DvP using CBDC: a "settlement choice model" for securities settlement

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Delivery vs. Payment is central to the world's securities settlement systems, but is implemented in multiple forms that differ by jurisdiction. All of these different models exist on a continuum from intraday gross settlement—which minimizes settlement risk while requiring a great deal of liquidity—to delayed batch settlement—which offers netting efficiencies but delays final settlement. Market participants acknowledge the benefits of real time gross settlement but continue to rely on the operational and liquidity advantages of delayed batch settlement. Acknowledging that reality, this paper proposes a new "best of both worlds" model that allows for a choice of settlement type at the time of trading and offers the ability to settle both gross and netted trades instantly using Central Bank Digital Currency and digital assets on a blockchain infrastructure.

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1. Introduction ●

The widespread exploration of Central Bank Digital Currency (CBDC) and decentralized technology by central banks and financial market infrastructures (FMIs) has opened the door to an interesting new securities settlement option. One where participants can dynamically choose between instant trade-for-trade settlement or batched netted settlement. This flexibility is unusual for the market, but consistent with the demands of market participants.

One of the challenges in today's securities settlement processes is that they have evolved unevenly in recent decades. Systems and processes were digitized at different speeds, local business norms often prevailed over standardization, and international (cross-time zone and cross-language) trades were low priority. Consequently, processes, systems, and especially market participants have adapted to existing constraints, which in some cases reinforce market inefficiencies.

Delivery versus Payment (DvP) processes are one example of how the market has adapted to these constraints. Delays of two days (T+2) in settlement are not just accepted today but relied upon to source liquidity and securities, and to reconcile multiple books and records. While there is now renewed interest in shorter settlement cycles, this need to source liquidity and align records is in part why market participants are currently more supportive of a move to T+1 over T+0.

To gauge where the financial industry is in its thinking about T+0 DvP, we undertook a survey of members of the R3 CBDC Working Group. This survey identified four inefficiencies in today's DvP process, covering both operations and technology. Atomic[1] settlement would address some of these inefficiencies, but in the absence of a technology upgrade could exacerbate others. We use the survey responses to guide our discussion of a novel model of securities settlement.

Our objective in this paper is to provide evidence that the confluence of new technologies available in securities settlement allows for flexibility in the choice of settlement model used by market participants. Rather than disintermediating existing market participants, a choice model allows them to take on distinct new roles in a new system defined by tokenized securities, CBDCs, and blockchain. We also focus exclusively on the DVP settlement process here—we are aware of the fact that moving to T+0 settlement would require changes in today's trading processes, systems and infrastructure.

This paper explores the benefits of settlement on blockchain using CBDC. This can potentially simplify the settlement process and provide an efficient path to T+0 DvP while preserving the important roles of existing mechanisms and market infrastructures. It constitutes an attractive idea to the sector because it would unlock value in the existing regulated securities settlement process. We acknowledge that an actual move to T+0 settlement would also imply changes to the current processes and market conventions in trading and clearing—these concerns would need to be addressed separately and are not covered in this paper.

The paper begins with a look at the history of DvP and CBDC research and experimentation by central banks and FMIs in sections 2 & 3. Section 4 introduces a settlement choice model that is distinct from but contains elements of existing DvP practices. To anticipate the benefits and challenges of this model, we undertake an architectural exercise in section 5. Specifically, we look at how the process in existing DvP models 1 and 2 would change with the application of blockchain technology, which is an essential feature of our proposed settlement choice model.

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1   Atomic settlement is different from, though related to real time gross settlement (RTGS). Atomic means that there can be no partial settlements. By contrast, partial settlements are possible using today's structure. Atomic means that the transfer of two assets is linked in such a way as to ensure that the transfer of one asset occurs if and only if the transfer of the other asset also occurs — that is, the settlement of both assets is conditional upon each other.

Delivery versus Payment (DvP) describes the process of exchanging securities against money. It is the common way that securities are settled, complemented by "Delivery free of payment" and "Delivery versus Delivery." By interlocking securities transfers to funds transfers, a DvP process can reduce or eliminate principal risk by requiring that payment is made at the same time as the securities are delivered[2].

There are various mechanisms for implementing DvP. The simplest form of DvP is gross settlement, where transactions are settled trade-by-trade rather than grouped together and netted.

Today's DvP procedures have received renewed focus because of both the turmoil caused by securities price volatility and resulting margin requirements, and the significant efficiency benefits offered by blockchain technology and wholesale CBDC. DvP mechanisms generally execute through a central securities depository (CSD) and involve central bank money transfers between participant accounts at the central bank. If CBDC were to become available for on-chain settlement against tokenized securities, this could introduce alternatives for DvP that would mitigate some of the risks and inefficiencies that we see today.

2.1 The role of central banks in the securities settlement process

The reason we undertook this research as part of the **CBDC working group** is because central bank money plays a central role in securities settlement systems. While central bank money is not required for securities settlement, from a risk perspective the ideal process is for the final and irrevocable settlement of payment obligations to be done using money that represents a direct claim on the central bank.

In today's settlement architecture, using central bank money requires parties to have accounts at the central bank, or to settle through banks that have those accounts. Central bank money exists electronically and can only be used between accounts of participants at the central bank. This practice means that there is a close existing linkage between most of today's securities settlement systems and their associated central banks.

We began our project by asking: what if securities could be settled without requiring institutions to be formally connected through the central bank?[3] We realized that for securities settlement, the combination of blockchain and CBDC could change two things about the securities settlement process. First, blockchain allows central bank money and securities to be settled against each other directly without requiring linkages between institutions. Second, having CBDC on the same ledger as digital forms of securities reduces the risks and potential delays of both real time gross settlement (RTGS) and netted settlement. Blockchain further allows for a single ledger for all participants, the benefits of which are described briefly later in this paper.

By removing the institutional requirement to be linked via central bank accounts, CBDC and blockchain technology offers the possibility of an alternative mechanism for DvP, which is not in practice today but could be adopted in the future.

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2   From BIS 1992 p. 1: "Principal risk in securities clearance and settlement systems is generally recognised to be the largest potential source of systemic risk, that is, the risk that the inability of one institution to meet its obligations when due will cause other institutions to fail to meet their obligations when due, ultimately jeopardising the stability of payment systems and of financial markets."
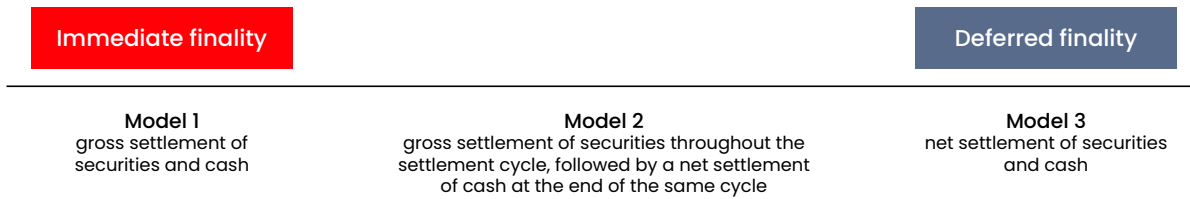**3**   Today's settlement architecture requires the settling banks to be direct members of a central bank settlement system. This is the case regardless of whether the settlement uses central bank money or commercial bank money. Under the CPMI roadmap for payments, a future question is whether a securities settlement system can be a direct participant (instead of a bank) of the central bank cash settlement system.

