which are run by themselves. Suppose central bank CB_X issues currency X and CB_Y issues currency Y. CB_X grants CB_Y a credit line regarding currency X while CB_Y grants CB_X a credit line regarding currency Y. To settle a trade exchanging X with Y, counterparties directly send payment to CBs. The CB who firstly receives payment in local currency from a counterparty will be credited the equivalent amount of foreign currency immediately by drawing upon its credit line and will in effect acts as a TTP.

An example for this model has Bank A buying currency Y from Bank B with currency X.\(^\text{18}\) This example assumes both of them only have direct access to the LVPS of the sold currency but no access to the LVPS of the purchased currency, and that it is CB_X who first receives payment. See Figure 9 for an illustration of the fund flows.

Description of the Model

1. Bank A makes a payment to CB_X in currency X.

2. Bank A instructs CB_X to make subsequent payments with a single atomic transaction. CB_X pays to Bank B’s correspondent bank. CB_X receives currency Y from CB_Y by drawing upon the credit line. (Credit is consumed). CB_X transfers currency Y to Bank A’s correspondent bank.

3. Credit is restored when Bank B makes payment later through an atomic transaction. Bank B pays currency Y to CB_X. CB_X returns the “borrowed” currency to CB_Y.

\(^\text{18}\)Bank A and Bank B could also submit payment instructions resulted from a bilateral netting procedure.
Evaluation

If Bank B does not make the payment in time, then the credit line of currency Y can be breached due to the subsequent transactions among other banks. In the case that the accumulated credit exceeds the limit, CB_X would transfer some of its foreign reserve into the account held with CB_Y to offset the consumed credit.

This model aligns the interest of central banks by letting them to behave on behalf of their own commercial banks. It also makes accessing foreign currency practical by integrating with the traditional correspondent network.

Moreover, there is no need for Bank A to wait Bank B to be ready. From the perspective of Bank A, the two payment legs are still synchronized even if the actual payment from Bank B occurs after Bank A receives its desired currency. This feature is achieved by transferring credit risk to central banks because in the case where CB_X has consumed its credit line but Bank B fails to make its payment to CB_X later, CB_X has to use its own fund to pay back the used credits.

However, there is an intrinsic asymmetry in the sense that the central bank which firstly receives payment from its commercial bank does the entire job. This problem cannot be ignored if the payment flows are not balanced between the two jurisdictions.

Conclusion for Central Bank Issuer Models

Some of the models extend a central bank’s role. Other have the potential to dramatically expand the central bank’s balance sheet and influence the money supply, depending on the implementation. The first two models would be particularly useful to continue to develop and research. The third too significantly departs from the traditional role of the central bank.

5 Trusted Third Party (TTP) Issuer Models

We now turn to a second class of models of cross border settlement. However in contrast to the central bank focus from the previous models, this set uses a trusted third party that is not a central bank. We explore 4 models that use a TTP. They are differentiated based on how the issuer of the DR is involved in the process of clearing and settlement and who bears what kinds of risk. We will evaluate a private sector-issued intermediate cryptocurrency, a pre-funded escrow account approach, a CLS-like model, and a deficit funded account model.

Option 4: Private Sector-issued Intermediate Cryptocurrency

This approach involves an intermediate cryptocurrency as described in Option 1, but issued by the private sector. To maintain a stable market value, it should be pegged to some assets with relative stable market value. For example, such a cryptocurrency could be pegged to a basket of major
currencies, similar to the IMF’s special drawing right (SDR) or another widely accepted store of value, such as gold. In other words, there should be enough collateral as a corresponding asset for each unit of issued cryptocurrency. The collateral could be kept by a special purpose bank to ensure the ability to redeem the cryptocurrency. With this approach, central banks could enroll themselves actively as market makers to stabilize the intermediate currency’s value.

The private sector-issued cryptocurrency approach may make it easier to implement the borderless feature for the intermediate cryptocurrency relative to central bank-issued cryptocurrencies. However, the maintenance of the currency value and avoidance of price volatility would be more complicated.

Option 5: Pre-funded Escrow Accounts

This example uses two central banks, Bank of Canada (BOC) and Monetary Authority of Singapore (MAS), two commercial banks, Credit Suisse (CS) and Royal Bank of Canada (RBC), and a third party. The TTP holds accounts at both central banks for each commercial bank it can settle for (in a subaccount manner). Settlement of a FX transaction is reflected as updates in the book of the TTP.

