

Experimenting settlement of French government bonds in Central Bank Digital Currency with blockchain technology

Insight report

October 2021

1. EXECUTIVE SUMMARY	3
2. DESCRIPTION OF THE EXPERIMENT	10
1. Banque de France call for project	10
1. Banque de France experiment	10
2. Other experiments	11
2. Organization and methodology	12
3. Objectives	
4. Technological focus	15
5. Use case	16
3. EXPERIMENT RESULTS	17
1. Blockchain technology deployed	17
1. Permissioned approach	17
2. Privacy Management	18
3. Multi-cloud IT deployment	19
4. Network topology	19
2. Post-trade operations on Blockchain technology	20
1. Securities settlement of OAT against CBDC	20
2. Conclusions	26
3. Value of blockchain for post-trade execution	27
1. More direct participants – less reconciliations	27
2. Lower running costs	28
3. Resilience – data dissemination	29
4. Direct process on shared data	30
5. Shortened trade to settlement cycle	30
6. Conclusions	32
4. Looking forward	33
1. Token versus account-based model	33
2. Permissioned (private) versus public blockchain platform	33
3. Post-market restructuring	34
4. Co-existence with legacy systems	35
5. Regulatory frameworks	35
4. CONCLUSIONS	36
5. ACKNOWLEDGEMENTS	37

1. Executive summary

In March 2020 the French Central bank, Banque de France, launched a wholesale Central Bank Digital Currency (“CBDC”) experiment program to test the integration of CBDC in innovative procedures for the exchange and settlement of tokenised financial assets between financial intermediaries¹. A consortium of banks led by Euroclear was selected to assess the potential of post-trade capital market settlement operations in CBDC for French Sovereign Debt Securities (OAT²).

The Euroclear CBDC securities settlement experiment was set up together with the major participants in the OAT activity including Agence France Trésor (“AFT”), the public Debt Management Office of the French government, Euroclear France (“Euroclear”) and primary dealers and custodians of the French market, such as BNP Paribas, BNP

Paribas Securities Services, Crédit Agricole CIB, HSBC and Société Générale. In addition to organising the CBDC experiment program, Banque de France participated directly in the experiment by acting as the Central bank to manage the CBDC process and by making available a permissioned blockchain platform (hereafter “DL3S”³).

Euroclear selected IBM as technology partner based on their blockchain and post-trade know-how on the development of Hyperledger Fabric protocol and community.

¹ <https://www.banque-france.fr/sites/default/files/media/2020/03/27/200327-call-for-applications.pdf>

² Obligations Assimilables au Trésor

³ Distributed Ledger for Securities Settlement System

The objectives of the experiment were to...

- 1) check and assess that a large range of post-trade functionalities can be run on blockchain,
- 2) identify from a user point of view, the added value of blockchain technology and CBDC for the capital markets, and
- 3) assess the potential next steps.



Post-trade functionalities on blockchain

Over the last years, blockchain technology providers have worked to adapt DLT⁴ services with a framework of control, privacy and confidentiality and through this have defined the concept of permissioned blockchain. Hyperledger Fabric is an open source permissioned blockchain technology where all the members are identified and authorised to participate according to a well-defined governance, as opposed to a public blockchain where anyone can access the ledger.

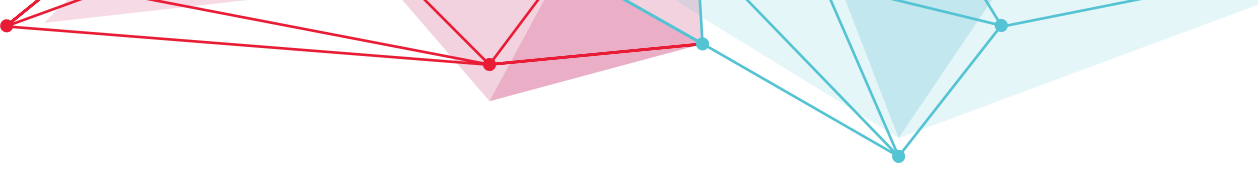
In the context of this CBDC experiment, the DL3S blockchain application of Banque de France was upgraded and deployed in a multi-cloud environment, where Euroclear, the AFT and the banks ran separate virtual nodes in a dedicated cloud, while Banque de France operated their nodes on their own private cloud infrastructure.

The post trade functionalities developed and rolled out during the 10 months experiment provided important insight into the viability of running core post-trade operations in a blockchain environment.