We call this the settlement choice model. It combines the characteristics of existing DvP models and adds features that address some of today's inefficiencies (See the appendix for the results of a survey of CBDC Working Group members on this topic). DvP is enabled in this model by allowing market participants to choose, on a per transaction basis, whether to use netting or trade for trade. To understand how novel this process is, we first detail the existing DvP models in use today.

2.2 Typology of settlement models

In 1992, the Bank for International Settlements (BIS) published a report on **Delivery versus Payment in securities settlement systems**. In this report, the BIS presents a taxonomy of existing DvP mechanisms. The report divides these mechanisms into three model cases. Each is distinct, though they exist on a clear continuum from immediate finality of both the cash and securities legs (Model 1) to deferred finality of both legs (Model 3).

Figure 1. Spectrum of BIS DvP models

Immediate finality		Deferred finality
Model 1 gross settlement of securities and cash	**Model 2** gross settlement of securities throughout the settlement cycle, followed by a net settlement of cash at the end of the same cycle	**Model 3** net settlement of securities and cash

Model 1 settles transactions trade-by-trade. In this workflow, full payment is exchanged for full delivery of securities. Model 1 transactions can, in theory, be implemented on a blockchain-based platform using atomic swaps between the securities and the cash leg.

In Model 2, securities settlement occurs intraday, but payments are netted among participants and are only exchanged during the final securities settlement. This requires a record-keeping process throughout the settlement cycle which at the end leads to a net cash obligation between two counterparties. Throughout the cycle, participants typically use collateral (other securities in their portfolio) to obtain credits for the acquisition of the securities in the record-keeping process.

With Model 3, the finality of settlement for both payments and deliveries only occurs on a net basis at the end of the netting cycle. Model 3 therefore provides no finality on either of the legs of the trade throughout a trading cycle. Both securities and cash are recorded and then settled in transactions between the two counterparties at the end of the cycle.

The BIS based this taxonomy on processes that were being used in 1992. These are still the common DvP models used today, with different jurisdictions using their own versions of these models for securities settlement. Model 2 settlement is prevalent in the US and Canada, for example. Whereas the European TARGET2-Securities (T2S) system uses a combination: T2S employs Model 1 throughout the day and offers short periods of Model 3 for night batches and other limited cases. To compensate for liquidity issues, participants of T2S can use their securities as collateral to obtain credit during the trading cycle. They can do this through central bank auto-collateralisation and/or through client collateralisation. However, the cash payments are still settled right away, not netted later in contrast to Model 2.

What all of these models have in common is that they settle using central bank accounts. It is for this reason that we introduced an exploration of DvP into discussions taking place in the R3 CBDC Working Group. DvP as a use case for CBDC isn't entirely novel, however. To provide some context to our proposal in this paper, the next section considers the very recent but extremely active history of central bank exploration of DvP in the CBDC context.

3   A history of central bank exploration of the wholesale CBDC DvP use case •

DvP is just one use case in today's widespread international activity around CBDC design and issuance. The current attention to CBDC research is a deliberate attempt to thoughtfully and carefully integrate decentralization into the existing monetary system.

There are two forces that are converging to raise interest in the CBDC DvP use case for securities settlement. The first is that there is now a considerable foundation of central bank research on the DvP use case. We go through this in some detail in section 3.1. The second reason is that settlement times have shortened, and blockchain provides a clear path to T+0 securities settlement, the utility of which has raised considerable debate. We cover that in section 3.2.

3.1 Drivers of central bank interest in blockchain

Today's activity in the CBDC space is partially in response to the growing prevalence of Bitcoin and other cryptocurrencies. Other factors that have driven this include the globally diminishing use of central bank-issued banknotes and the increasing activity of largely unregulated Big Techs in the payments space. There have been concerns that the ability of central banks to continue to set monetary policy may be eroded by these factors unless the central banks themselves were also actively participating in the digital payments space.

Central banks began their exploration into digital currencies as early as 2014. The BIS reports that in January 2021 **86% of surveyed central banks were exploring CBDC use cases**. Several countries have trialled, are currently deploying, or are in the process of issuing general purpose or retail CBDCs, including Ecuador (2014-2018), the Bahamas (Sand Dollar in 2019), the Eastern Caribbean central bank (D-Cash in 2020) China (Digital Yuan in 2020), Venezuela (Petro-Dollar in 2018) and Nigeria (e-Naira in 2021).

While these retail-focused cases have been the predominant focus in the popular press, the DvP use case that we explore here is on the wholesale side. Wholesale CBDC is only available to financial institutions and payment service providers rather than consumers directly.

For securities settlement, wholesale CBDC is of particular interest because it could offer significant efficiency benefits for various financial transactions while contributing to systemic stability in financial markets.

Central banks have undertaken a great deal of detailed research into wholesale CBDC use cases. Many of the wholesale CBDC projects to date have focused on the use of CBDCs for cross-border payments and atomic settlement for various asset classes including securities (see Table 1).

3.2 Four foundational research reports on the CBDC DvP use case

There are four wholesale CBDC projects in particular that inform this paper. We describe them briefly in the table and paragraphs below. This summary is meant to give some context to the proposal we introduce in section 4 of this paper. These projects provided both design requirements and business considerations for our proposal.

Table 1. Wholesale CBDC research related to securities settlement

	Jasper Phase 3	Stella Phase 2	Ubin Phase 3	Helvetia
Regions	Canada	EU and Japan	Singapore	Switzerland
Participants	Bank of Canada, Payments Canada, TMX	ECB, Bank of Japan	MAS, SGX, The Association of Banks in Singapore	BIS, Swiss National Bank, SIX group
Topic	Interaction of tokenized fiat money and securities	Single vs double ledger settlement of securities and fiat money	Interledger settlement of securities and fiat	Single ledger settlement of digital securities

The first of these is the Bank of Canada's **Project Jasper** Phase 3. This proof of concept was conducted jointly by the Bank of Canada, Payments Canada, and TMX Group and was supported by Accenture and R3. It demonstrated the successful interaction of tokenized central bank money (Digital Depository Receipts) and tokenized securities on a shared distributed ledger for the settlement of previously cleared and netted transactions. The primary lessons from Jasper Phase 3 are that (1) the interaction of tokenized fiat money and securities can successfully occur on a shared ledger; (2) using this ledger, there is liquidity efficiency achieved via direct interaction between fiat money and securities; and (3) it is possible to use "loose coupling" between the Bank of Canada and the Canadian Depository for Securities, allowing direct interaction between fiat money and securities to happen without requiring either the integration of the two systems or an interface between them.[4]

A second CBDC project is Project Stella Phase 2. This proof-of-concept was a joint project by the European Central Bank (ECB) and the Bank of Japan. It compares settlement of fiat money and securities both on a single ledger and on two separate ledgers, using several different types of distributed ledger technologies. The principal take-aways of Project Stella Phase 2 are: (1) there is utility to be gained from DLT for DvP settlement on both the dual-ledger and single-ledger models, and (2) there is added complexity in using separate cash and securities ledgers instead of the direct interaction of cash and securities on a single ledger.

As a third project, **Project Ubin** Phase 3 demonstrated successful and efficient interledger settlement of securities and fiat money using several different DLT providers. Project Ubin showed (1) the potential for DvP on DLT to compress settlement times, (2) that smart contracts could enable enforcement of participant rights and obligations and investor protection, and (3) that this settlement model has a central role for a recognized market operator (RMO) to monitor and facilitate market functionalities.

A final project that informs our research is **Project Helvetia**, a joint experiment conducted by the BIS Innovation Hub, the Swiss National Bank and the SIX Group. Project Helvetia compared single-ledger settlement with a settlement model that links digital securities and an existing central bank payment system. The project found an efficiency advantage in single ledger settlement, but it was accompanied by potential CBDC design and implementation challenges.