RBC and CS buy foreign currency using local currency. After RBC and CS pre-fund their local currency in central banks, central banks issue depository receipts and send it to the TTP’s account with central banks. The TTP’s account with central bank are an omnibus account with all its participants having a subaccount in it. Then depository receipt transfers between the subaccounts of the omnibus TTP account. Table 4 reports the balance sheet of the TTP for each of the two steps.

Figure 7: Pre-funded Escrow Account Model

Description of the Model

1. At T_1: RBC deposits CAD in BOC and CS deposits SGD in MAS. BOC issues an equal amount depository receipt (CAD-DR) onto the distributed ledger and send payments of the depository receipt to the TTP. MAS issues an equal amount of the depository receipt (SGD-DR) onto the distributed ledger and sends payments of the depository receipt to the trusted third party.

2. At T_2: After the agreement on CAD/SGD rate, RBC instructs the trusted third party to pay CS CAD DR and CS instructs the trusted third party to pay RBC SGD DR.
Table 4: Trusted Third Party Balance Sheet

<table>
<thead>
<tr>
<th>Before</th>
<th>TTP</th>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>+CAD DR</td>
<td>+deposit from RBC in CAD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+SGD DR</td>
<td>+deposit from CS in SGD</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>After</th>
<th>TTP</th>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>+deposit from RBC in CAD</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-deposit from RBC in SGD</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>+deposit from CS in SGD</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-deposit from CS in CAD</td>
<td></td>
</tr>
</tbody>
</table>

Evaluation

The required liquidity is as much as the value exchanged due to the complete pre-funding requirement in this model. Because transactions are entirely pre-funded in advance, this model is the best of the three options from the third party’s settlement risk perspective, but from the commercial bank’s liquidity management perspective it is the worst. As a result, a TTP would be more likely to favor this model, while commercial banks likely not approve of this approach.

Option 6: CLS-like Model

This option mirrors the function of CLS, of a financial market utility. However, the model differs from CLS in a fundamental way. CLS Bank helps to eliminate settlement risk by implementing a PvP mechanism. The central clearing agency in this enhanced CLS model interposes itself between the seller and buyer, taking over the settlement risk. This modification gives the central clearing agency more power to facilitate cross-border value-exchange activities.

The TTP holds accounts at the LVPS for each currency it can settle. Banks maintain multicurrency subaccounts at the TTP. Settlement of a FX transaction is reflected as updates on the book of TTP. There could be several variations.

Settlement could be done in a truly multilateral way. For example, consider the example illustrated in Figure 8. The three trades can be settled at the same time while the actual fund flow is on a net basis. However, when there are multiple choices for netting, determining which trades should be settled together could be improved (Martin and McAndrews 2008).

Figure 8: Multilateral netting
The TTP could operate 24 hours a day, if central banks extend their LVPS operating hours. A transaction submitted by members can be settled in real time as long as the involved LVPS are open and enough collateral is provided by the counterparties.

Overdrafts could be allowed without the requirement of a positive overall balance. This would put the TTP in a riskier position than CLS because in the case of default, it is the TTP who will take the loss. Note that the TTP might establish default funds, default insurance or other methods to manage this risk, but there would be a cost associated to these approaches.

**Evaluation**

There is the potential to reduce systemic risk. Some argue that TTPs themselves increase systemic risk by creating a single point of failure in the market (the collapse of which would be catastrophic). This can be mitigated by giving TTPs access to central bank liquidity. In contrast, they reduce systemic risk by absorbing the impact of a single party’s default and minimizing the risk to the rest of the market. In addition, the TTP could require default funds to be posted by all participants to cover a default event.

There is the potential to reduce counterparty risk. The application of DLT enables real time gross payment and will reduce the risk of default. Moreover, DLT is expected to significantly reduce the implementation cost of the system designs outlined in this section.

**Option 7: Deficit-funded Accounts**

In this option, the TTP bears the settlement risk. This is because overdrafts are allowed for the transactions. This model involves the two commercial banks, RBC and CS, two central banks, BOC and MAS and a TTP as the intermediate clearer. As overdrafts are allowed, the balance sheet of TTP will be different. In this model, CS and RBC will receive the foreign currency depository receipt in a real-time basis at the same time of the overdraft of the local currency depository receipt. Then RBC and CS need to the pay back the local currency.