To simulate real OAT activity volumes, the consortium members generated hundreds of instructions over four days reflecting a wide range of primary market distribution and secondary market trades scenarios. These scenarios included Delivery versus Payment (“DvP”) instructions settling normally, DvP instructions failing to settle due to lack of CBDC or lack of securities, unmatched and recycled settlement instructions. On the technology side, DvP instructions were handled through swaps of CBDC tokens against OAT securities tokens.

The experiment started with the AFT issuing securities tokens and Banque de France issuing CBDC tokens in the blockchain environment. The ISIN was generated by smart contracts and disseminated in real time to all participants on the platform. After issuance, the CBDC tokens were transferred into the wallets of the consortium members and used to settle OAT transactions in the primary and secondary markets.

⁴ Distributed Ledger Technology



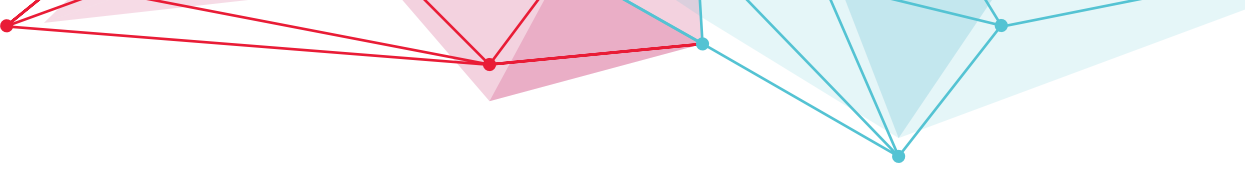
The experiment included several liquidity optimization mechanisms such as auto-collateralization and repo. Full life-cycles of repo instructions in CBDC were generated and repo instructions were tested in various situations including the recycling and settlement of failed instructions lacking CBDC or securities token positions.

A full repo life-cycle across multiple platforms was also covered by the experiment. Based on the test environment of Target2-Securities⁵ (T2S), and relying on dedicated smart contracts, a cross-platform repo life-cycle included a securities transfer to Banque de France in T2S and a subsequent CBDC injection in the blockchain platform by Banque de France to the CBDC wallet of the owner of securities transferred in T2S.

Intraday auto-collateralization operations are intensively used by CSD participants to get intraday liquidity to settle their transactions. Dedicated smart contracts were implemented to manage auto-collateralization on settlement flows when the blockchain system detected a lack of CBDC tokens and when the eligibility conditions of the traded securities were met.

The OATs selected for the experiment were securities with fixed rate coupons. Dedicated smart contracts were developed to test the handling of coupon payments based on the holdings of securities token. Payments were automatically prepared at defined record date and automatically settled in CBDC at defined Payment Date on the blockchain platform.

⁵ The Eurosystem single technical platform for the delivery-versus-payment settlement of securities in central bank money



Added value of blockchain for CBDC securities settlement

During the experiment, the role of ‘wallet manager’ was extended to allow custodians to open securities wallets for their own clients and manage their related keys. While the custodians keep full control of the relationship with their clients, the wallet of their clients is on the blockchain platform. This means that securities transactions between clients of a custodian can be directly managed on the blockchain platform like any securities transaction between two direct participants of the CSD and privacy is preserved.

Having client settlement flows taking place directly on the blockchain platform will allow custodians to reduce (or even remove) the reconciliation workload with their clients. This increased level of transparency could also facilitate the identification of end investors and ease the registry management for issuers. Furthermore, CBDC and security tokens can be easily transferred across different blockchain platforms because of their atomicity and simplicity, which makes them ideal for cross-border purposes (fungible across platforms and lower cross-border reconciliation processes).

Blockchain could therefore facilitate a reduction of the settlement cycle to T+1 or even T+0 leading to capital and margin cost reductions. With the current technology prevalent within CSDs, settlement life cycle could already be reduced down to T+0. Indeed, the T+2 settlement cycle is actually the result of the current market organization where intermediaries need time to reconcile their positions on trades and settlement chains.



Looking forward

Although initially developed on an account-based model⁶, the DL3S platform was changed to a token-based model as part of the experiment. For DVP settlement within the blockchain platform, a token based approach proved to be as efficient as an account based approach. Moreover, it was found that a CBDC token-based model could be more suitable to deal with cross-border movements with other blockchain or legacy platforms. Being agnostic of wallet data, the token carries less data and is easier to manage and transfer. This implies, however, some protocols agreements between the platforms.