Our paper on DvP for securities settlement is an extension of these earlier (and ongoing) efforts to build out the DvP use case for CBDC. The model we introduce in Section 4 incorporates the efficiency and complexity learnings from Projects Jasper and Stella and Helvetica, and acknowledges Project Ubin's result that existing intermediaries can remain as part of a functioning DLT settlement system.

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4   The term loose coupling refers to a scenario in which two separately governed systems are logically connected without compromising the control of either authority over its system or assets.

3.3 How changes in settlement times impact the incentives for DvP using blockchain

Central bank research on the DvP use case is not the only reason that there is renewed interest in blockchain for securities settlement in DvP. The progressive shortening of settlement times provides a further incentive for central banks to understand how CBDC and blockchain might adjust how DvP is executed.

Today, securities settlement is available in T+2. The US securities settlement system operator (DTCC) has published a **roadmap** to settlement in T+1. T+0 settlement would be a dramatic departure from what was the historical movement of T+5 to T+3, and then to T+2 today. It would require considerably more than just increasingly frequent settlement cycles.

You might ask why central banks are not aiming for T+0 in the short run. The answer is that while the technology is available, current market structures, operational processes and market conventions still require time to settle transactions efficiently. Multilateral netting provides enormous efficiencies to the market, and further work is required before T+0 settlement can include the benefits of multilateral netting.

Complementing central bank research work on CBDC for DvP, there are regulator efforts to understand the implications of blockchain on DvP in the context of settlement times. The DTCC has announced development work on a DLT settlement platform for securities. **Project ION** will function alongside and interact with the current infrastructure to allow participants to prepare for digital asset settlement in the future and help enable this compression of settlement times.

It is these two forces that led us to propose a new model for DvP and securities settlement. CBDC research clarified the efficiency benefits of blockchain, while operational frictions, liquidity requirements and market conventions are impediments to T+0 settlement today. Building upon these considerations, we propose a model that we believe uses both blockchain and CBDC in a way that would build on existing processes, offer new efficiencies and options, and not completely disrupt or disintermediate market infrastructures that play important roles in ensuring consistency, confidence, and market integrity.

4   DvP Model 4? A proposal for a settlement choice model •

One of the major concerns raised in every CBDC discussion is disintermediation. This gets to the heart of the slow adoption of blockchain. Today's intermediaries play important roles in securities settlement, and while it is technically possible to settle without them, it may not be wise from a financial stability perspective at the current time.

This fundamental tension informed our design of the settlement choice model. We propose this model as a way of taking advantage of the new functionalities that blockchain provides for DvP, while continuing to leverage existing market infrastructures like CSDs and central banks. This could also be an introductory step in the move towards greater disruption, but one that allows all market participants to adjust.

In contrast to what is often assumed, blockchain will not necessarily lead to a complete disintermediation of existing players. Instead, they will still perform important roles, e.g., provide infrastructure or accept accountability for certain processes. Figure 2 shows all parties involved in our simplified process overview, with a color code which we will find again in the process descriptions. These parties can be thought of as being interconnected via a blockchain (or several connected blockchains). Each of them could theoretically run a node that connects them to one another.

Figure 2: Involved parties in a DvP process on blockchain
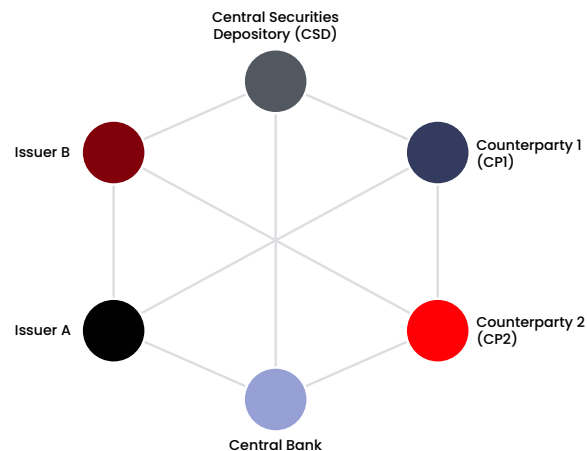
Blockchain, tokenization, and CBDC are inherent components of this simplified approach, and all the challenges arising from an adoption of each of these innovations individually as well as from integrating such a platform into existing systems will need to be investigated in future studies. An implementation will challenge existing market conventions, which are notoriously tough to change.

In the following subsections, we take an expansive view of securities settlement. We begin by describing our settlement choice model and the two innovations it presents to the existing process of DvP. This covers both the technical architecture and how it would change how we do DvP today. Finally, we take the model to its logical extreme to understand how it might change the DvP process in the future.

4.1 Two ways the settlement choice model changes today's DvP process

The model that we propose here is a combination and extension of DvP Models 1 and 2.

There are two innovations in this model. The first is that participants in the securities settlement system have a choice as to how their trades will settle. If participants wish to settle on a real-time gross basis, they can mark the trade for RTGS and it can be settled on-chain via atomic settlement achieving finality of both legs. If they prefer to take advantage of the benefits of netting, they can mark their trades to settle via the netting mechanism—finality of securities settlement is achieved as it is today in real time and cash legs are settled intraday via CSD credit tokens.

The second innovation is for participants that decide to net, they can opt at any time during the day to calculate and finalize a net settlement using CBDC on-chain in the CSD. This settlement will finalize the cash leg and release any collateral that was committed to secure the CSD Credits.

To better understand how this new model works, we use a simplified setup where all tokens, market participants, and smart contracts (e.g., for DvP and settlement) are placed on the same blockchain.

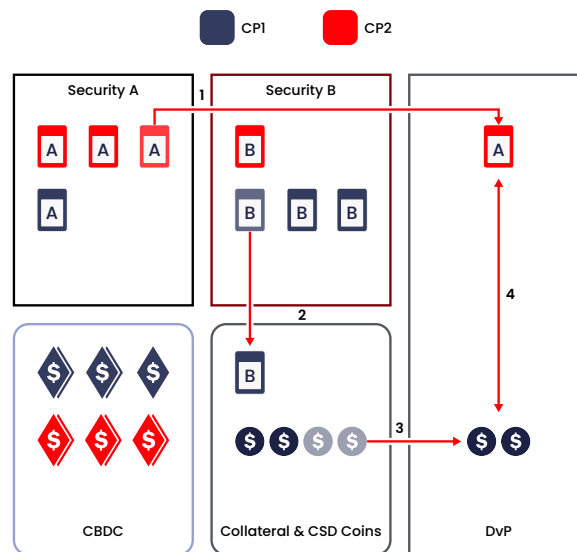Figure 3: Components in the settlement choice model (illustrative model)

Figure 3 illustrates one possible way of trading in the DLT-based securities settlement system: (1) CP2 sends one Security A token to the DvP smart contract in order to swap it against two CSD coins. (2) CP1 stakes one Security B token and receives four CSD coins in return (according to a current market price). (3) CP1 transfers two of these tokens into the DvP smart contract. (4) Now, the trade can take place. Afterwards, the tokens will be sent back to the respective contracts with a changed owner. Alternatively to this process, the two counterparties could also use the DvP smart contract to trade securities against securities (delivery-versus-delivery), CBDC against securities, or CSD coins against CBDC (peer-to-peer netting).