**Description of the Model**

1. At T_1: RBC receives SGD DR and CS receives CAD DR. RBC has an overdraft in CAD DR and CAD has an overdraft in SGD DR.
2. At T_2: RBC pays back CAD and CS pays back SGD (the time for RBC and CS to pay back might be different).

Figure 9: Deficit-funded Accounts Model
The TTP creates overdrafts to fund receiving accounts in the local currency of the sending account to settle the transaction. There is the risk the TTP may get overwhelmed by overdue overdrafts and run out of liquidity. Central banks could play a role in reducing this risk by issuing short-term loans to the TTP. Therefore, the approach would have a stronger demand for central bank involvement.

The TTP in this model will have settlement risk as it allows its participants to overdraft. However, the liquidity demands for participants would be reduced. There would be a need to manage the credit lines that the TTP grants to its participants and a need to price the time difference as RBC and CS might pay back at different times. Depending on how the overdraft backed payments are funded, there may be a temporary increase of the monetary supply. Indeed, all existing central counterparties assume this ability to some extent.

All things considered, this approach would likely lead to intraday exposures for the TTP that would not meet the PFMI criteria.

Conclusion for Trusted Third Party (TTP) Issuer Models

For this approach, there would be value in having regulators play a role as coordinators. This would bring market participants together to develop best practices and standards for TTPs. The regulator could monitor transaction activity on the ledger and see how market structure may change with the introduction of DLT. Regulators (and also central banks) would need to at least have a passive role in the development of any of these solutions.

Because multilateral netting is the core of the settlement process, DLT should at least serve the collateral management, the multilateral netting and regulatory functions of the TTP. (Matt Britton et al. 2016). For collateral management, the design of ledger should consider the following:

1. Initial Margin & Smart Contracts: how to use smart contract to set up initial margin which serve as a cushion against adverse market fluctuations
2. Variation Margin: how to calculate variation margin to prevent the buildup of market loss.
3. Default: how to deal with a default process (Platt, et al., 2016).

If all of these are achieved, TTPs could benefit from DLT with automated margin calls, reserving required collateral, and automated default handling. For automated margin calls, TTPs often require clearing members to meet margin calls within 1 hour. This presents operational risk whenever a party may not deliver collateral due to human error or slow process. An automated process can help facilitate this step. DLT could also help to quickly reserve required collateral. TTPs...
are required to reassess members risk before trade novation. In some scenarios, this may result in trade rejections (including client clearing trade rejections). DLT could help TTPs quickly reserve required collateral. Additionally, clearing members maintain collateral ownership. Automated default handling could occur via recourse to automatic novation, automated auction of assets, or through access to pooled default funds.

6 Conclusion

This paper reviews existing solutions and potential models for cross-border interbank settlement to progress discussions with commercial banks, partners, and central banks.

As the paper has mentioned, achieving real time settlement for cross-border payment usually can introduce complexity in other layers of the financial system. Whether this complexity should be taken by central banks is a topic for future research. We highlight some potential difficulties a central bank may encounter if it wants to involve itself in the settlement procedure in a more active way.

Looking forward over the next five to ten years, new innovations with core domestic payment infrastructure would have consequences for approaches to international payments. The opening up of digital central bank liabilities beyond commercial banks which hold central bank settlement accounts could have implications for international payments. Expanded access to digital central bank money could ultimately affect payments internationally, as more participants would have access to domestic core settlement systems.

Further, given the importance of netting with international payments, decentralized liquidity savings mechanisms (DLSMs) are an area for further research. Continuous Net Settlement (CNS) systems implemented through DLSMs have the potential to allow more efficient liquidity use for commercial banks with domestic payments. A DLSM allows commercial banks to make proposals that reflect, in real time, their current conditions. Recursive graph scanning algorithms identify all the potential netting opportunities network-wide. Such an approach may offer advantages domestically relative to centralized LSMs given that centralized netting systems have incomplete information about each commercial bank’s liquidity positions. Eventually, similar innovations which allow peer-to-peer payment communication could occur internationally as well.