At the current level of maturity of the blockchain technology, it does not seem possible for a public blockchain model to meet all the regulatory requirements to run post-trade activities. KYC checks on parties, privacy, confidentiality and scrutiny controls on transactions require a centralized approach on user access and management.

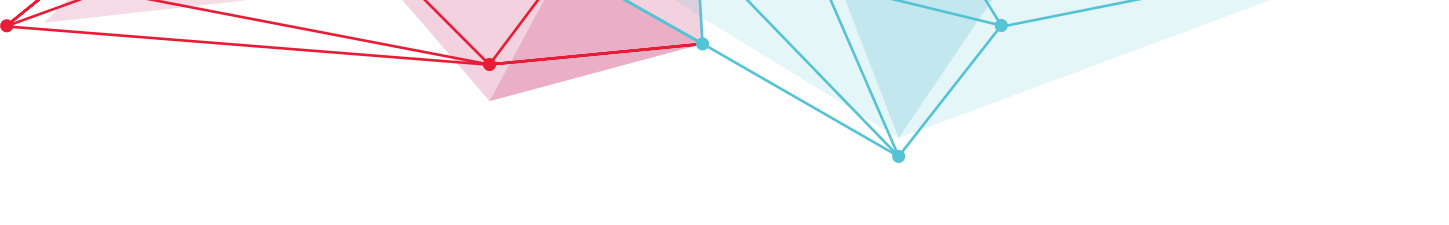
The permissioned DL3S blockchain platform proved to be more suitable to comply with

these requirements. Indeed a permissioned blockchain offers adequate control and monitoring tools on both the network and the entities on it, which is of particular importance for the heavily regulated capital markets. This should lead to a larger adoption of permissioned ledgers in the capital markets and further fuel the debate between blockchain experts on public versus permissioned blockchains.

The ability for issuers to directly create and distribute security tokens on the platform and for custodians to open and manage securities wallets for their clients are the most concrete cases of increased autonomy that we have observed during our experiment. This increased autonomy can enable capital market participants to redesign their current processes into leaner and more efficient ones.

Smart contracts can execute specific operations in a well-defined context based on controlled and immutable data. If the conditions are met, there is no need to ask for an additional validation by an operator and

⁶ An account-based system requires verifying the identity of the payer, while a token-based system requires verifying the validity of the object used to pay



processes can be executed automatically. However, to ensure full legal, contractual and regulatory compliance, the definition and the implementation of smart contracts must be fully controlled and managed by the appropriate organizations which have the rights, capabilities and duties to manage such activities. This means that smart contracts on CBDC and securities tokens must be managed and/or validated by trusted and regulated Financial Market Infrastructures such as CSDs, or by platforms operated by Central Banks, as was the case for this experiment.

The experiment also included an interoperability analysis with the T2 and T2S platforms. It was confirmed that a blockchain process can be synchronised with a T2S process via adequate ISO messages and proper workflows. It is clear that interoperability between emerging blockchain platforms and current legacy platforms will be a prerequisite to the success of any new blockchain solutions in the post-trade market.



Conclusions

The experiment confirmed that blockchain technology is suitable to manage post-trade market operations in CBDC, subject to the completion of additional testing with real-world volumes.. These additional tests would also provide the data required to make a quantification of the potential efficiency gains and cost savings that a blockchain-based infrastructure could offer for the securities business. The tested CBDC operating model demonstrated the security required to settle in central bank money. The experiment also showed us that blockchain platforms can coexist and interoperate with existing legacy settlement platforms.

Our experiment also highlighted that the full value of blockchain cannot be realized by simply replicating ‘as is’ the securities settlement operations processes. However, enabling direct access by end investors on the blockchain platform via their custodians and/or removing the current post trade processing breaks, would allow blockchain technology to significantly improve post-trade operations. This could then remove

reconciliation processes, reduce the overall cost and increase the efficiency of the capital markets.

There are still several challenges ahead before we can implement a blockchain platform in a true production environment, such as the maturity of the technology itself, the management of distributed ledger platforms and the interoperability with other platforms.

The on-going blockchain analysis conducted by IT providers and the market overall will certainly bring solutions to these challenges. We are proud of our contribution to the overall CBDC experiment and the long blockchain journey of the capital market.



2. Description of the Experiment

1

BANQUE DE FRANCE CALL FOR PROJECT

Banque de France experiments

In March 2020, the Banque de France launched a wholesale CBDC experiment program to “test the integration of a central bank digital currency (CBDC) in innovative procedures for the exchange and settlement of tokenised financial assets between financial intermediaries”.