Figure 3 shows this setup. Two smart contracts representing securities A and B contain squares which indicate the single securities owned by either Counterparty 1 (blue) or 2 (red). The CBDC smart contract (owned by the central bank) contains several CBDC coins as diamonds with the same coloring for ownership of these tokens. The CSD provides two smart contracts: one where securities (rectangles) can be staked in order to receive CSD tokens (circles) and one where the actual swap / trade takes place.

Let us assume that tokens are standardized (like an ERC-20 token on the Ethereum blockchain) in a form such that, for their technical representation, it does not matter what they represent: CSD coins, CBDC, or securities.

The following actions will then be possible with a setup as depicted in Figure 3:
- An atomic swap in the DvP smart contract between CBDC and a security (Model 1).
- Moving (staking, locking) a security token into the Collateral smart contract of the CSD in order to receive newly minted CSD Coins / tokens which can be used as intraday payments (intraday cash).
- An atomic swap between a security and such a newly minted CSD Coin.
- Re-use of CSD Coins for different trades.
- An atomic swap between CSD Coins and CBDC as a cash settlement (Model 2).
- Freeing collateral by burning CSD Coins and moving the security tokens back into their smart contracts.

We make a number of simplifying assumptions in this model. First, we assume that all assets in the transaction are represented on the same blockchain. Other assumptions include: there is just one currency, the collateral smart contract always knows the market value of securities and will create the correct amount of CSD coins, and the CSD coin is worth the same as a CBDC token.

In reality, cross-ledger technology may be required, currency conversion and different values and risks of securities and CSD tokens will need to be considered. Complex risk models, additional players with niche functionality, and various oracles need to be created in order to implement such a solution.
All of these capabilities are already available today and can all be applied to this new model while still providing a choice for market participants. How to incorporate these additional features, players, and processes is a subject for future study.

4.2 Impacts on participants, CSDs and central banks

The technical architecture we describe above innovates both the DvP process and also more specifically the netting process. What we are proposing can offer significant advantages. We can divide these benefits into those which impact the participants, the CSD and the central bank.

The market participants involved in securities settlement are the beneficiaries of this model. The benefits they could gain include:

- Direct netting, providing instant finality at T+0, if participants want, without impairing the ability to also benefit from DvP Model 2 for other trades.
- Direct access to CBDC for all those on-boarded to the central bank smart contract (either via the central bank itself or through intermediaries or representatives).
- If the CBDC and the securities share a common ledger, independent actors can issue a variety of tokens on this ledger and interact directly with capital, lowering the barrier to entry and promoting competition.
- Participants need not worry about linkages to accounts at a central bank.
- The usage of smart contracts allows for instant feedback on the success of a trade. This does not take out all risks, as that also depends on the assets being exchanged, but it allows for immediate re-use of the exchanged assets and a higher degree of automation.

There are also benefits to the CSD. These include:

- Simplification of netting and record keeping with smart contracts. Any net and final payment in central bank money can be done at any time by exchanging CBDC and CSD Coins via the DvP smart contract. As the CSD Coins are created by locking collateral, participants will have an incentive to obtain CSD Coins as soon as they can to unlock their collateral, e.g. in order to trade it.

- Without the need to adhere to banking schedules, there is additional flexibility for the CSD to operate on its own schedule.

Finally, central banks may also benefit from a settlement choice model. They could easily offer a service to stake certain qualified securities as collateral in order to mint CBDC for the staking party. This would enable deals according to model 1 but with credit extended in the form of CBDC.

4.3 Settlement choice model vs decentralized finance applications

The savvy reader might notice that our proposed settlement choice model has features that are very similar to another trend in securities markets—decentralized finance (or, DeFi). However DeFi exists at the opposite extreme: it has no intermediaries, requires no trust in counterparties or centralized service providers, and as a result, requires over-collateralization.

DeFi has grown considerably over the last two years. It consists of applications for exchanges, derivatives, synthetic instruments, algorithmic stablecoins, lending, hedging, and more. These products usually consist of a number of smart contracts and specific tokens, which create incentives for market participants, in the form of financial rewards or governance features.

In this section, we look at the consequences of implementing the settlement choice model infrastructure in the DeFi space and compare the features in both ecosystems. The previous sections assumed that our settlement choice proposal would be applied in a way where existing intermediaries were retained and overall market disruption was minimal. Here we consider what it might look like if the role of the CSD was fully automated.

Though it is not our original intent, the proposed settlement choice model could also be set up as a DeFi application. In such a decentralized settlement security system, certain tokens could be used as collateral to create payment tokens which are valid within the ecosystem (for us, the job of the CSD). The DvP smart contract (in our example, also owned by the CSD) would then be a decentralized exchange where tokens can be swapped. The CBDC equivalent could be the native token of the blockchain or a stablecoin created by an external entity or by an algorithm, for example as in the case of **DAI**.

There are three key aspects of such decentralized systems: (1) They are open to anyone. This means that today's anti money laundering measures which are designed for centralized systems will be difficult to apply. (2) In order to receive tokenized value of any kind (stablecoins, derivatives, etc.), over-collateralization is the rule, together with forced sales in cases when borrowed asset prices fall below established thresholds. In such a system it is not possible to extend credit based on ratings or to create money (as banks can) based on future payments.

Finally, (3) any connection to off-chain values (fiat currencies, gold, etc.) is handled through decentralized oracles or economic incentives that rely on network effects. This imposes a risk on financial transactions that involve off-chain values.

In general, DeFi applications are often created by startup companies on relatively new infrastructure. Additionally, most market participants manage the private keys (which give them access to their assets) on their own, which means there is no third party to assist them in case of loss. These two aspects each can lead to the total loss of all assets. This could occur through key loss, hacked smart contracts, or protocol errors. Moreover, untrained traders are not protected from malicious actors, complex structured products, or inappropriate financial decisions.

On the plus side for DeFi, one can never lose more than one owns, while in centralized systems, leveraged products and margin calls can in some cases lead to default.

However, centralized players can be forced (1) by regulators to follow certain rules and thus prevent criminal activity (2) by the market to use money and other values efficiently and extend credit based on ratings or for a lower amount of collateral than in DeFi markets, and (3) by law to accept liability and accountability for provided rates and accepted deals. Moreover, extensive record-keeping and reporting requirements make total loss of assets for market participants due to technical errors unlikely.

Our proposed settlement choice model can hence leverage the efficiencies of smart contracts, automation, ease-of-use, simple onboarding, and openness, but also the centralized aspects of regulation, efficiency, and clear accountabilities.

5   An exploration of DLT's impact on existing models in securities settlement ●

In our proposed settlement choice model, market participants will choose which settlement type they wish to use at the time of trading—either netted or immediate and gross. If they choose netting, our model would further allow participants to decide when they wish to do netting without having to wait for the end of a trading cycle. This is a notable change from the process as it works today.

Because our proposed settlement model includes elements of both BIS DvP Models 1 and 2, translating each of these processes to a blockchain architecture allows us to anticipate some of the challenges that will accompany the implementation of our settlement choice model. In this section we therefore deconstruct BIS DvP Models 1 (gross settlement of both securities and cash) and 2 (gross settlement of securities, net settlement of cash) to explore how each would respond to using a blockchain architecture. We highlight both the efficiencies and the challenges that this innovative technology can introduce.

5.1 DvP Model 1

In the settlement choice model, participants have two choices. One choice is gross settlement of securities and payment on a trade-for-trade basis. This model of DvP is the primary form of securities settlement in the European T2S system (with the exception of a few hours at night when settlement is netted) and is available for use in Canada for certain trades and in the US for securities that are not eligible for continuous net settlement.