Once determining a particular approach, the combination of DLT and smart contracts could natively support a decentralized PvP solution for settling FX transactions because the submission of payment instruction to the LVPS of one currency can be programmed to be conditional upon the submission of payment instruction to the LVPS of the other currency. For a fully funded settlement, the coordination of payments could be done automatically and there may be no need for a third trusted party like CLS to step in. Still, a centralized cross-border clearing system on DLT may be preferred for netting and liquidity savings. We hope this paper invites further research and discussion on new, different approaches for improving cross-border payments.

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19The reasons why it is difficult for the existing technology to be used along with correspondent banking to support this PvP feature is left for future study. Alternatively, the feature can be integrated into the LVPS itself. See the R3 Foundations of DLT Whitepaper Series: Smart Contracts.

20In times of stress, a central counterparty can provide liquidity to one of it’s members by issuing its own liabilities (Norman, Shaw, and Speight 2011).
Appendix

Jasper

Objective: Evaluate the suitability of a CBDC transferred between participants on a distributed ledger network for CAD domestic large value wholesale payments.

Platform: Phase 1: Ethereum, Phase 2: Corda

Key Considerations: Operating efficiency and resiliency Management of settlement risk Principles for Financial Market Infrastructures

Model: CADCOIN asset model

Potential Benefits: Reduce the need for a Trusted Third-Party for Value Transfer Eliminate Systemic Risk due to Centralization Safeguard against Fraudulent Activity Improve Data Quality and Governance

Major Work: Build a platform that could accommodate multiple settlement options (‘Atomic’ option and ‘Liquidity Saving Mechanism’ option) similar to those available in incumbent infrastructures today. A central queue draws on a payment matching algorithm to routinely settle batches of queued payments on a net basis to promote funding efficiency, and a smoother intraday flow of payments. Data-driven simulation exercises were completed to evaluate the operation of the Jasper platform.

Future Work: Define the operational (non-technical) considerations that need to be addressed to support a DLT settlement solution. Central bank to central bank digital cross-border currency exchange. Connect domestic settlement capability with another domestic DLT/blockchain use case.

Ubin

Objective: Evaluate whether DLT can benefit Singapore’s financial ecosystem (Technology, economic and business case evaluation should be considered).

Platform: Phase 1: Ethereum Phase 2a: Corda, Hyperledger Fabric, Quorum

Key Considerations: Replacement and settlement risk Inefficient funding and reconciliation cost Principles for Financial Market Infrastructures

Model: Continuous depository receipt model

Potential Benefits: Improve domestic securities transactions, offering Delivery-vs-Payment settlement in cases where it is not already available. Significantly improve cross-border payments (Payment-vs-Payment) and securities transactions.

Major Work: A working interbank transfer prototype on a private Ethereum network was built. The Ubin Phase 1 prototype evolved Project Jasper’s monetary model and a new Smart Contract codebase was developed. End-to-end integration between the private Ethereum network and MAS Electronic Payment System test environment. The research workstream built a solid foundation of questions and initial points of view across topics ranging from monetary policy to legal and operational concerns for taking this prototype to production.

Future Work: Technical consolidation of Project Ubin’s Phase 1 to address immature coding tools establish immutability and future proof by supporting ISO XML standards for API and enabling data encryption. Perform business analysis of Project Ubin’s model, including business case benefits and future operating model Explore cross-border payments, with Payment-vs-Payment prototype network to be developed with other jurisdictions. Conduct international research workstream on CBDCs to explore legal, regulatory and monetary policy implications.
7 Bibliography


**R3** is an enterprise software firm using distributed ledger technology to build the next generation of financial services infrastructure.

R3’s member base comprises over 80 global financial institutions and regulators on six continents. It is the largest collaborative consortium of its kind in financial markets. Consortium members have access to insights from projects, research, regulatory outreach, and professional services.

Our team is made of financial industry veterans, technologists, and new tech entrepreneurs, bringing together expertise from electronic financial markets, cryptography and digital currencies.

**Corda** is an open source, financial grade distributed ledger that records, manages and executes institutions’ financial agreements in perfect synchrony with their peers.

Corda is the only distributed ledger platform designed from the ground up to address the specific needs of the financial services industry, and is the result of over a year of close collaboration between R3 and its consortium of over 80 of the world’s leading banks and financial institutions.