A consortium of banks led by Euroclear was selected to assess the potential of post-trade OAT settlement operations in CBDC.



Other experiments (from bibliography)

Several experiments have already been done concerning DvP transactions on a DLT platform: Ubin III by the Monetary Authority of Singapore, Jasper III by the Bank of Canada, Helvetia by the Swiss National Bank, and more recently Trigger by the Bundesbank. The Jasper III project looked at the circulation of both securities and CBDC tokens on the same DLT platform. The tokens were not native but pledged from the Canadian Real-Time Gross Settlement system (RTGS) and the local CSD. The Singaporean project Ubin III tested three ledger-interconnecting solutions in order to execute DvP operations between technically different DLT platforms. The Helvetia project compared two ways of executing tokenized securities settlement: with CBDC tokens on the DLT and with an interconnection between the DLT platform and the national RTGS. The Trigger project tested a settlement interface for digital securities settlement with T2, the Eurosystem's wholesale payment system.

More generally, according to the results of the third survey on CBDC, published in Jan 2021 by the Bank for International Settlements (BIS), 86% of central banks are now exploring the benefits and challenges of CBDC.



2

ORGANIZATION AND METHODOLOGY

Our CBDC experiment included the leading participants of the French Sovereign Securities activity: Banque de France (the French Central Bank), Euroclear France (the French CSD), Agence France Trésor (AFT) the public Debt Management Office of French government, primary dealers (Spécialistes en Valeur du Trésor or SVTs) and custodians of the French market such as BNP Paribas, BNP Paribas Securities Services, Crédit Agricole CIB, HSBC and Société Générale. A working group was set up with all these institutions for the experiment which was led by Euroclear France.

Euroclear selected IBM as technology partner based on their blockchain and post-trade know-how on the development of Hyperledger Fabric protocol and community.

Euroclear France contributed through expertise in the processing, management and DvP settlement of securities transactions, which are key elements in the design of securities issuance and secondary market operations in a blockchain environment.

The AFT brought extensive experience in bond issuance and long-term relationship with investors. Its participation allowed for the sharing of valuable data regarding the 2017 bond issuance which was partly “replayed” during the experiment. The SVTs and the custodians brought their knowledge of the OAT primary and secondary markets. The Banque de France provided the capability of issuing CBDC and managing it throughout its entire lifecycle on the DL3S platform. IBM, technology partner of the working group led by Euroclear, brought its know-how of developing blockchain solutions for financial markets to enrich this platform with specific functionalities.

The experiment was designed based on business needs expressed by the working group. On this basis, user stories were drawn to describe functionalities necessary to perform the required business operations. The experiment was run over a period of 10 months.



3

OBJECTIVES

Several blockchain experiments have already been conducted in capital markets worldwide, albeit with different objectives, and some other experiments are currently ongoing. However, the number of blockchain experiments testing real-life settlement processes has, so far, been limited. We believe this experiment was a first of its kind in terms of breadth and depth.

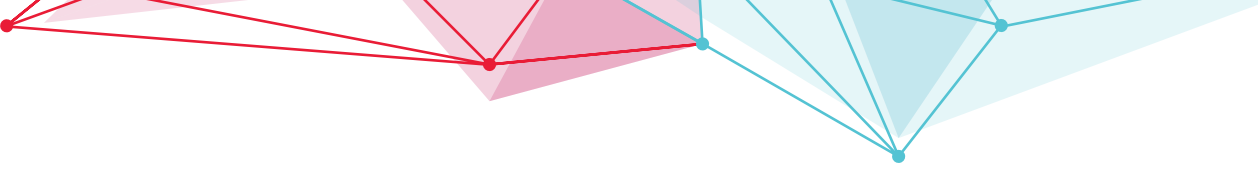
Blockchain technology is designed to transfer assets and to maintain an immutable register of these transfers and resulting holdings. At first sight, one may therefore believe this is suitable for the securities settlement business operated by CSDs. However, DLT is designed to transfer assets in a shared and distributed way and removes the need for any central trusted party supervising and controlling the operations. This conflicts with CSD responsibilities to ensure securities transfers and management are run in a controlled manner according to the rules set by regulators that also include privacy and confidentiality requirements.

Over the past few years, blockchain technology providers have worked to combine the best of both worlds i.e. distributed and shared data in a framework of control, privacy and confidentiality. One such combination has become known as ‘permissioned blockchain’. This technology already provides a notion of built-in confidentiality as participants are identifiable and authorised to access the ledger according to their permission.