In this section, we first look at how gross settlement works today, and then explore how using blockchain for Model 1 DvP addresses some, but not all, of the inefficiencies in today's DvP process as highlighted by R3 CBDC Working Group participants (see appendix). In particular, applying blockchain with on-chain CBDC to Model 1 can reduce the time elapsed between trading and settlement, and by definition a single ledger as contemplated by blockchain architecture can eliminate the need to reconcile multiple books and records and provide a single set of consistent static data describing securities. However, a domestic model does not address the issues of differing conventions between national systems and the resulting cross-border frictions.

We begin with an example. Figure 4 provides an overview of the steps in a securities settlement system. In this example, two market participants have agreed on a deal where Counterparty 1 purchases a security from Counterparty 2 (right-hand-side) for a certain amount of money (depicted by the diamonds with dollar signs on the left-hand-side). Both counterparties communicate this deal to their respective custodians, who will facilitate the trade on the securities settlement system.

Figure 4. High level graphic of DvP Model 1
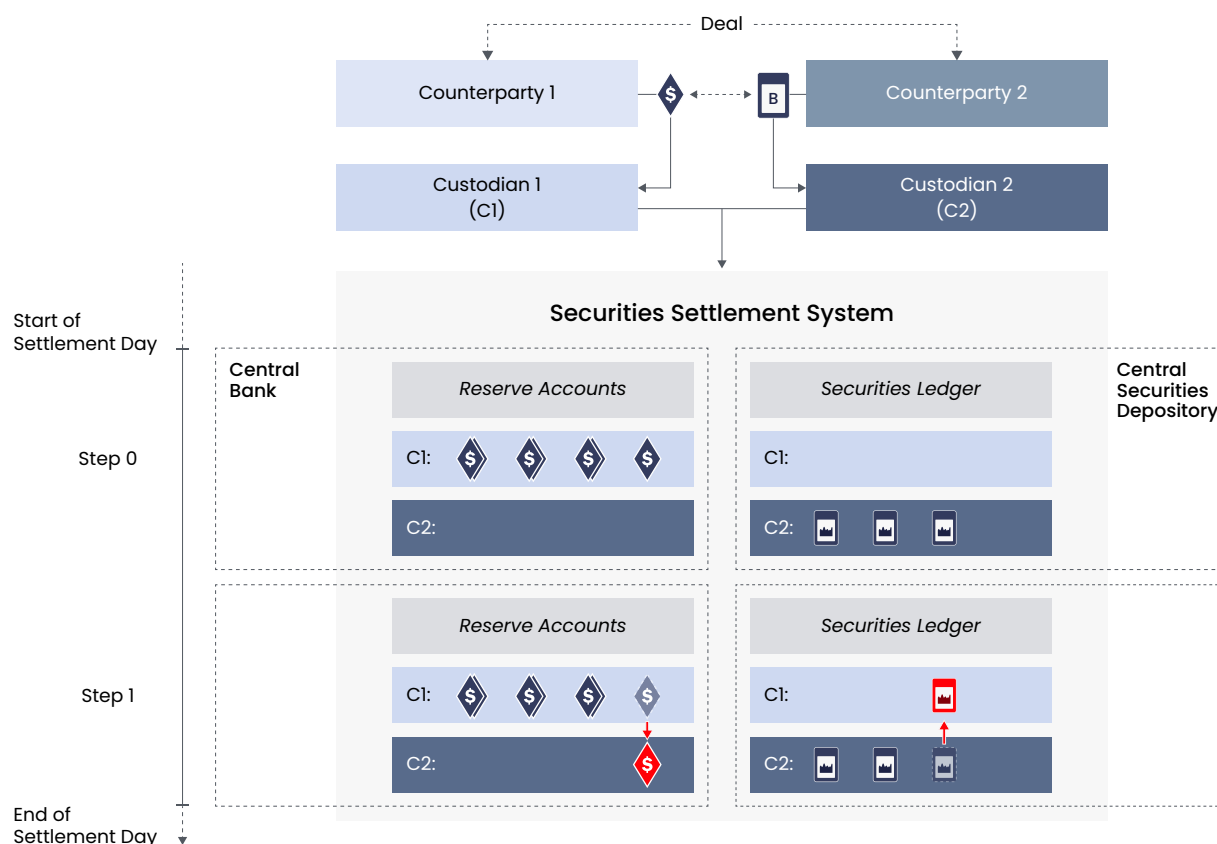
- On the left-hand-side, we see the balance within the reserve accounts of the custodians at the central bank. The right-hand-side displays the securities ledger for Custodian 1 and 2 within the Central Securities Depository (CSD).
- Step 0 shows the initial state at the time of the deal: On their central bank accounts, Custodian 1 owns three cash units, Custodian 2 owns two. On the securities ledger, Custodian 1 does not own any securities, Custodian 2 owns two of the same kind.
- Step 1 shows what happens in this simple DvP model on settlement day: the exchange of money on the central bank side and the securities exchange in the CSD happen in near-real time. Both accounts now reflect the state after the deal, where money and securities have changed owners. Money will have been sent using the relevant High Value Payment System (HVPS), e.g., RTGS.

The innovation that blockchain introduces is that the DvP process can be finalized using an atomic swap, especially if it is implemented on a blockchain using on-chain payments, tokenized securities, smart contracts, and automated flows. The value in using a CBDC in this atomic model is that the cash leg is settled in central bank money, just as if the settlement was affected in accounts at the central bank as previously illustrated.

The principal role of the CSD in this model is to provide and be accountable for infrastructure in the form of accessible, thoroughly tested, and robust smart contracts. The central bank will release a CBDC onto the ledger in the form of a smart contract that represents the currency as a digital asset. The two counterparties will interact with the same ledger and the smart contracts provided by the central bank and the CSD. They will also interact with the securities issued by Issuers A and B (see figure 5) in the form of smart contracts, again representing them as digital assets. Note that all participants are interacting with a single ledger and with the same smart contracts and digital assets.

This eliminates the current issues around multiple ledgers, multiple connected systems and potentially inconsistent data.

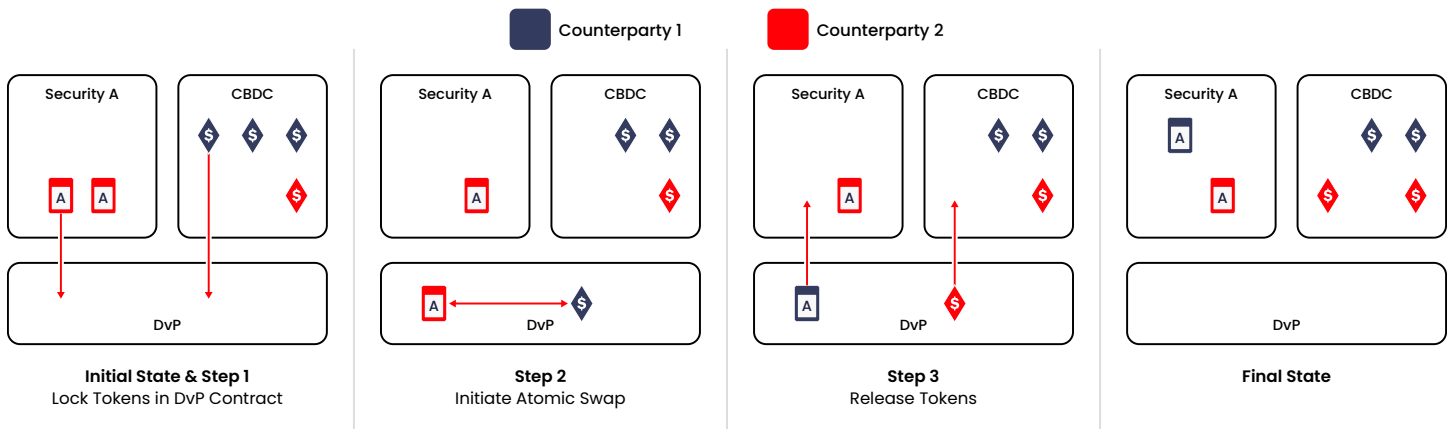**Figure 5: Securities settlement on blockchain using DvP Model 1**

	Counterparty 1		Counterparty 2

Initial State & Step 1
Lock Tokens in DvP Contract

Step 2
Initiate Atomic Swap

Step 3
Release Tokens

Final State

Figure 5 shows the simple process of an atomic swap for the same deal as in Figure 3 between the two counterparties: Security A and CBDC are both represented by tokens in a smart contract, in which assets are allocated to different owners, indicated by the colored tokens.

CP1 sends one CBDC token (indicated by the blue diamond) to a DvP smart contract while CP2 (red) transfers one Security A token into the same contract. In Step 2, an atomic swap will take place and the assets are then transferred back with switched owners.

Due to delays in markets, batch processing, different time zones, liquidity requirements and other factors, atomic swaps and DvP Model 1 have not always been the go-to choice for market participants. Consequently, the market infrastructure which has evolved around this constraint now leverages the time lapse between trading and settlement, allowing participants (to use a common expression) to use money they do not have to buy securities that the seller does not own.

5.2 DvP Model 2

This model provides finality on the securities leg right away, however the cash side is settled at the end of the trading cycle. Examples of using Model 2 include Canada (CDS) and the US (DTCC) for securities settlement.

In order to understand the increased complexity, the involvement of collateral, and how an additional record-keeping process is required, we will present you with an example of a deal between two counterparties involving more than one trade which they will net at the end of the trading cycle.

## Figure 6: Initial state of a trade using DvP Model 2
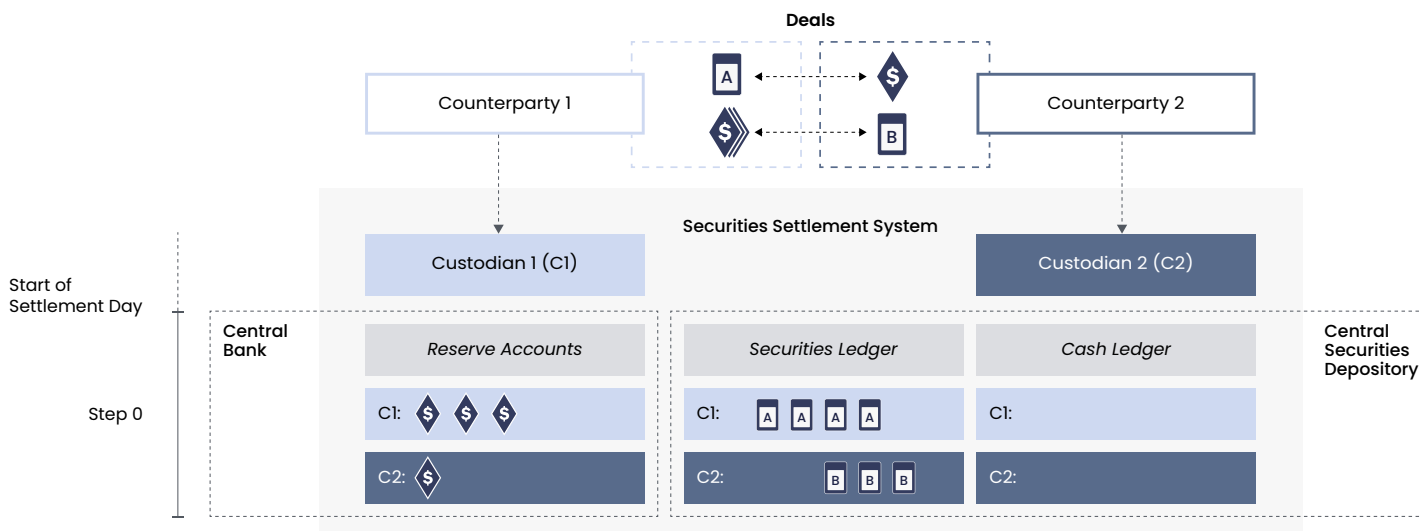
In this example, starting in Figure 6, the two involved market participants have agreed on two transactions: (1) Counterparty 2 purchases Security A (top; left of center) from Counterparty 1 for one money unit (depicted by the dollar coin on the right of center). (2) Counterparty 1 purchases Security B from Counterparty 1 for three money units (depicted by the three dollar coins).

As in DvP Model 1, both counterparties communicate this transaction to their respective Custodians, who will facilitate the trade on the securities settlement system.

On the left-hand-side of the securities settlement system, we see—again—the balance within the reserve accounts of the custodians at the central bank. The right-hand-side displays the securities ledger for Custodian 1 and 2 within the CSD but now also the accounts on the Cash Ledger within the CSD, which can be filled by "locking" securities from the securities ledger as collateral.

Figure 7: Locking collateral to get intraday cash
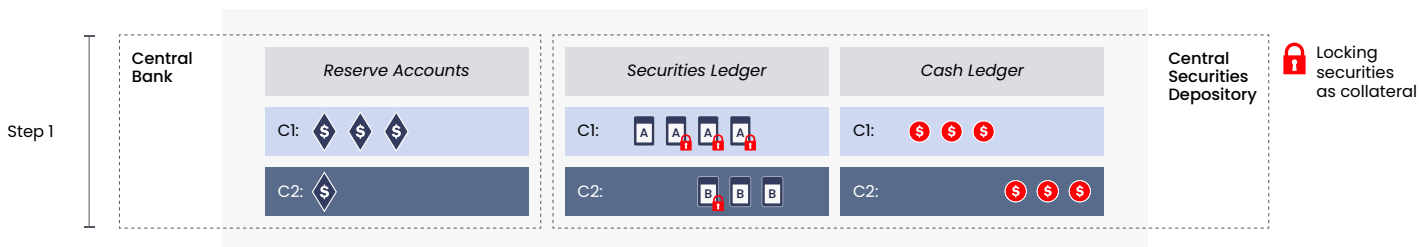
Step 0 shows the initial state at the time of the deal: On their central bank accounts on the left, Custodian 1 owns three cash units, Custodian 2 owns one cash unit. On the securities ledger, Custodian 1 owns four A securities, Custodian 2 owns three B securities. The cash ledger is empty for both.

In step 1, as indicated in Figure 7, both cash ledger accounts in the CSD are being filled by locking the corresponding amount of securities on the securities ledger. This is necessary to later purchase the securities involved in the deal. From that deal at the top, we see that security A's market value is one cash unit. Security B's market value is three cash units. By locking three A type securities, Custodian 1 hence receives three cash units, Custodian 2 receives the same amount by locking one B type security. Note that the central bank accounts do not change.