Hyperledger Fabric enables secure interactions among a set of known, identified participants who have a common goal, but do not fully trust each other. By relying on the identities of peers, a permissioned blockchain like Hyperledger Fabric can use traditional Byzantine-fault tolerant⁷ (BFT) consensus as opposed to Proof-of-Work⁸ (PoW) consensus algorithms which are very energy intensive.

⁷ Byzantine Fault Tolerance are consensus algorithms that enables a decentralised network to function even in the presence of malfunctioning or malicious nodes.

⁸ Proof-of-work is the consensus algorithm used in permissionless network like bitcoin.



Use Cases make progresses to the state of the art of such technologies, adding the capability to leverage on advanced encryption and zero knowledge proof to bring privacy while preserving access control and auditability, which is more in line with the obligations of financial institutions and infrastructures.

Along with this trend, the objectives of the experiment were to:

- **Assess whether a comprehensive range of CSD functionalities can be run on blockchain,**
- **Identify the added value that such blockchain technology and the usage of CBDC could bring to the capital market,**
- **Identify and explain the challenges that remain to be tackled.**

By completing the above, we believe that we have made a significant contribution toward the wider research being conducted into the value of blockchain for the post trade industry.



4

TECHNOLOGICAL FOCUS

The solution used during the experiment demonstrated consistency in its privacy-preserving mechanisms. It was deployed and tested in a multi-cloud environment, with blockchain nodes distributed across several organizations in private and IBM public clouds.

The DL3S platform relies on permissioned blockchain technology, where all the members are identified and duly authorized.



5

USE CASE

One of the objectives of the experiment was to ensure an adequate representation of real-world securities settlement processes. We opted for a number of OATs (the French Sovereign debt) which is one of the most important and emblematic bond classes of the Paris financial market place.

We used real OAT ISINs issued in 2017 for the experiment which allowed us to be closer to real primary settlement flows and coupon payments. During the experiment the following securities settlement features were executed on the DL3S blockchain platform.

- Setup of securities and CBDC wallets
- CBDC issuance by Banque de France
- Securities issuance (OAT) by the AFT
- Primary distribution
- Secondary market operations
- Repurchase agreement (Repo)
- Auto-collateralization on flows (Auto-collat)
- Coupon payment
- Intraday CBDC liquidity management with collateral pledge in T2S test environment

The experiment led by Euroclear was conducted as a “Proof of Concept” in test environment only for which both the CBDC tokens and OAT securities were natively issued on Blockchain ledger.

The banks involved acted as OAT market players and custodians in the experiment and helped simulate the securities trades.

3. Experiment results

1

BLOCKCHAIN TECHNOLOGY DEPLOYED

1/ Permissioned approach

Permissionless blockchain is an environment where anyone can join a network, participate in consensus, and write new blocks or access data in the chain without any controls. Consensus mechanisms in permissionless blockchains such as Bitcoin also require substantial computational power for “mining”, a process which consumes huge amounts of energy.

Although permissionless blockchains are evolving in a number of ways (for example, the introduction of anonymity when required, white listing, performance optimization), we opted to use a permissioned blockchain for the purpose of the experiment, which offers a certain native level of privacy, confidentiality, KYC and transaction execution controls which are a requirement for our industry.



2/ Privacy Management

Hyperledger Fabric provides several mechanisms that ensure confidentiality regarding the content of each transaction and privacy in relation to the counterparties involved. Some of the key mechanisms we used – amongst others – were:

- Channels: a virtual blockchain network which sits on top of a physical blockchain network with its own access rules. Channels employ their own transaction ordering mechanism and thus provide scalability, ultimately allowing for effective ordering and the partition of huge amounts of data
- Private Data Collections: mechanisms allowing the restriction of the visibility of pieces of data, called collections, to properly authorised peers (defined in the collection's access policy), while at the same time maintaining traces of that data (seeded hashes) to the system's ledger.
- Identity Mixer: a Zero-Knowledge Proof based client authentication mechanism allowing for anonymous and non-linkable