**Figure 8: The first of two trades on securities side**
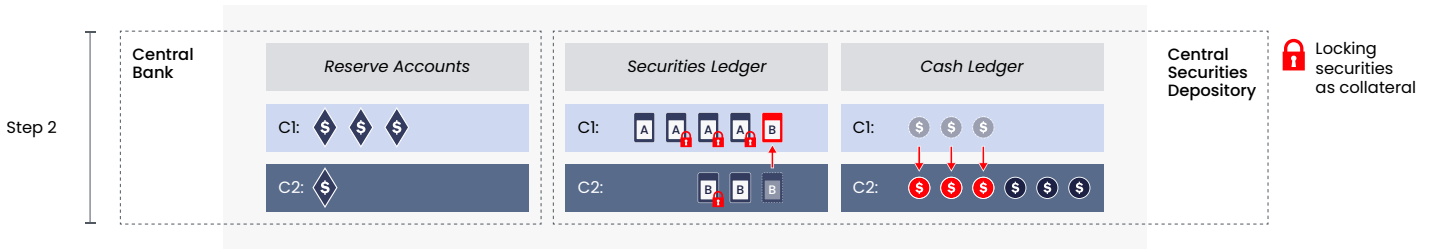
Step 2 (Figure 8) displays how one security of type B is transferred from Custodian 2 to Custodian 1 while three cash units are moved on the cash ledger to pay for the security. Again, the central bank accounts don't change.

Figure 9: The second of two trades on the securities side
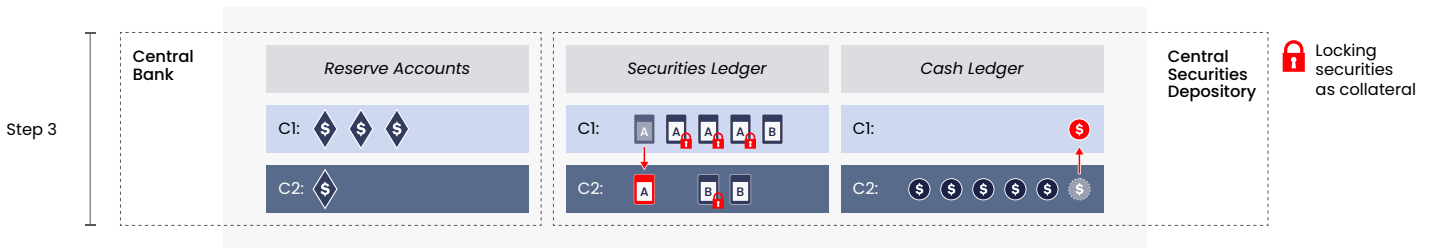
In step 3 (Figure 9)—and we're still inside the same settlement cycle—the security of type A will move from Custodian 1 to Custodian 2 on the securities ledger, while one cash unit is transferred on the cash ledger. Legal finality of settlement of the securities leg occurs during the cycle. Final settlement of the payment leg has not yet occurred, and reserve accounts on the central bank side are unaffected.

**Figure 10: The netted cash settlement**
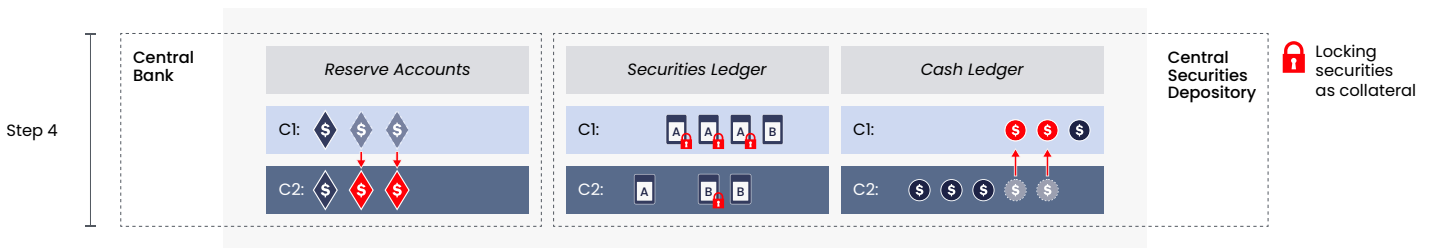
Step 4 (Figure 10) now shows the actual net payment and final settlement of the payment legs on the central bank side (on the left): Custodian 1 transfers two cash units to Custodian 2. This step contains several simplifications:

- First, in several countries and systems, custodians do not have direct access to an electronic form of central bank money, so the CSD will arrange the netted payment between the custodians' bankers through their reserve accounts.
- Second, the question of the amounts of netted cash obligations does not become obvious from the two ledgers we show in the CSD. Some additional record-keeping needs to take place within the CSD to calculate and record the obligations for netted payment.

In our proposed Settlement Choice Model, we will show how these two aspects can become considerably simpler with CBDC and a shared ledger on a blockchain.

In the final step, the CSD unlocks the collateral after the net payment has been made (Figure 11).

Figure 11: Releasing the collateral
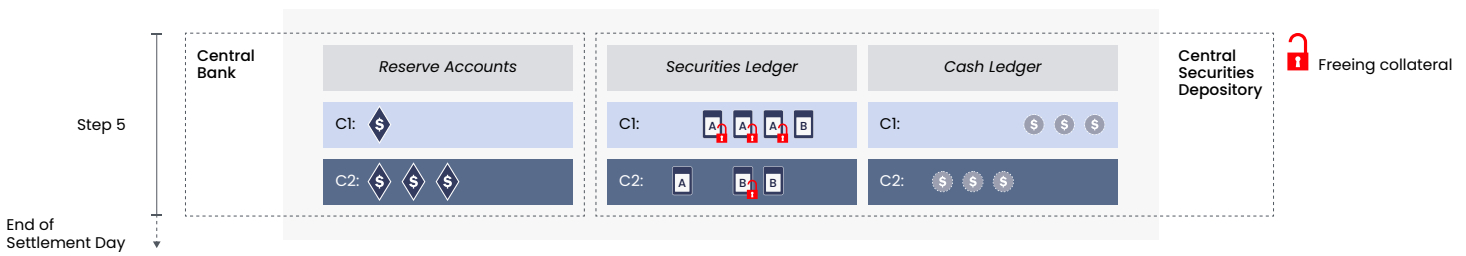
At the end of the settlement day,[5] the securities will have changed owners and only the net amount of money will have been transferred in the central bank accounts. With CBDC, one could replace the extended credit within the CSD, which would make all deals DvP Model 1 type transactions and introduce potential issues, as market participants currently use the time between trade and settlement to optimize liquidity and trading strategies.

As illustrated previously, Model 2 introduced considerably more complexity as compared with Model 1. However, switching from a Model 2 system to a Model 1 system is not in the interest of all market participants, given the liquidity requirements to support trade-for-trade settlement.

In summary, Model 1 provides quick finality and requires considerable liquidity, Model 2 allows immediate finality for securities legs and saves liquidity via netting final payments. Model 3 does not provide new insights with regards to the benefits of blockchain or CBDC.

Today, systems use either the one or the other model, at least within certain time windows. Market participants are hence forced to accept trade-offs in terms of the speed of settlement finality versus liquidity requirements that may not be optimal. Rather than arguing that one model would be superior to the others in every instance, we believe that the best solution will be a system which incorporates all advantages from all models, but not at the cost of additional inefficiencies. This is reflected in our proposal of the Settlement Choice Model.

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5   Which is usually two days after the closure of the underlying deals.

6   Conclusion •

Securities settlement in DvP provides a tangible example of how CBDCs might be used to diminish risk and improve efficiency within wholesale financial markets. Of course, even as the CBDC discussion advances globally, to apply CBDC to securities settlement, there are a number of different policy and technical questions that must be addressed.

Regulatory considerations

First, on the regulatory side, CBDCs need to be enabled to work in each jurisdiction as well as between them. Regulators must determine the specific regulations that need to be enacted to accomplish this.