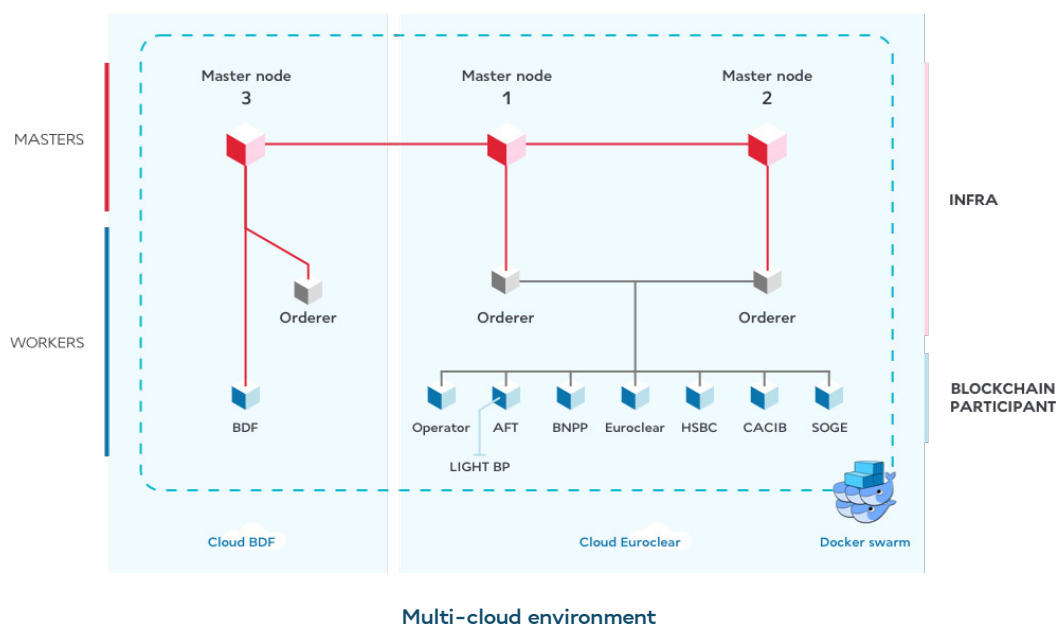
transaction creator authentication. More specifically, the transaction creator can prove to the network that they are a member of a particular organization without revealing their identity or being connected to other transactions that they have submitted to the system.

Based on the above mechanisms, the technical governance was implemented in such a way that roles and permissions could be configured according to the network topology, independently of whether a participant has direct or indirect access to a blockchain node. These roles are configurable on each member's nodes, according to their permissions.

3/ Multi-cloud IT deployment

In the context of the experiment, the technical stack was deployed in a multi-cloud environment, with Euroclear, the AFT and the participating banks running their nodes separately in a virtual IBM Cloud, while Banque de France operated its nodes on its own private cloud infrastructure, as shown below.

The solution relies on Docker containers, packaging up software code and all its dependencies so that it can run uniformly and consistently on any infrastructure. At the same time, containerization allows developers to create and deploy application faster and more securely, ensuring portability and agility.



4/ Network topology

The network topology for the experiment consisted of seven participating nodes (one per participant in the blockchain) and one additional node for a technical operator. The nodes were distributed in the multi-cloud environment across several virtual servers.

Each blockchain participant was essential for the decentralisation of trust on the blockchain platform, since each participant had its own copy of the ledger and was involved in the validation of transactions. The nodes of

Banque de France and Euroclear were involved in each DvP transaction on the platform to manage respectively the CBDC and securities token aspects of the transaction. The nodes from the other participants were used for the validation of their respective transactions (as seller or buyer of securities against cash). By leveraging the distribution of hashed and anonymized transaction proof, every single node held the evidence, in trusted format, of all transactions which had taken place on the platform.

2

POST-TRADE OPERATIONS ON BLOCKCHAIN TECHNOLOGY

Over the 10 months of the experiment, we obtained an insight on not only the capabilities but also the challenges of the development of core post-trade execution functions on blockchain.

In order to test these functionalities in an environment as concrete and real as possible, all participants of the experiment, according to their roles, participated actively in the test phase. Timing wise, it took four accounting days to run all the scenarios of the test playbook.

1/ Securities settlement of OAT against CBDC

The core functions of CSDs are securities settlement and registry management. Beyond those core functions, CSDs also provide a wide set of other functionalities such as securities financing, income payment and, corporate actions processing as well as compliance checks.

As the experiment was run on a permissioned blockchain, each participant received defined roles granting them specific rights and obligations required to run the OAT business in a CBDC environment.

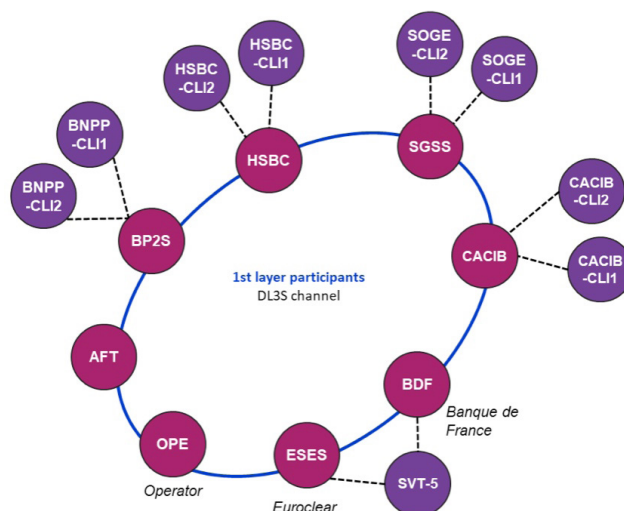
The predefined roles were the following:

Banque de France: CBDC wallet manager, CBDC issuer, Intraday Credit Provider and CBDC supervisor

Euroclear: Securities Wallet provider for the direct participants (SVT and custodians) and Securities supervisor

AFT: issuer of the OATs

BNP Paribas CIB, Crédit Agricole CIB, HSBC and Société Générale: primary dealers for the OATs and Securities wallet managers for their customers.





The first objective of the experiment was to demonstrate that the permissioned blockchain environment could support a large range of post-trade functionalities in a stable and flexible way.

Setup of Wallets

Banque de France and Euroclear were the wallet managers for CBDC and securities respectively, opening wallets for their participants and monitoring the good execution of settlement activity on the blockchain. On the securities side, Euroclear partially outsourced the wallet management function to the custodians which were able to handle them for their direct clients.

CBDC Issuance

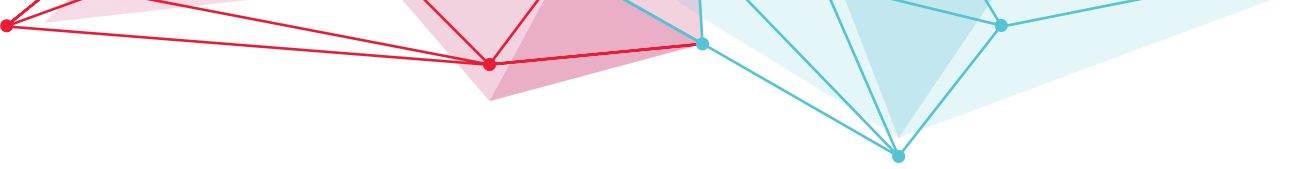
The CBDCs were issued in token-form directly on the DL3S platform. The issuance of CBDC was the responsibility of the Banque de France which was the sole actor able to create and destroy CBDC tokens under the DL3S protocol. After issuance, CBDC tokens were transferred to the participating banks' wallets and could subsequently be used to settle OAT transactions in the primary and secondary markets. CBDC tokens could only circulate on the DL3S platform. Each CBDC

token had a unique identification number in DL3S to guarantee its integrity.

Primary market operations (issuance and distribution)

Based on the auction mechanism, three OAT securities were issued on the platform with characteristics similar to those issued in 2017. The distribution was executed for the same initial nominal amounts. The auction was done outside of the blockchain environment and its results were injected in the platform by file transfer.

The AFT issued and distributed the OAT directly to the SVTs without transiting via the account of Banque de France as per current market practice. The ISIN was disseminated in real-time to all participants on the platform. The generation of a report to disseminate the ISIN outside of the blockchain was analysed, allowing an off-chain circulation of ISIN data in parallel to the circulation within DL3S.



The AFT, as issuer, was able to see the OAT token positions and holdings through a dedicated report without being able to view the wallet of the OAT holders. The payments were directly routed to the wallet of the token owners by smart contracts.

Although OAT securities were created without recording in T2S, every created ISIN was registered in a common index on DL3S which enabled a potential switch to the off-chain environment. In addition to the ISIN number, security tokens have a unique identification number in DL3S, like the CBDC tokens.

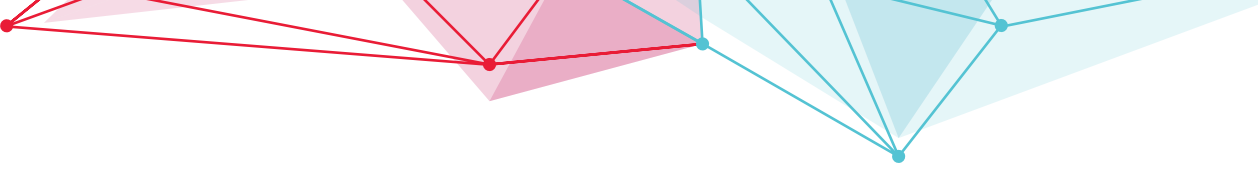
Secondary market

To simulate realistic OAT activity, a few hundred instructions were generated by the banks to cover scenarios ranging from primary market distribution to secondary market trades between themselves and with their clients.