As one example, central banks in general issue and circulate cash and provide settlement accounts. What that would mean for the Eurozone and the roles of national central banks vs the ECB issuing and circulating Euro might be quite different from the role of the central bank with a national currency (as for example in Denmark). Such an undertaking will also require a clear understanding of the participant roles and relationships required for each market. For example, how central banks will relate to commercial banks and other payment interface providers which may be granted access to central bank money for securities settlement. New participant roles and activities will need to be examined and tested.

Payment system implications

Another angle of regulatory consideration relates to the statutory implications of the categorization of CBDC as a payment instruction. The token represents the instruction by the first holder of the token and each subsequent holder to the CBDC issuer of the token, to debit the current payor's node on the ledger and credit the same amount on the node of the next holder of the token. The CBDC token will not represent legal title, it is electronic information—a declaration of interest that can be transferred pursuant to (and in accordance with) the laws governing the payment instruction. As such, no specific form of assignment would be required to effect the transfer under the relevant statutory framework. The regulatory frameworks of relevant countries for sending and receiving payments including settlement finality, should be reviewed to ensure they are compatible across jurisdictions.

Business practices and operational considerations

A major category that needs to come under consideration is the impact of a new settlement model on operational and business practices. It is not yet obvious how a settlement choice model might impact current practices and market conventions employed by participants to trade. If reliance is currently placed on settlement delays to provide windows to either acquire securities or source cash consideration, changes to market behaviour will need to be introduced to enable atomic settlement as envisaged by the proposal to become the prevailing model.

There are similar operational questions that need to be answered on the central bank side as well. The first is settlement timing. central banks need to decide whether they require intra-day or end-of-day settlement and what type of transparency and intervention rights they will require as part of maintaining control over monetary policy on a DLT platform, and the extent to which DLT platforms need to be adopted in relation to the CBDC operation. For example, the Chinese DC/EP does not provide for operation on any DLT platform.

A second issue is the funding model. Pre-funding which currently occurs in some RTGS models (involving intra-day facilities provided by settlement banks to other RTGS participants), would lead to higher liquidity demands either for CBDC, RTGS systems, or privately issued coins backed by central bank money. Our proposed Settlement Choice Model contemplates both pre-funding and the elimination of some settlement delays under Model 1, as well as immediate finality for securities legs and liquidity efficiencies via netting under Model 2.

A third issue is a change in how RTGS interacts with multiple accounts. For interoperability with DLT platforms (e.g., to enable atomic settlement for various asset classes), RTGS systems would require the functionality to block account balances across multiple accounts. Real-time payment systems allow 'parallel' instead of sequential settlement, and in this respect are better suited to atomic multilateral settlement.

To conclude, CBDC is a rapidly changing field which requires coordination among many different actors in the monetary and payments space. In this paper we suggested that the issuance of a CBDC opens up the possibility of more efficient securities settlement. This would increase efficiency in a system that has seen limited innovation in the decades since the BIS first took their taxonomy in 1992.

Appendix: CBDC Working Group survey results ●

Many of the innovations in settlement have focused on the dual problems of liquidity risk and settlement risk. Improving the DvP process began in earnest in the wake of the 1987 collapse in securities prices. Since then, settlement delays have been reduced materially.

Market participants have already benefited from the efficiency gains of the reduction from T+5 to T+2 settlement cycles. However, the current DvP workflows continue to present challenges beyond liquidity and settlement risk. These challenges have not yet been thoroughly inventoried.

Survey procedure

To fill this knowledge gap, in February 2021, we surveyed the members of the R3 CBDC Working Group on the problems that they would like to solve in post-trade activities. Respondents reported four general categories of difficulties perceived with securities settlement today:

- Multiple books and records
- Inconsistencies involving securities static data
- Multiple standards
- Time lapses between trade and settlement

The prioritization of these individual pain points depends on both the market role of the respective institution, but also on the role individual respondents play in the settlement process within their institution. The specific characteristics and features of the settlement systems run by the participant banks also play a role in which problems have the biggest day-to-day impact.

Although we believe that the first three pain points can be solved, or at least eased by the introduction of a DLT-based settlement infrastructure, the focus of this paper is to propose a solution for the fourth point. In the remainder of this section, we describe each of the four points in some detail along with a discussion about how DLT based settlement solutions could contribute towards a solution.

In legacy securities settlement systems, participants have multiple books and records, and different ways of accounting for customer positions including omnibus accounts. This creates challenges and inefficiencies for custodians and dealers, such as delivery management, hold/release functionality, reporting requirements, and reconciliation.

Having to maintain multiple books and records for one market/settlement system is compounded for some participants by the necessity of having multiple custodian relations. This also leads to a fragmentation of the necessary funding of pending settlements. In general, the large number of parties involved in a transaction is seen as one of the main reasons for failed settlements.

Some participants viewed "multiple books and records" to be the root cause of the other pain points around inconsistencies involving data, the need for multiple standards, and delays. As a result, one respondent noted that the value proposition for DLT would be to keep books and records entirely on the ledger and thus make information instantly available to the affected parties where the processing today is rather sequential from party to party and slows down the information flow. In a DLT orchestration, smart contracts

(conditional code) could take over some parts of the role of share registries. And even if not all participants fully leverage DLT and the data which might be available on it, the introduction of a 'golden source', in the form of a shared ledger, for data in subsequently used systems could lead to fewer disputes and slimmer reconciliation processes.

Inconsistencies involving securities static data

There are delays in the distribution of static data for new issues across systems, which lead to data inconsistencies between platforms. Further inconsistencies arise from the broad range of securities properties (e.g., quantity or nominal based) and the many different ways in which these are represented in different systems.

Inconsistencies involving static data is a problem for all participants, as is the manual effort and complex system set-up necessary to fulfil each market's specific requirements. A blockchain holding static data would ensure data consistency across all users and provide the means to distribute updates instantaneously.

Multiple standards

Many different country-specific standards or practices exist with regards to securities and cash settlement. This leads to complex processes and manual efforts in areas such as tax, reporting, and valuation.

Introducing a new technology will not be sufficient to align all country-specific processing, most notably in the area of tax requirements. However, smart contracts could be a way to consistently implement some of these requirements in a consistent way, which would remove the burden from individual institutions to implement these requirements on their own. Additionally, these smart contracts could make specific requirements transparent for other market participants, which in turn can lead to greater efficiency.

Delays between trade and settlement

Delays between trade and settlement are seen as necessary in today's markets, especially for international investors. Time zone differences play an important role here, making T+0 or even T+1 impossible or undesirable in some situations.

Delays in settlement generate risks, which must be mitigated by central counterparties (CCP)s and participants. This requires additional resources (collateral) as well as liquidity at the CCP.

There is a counterpoint however: Reducing these delays can create additional liquidity demands on the participants. In a cross-border context, delays can manifest when assets are inaccessible due to different banking hours across time zones.

This is the main issue that we're aiming to address. A DLT-based system is not only able to deliver instant settlement solutions even better than today's gross settlement systems, but also that the direct interaction of securities and CBDC on a single ledger can provide greater efficiency in an environment where multilateral netting (and thus reduced liquidity requirements) is prioritized over RTGS.

We found that many respondents viewed the issues as highly interrelated. In general, any initiative aimed at improving information flow between participants and/or addressing the trade-off between liquidity requirements and settlement risk would be seen as beneficial for the whole process. As in a DLT setup, information flow is not dependent on any central operator distributing messages, and transactions can

be instantaneous and are not bound to any local time zone's operating hours or business days. There is therefore a huge potential in DLT settlement solutions in general to address the pain points raised by survey participants.

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