Scenarios also covered all types of DvP instructions, such as successfully settled, unmatched, failed and recycled settlement DvP instructions.

These scenarios were run over an accounting period of four days and provided us with a good understanding on the behaviour of transaction chain processes in the blockchain environment. Overall, the behaviour and patterns were relatively similar to those in the standard central database process.

On the technology side, DvP instructions were settled via atomic swaps of CBDC tokens against OAT securities tokens. The DL3S platform assessed the token positions before processing transactions. In its consideration of the available CBDC and securities tokens for settlement purpose, the DL3S platform looked at the total combined value of the tokens across the participant's wallet and reshaped them through deletion and creation of tokens (for the same total wallet amount).



Trades done outside of the blockchain platform through standard channels like multi-lateral trading facilities (“MTFs”) and phone were directly injected into the blockchain platform by the middle offices. Prior to settlement, the back offices enriched the trade and confirmed them, generating instructions in a ready-to-settle status. Reference data in the standing settlement instructions (“SSI”) was made available to the participant on the blockchain platform. Once ready the settlement instructions were automatically positioned by the platform.

To shorten the current process and to optimise the flows, trades and settlement cycles were brought together into logical groups.

Repo instructions

Several liquidity optimization mechanisms like auto-collateralization and repo operations can increase settlement efficiency by facilitating settlement when insufficient resources are available in the participants’ wallets.

The full life cycle of repo instructions in CBDC was generated. Once matched, repo instructions were converted into settlement instructions for both the near and the far leg. When the settlement conditions were met, the instructions settled automatically. Several scenarios of repo instructions were tested including the recycling and settlement of failed instructions which lacked either CBDC or securities token positions.

Intraday CBDC liquidity management with collateral pledge in T2S

We also experimented repo instructions across platforms. Based on the test environment of T2S, a cross-platform repo life cycle was managed via dedicated smart contracts. The particular test case was one where securities were transferred to a central bank securities account in T2S, followed by an injection of CBDC by Banque de France to the



CBDC wallet of the securities deliverer in the blockchain platform. With this test case, we explored a way to improve and facilitate the management of CBDC (and purchasing power) across platforms.

Auto-collateralization

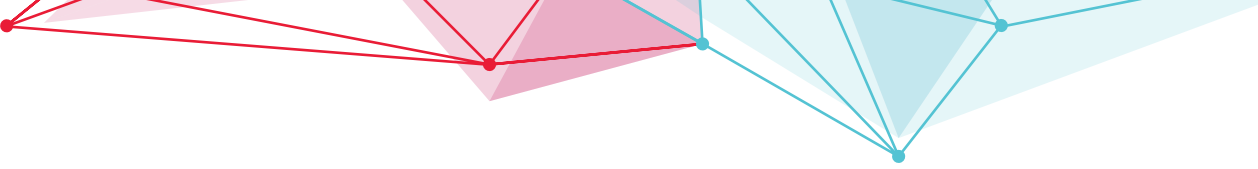
Intraday auto-collateralization operations were a key element of our experiment as they are intensively used by CSD participants to get intraday liquidity to settle their OAT activity. Dedicated smart contracts were implemented to trigger and manage auto-collateralization operations on the settlement instructions when the blockchain system detected a lack of CBDC tokens and when the eligibility conditions of the traded securities were met.

The settlement of the main DvP transaction and of the auto-collateralization operations occurred on an “all-or-nothing” basis, i.e. either they all settled or none did. The validation was done by the nodes belong-

ing to the parties involved in the transactions (the participants of the deal, Banque de France and Euroclear).

In this scenario, Banque de France acted as credit provider by issuing the required number of CBDC tokens to cover the lack of CBDC faced by the buyer and by receiving in return the corresponding securities as collateral. The securities posted as collateral were taken from the initial DvP transaction and the number of CBDC tokens to be issued was calculated by looking at the value of the securities and the haircut applied by Banque de France on these securities.

Furthermore, only the buyer and Banque de France were aware that an intraday auto-collateralization operation has been executed to allow the settlement of the main DvP transaction. The seller was only aware of the successful settlement of the main DvP transaction and had no visibility at all on any auto-collateralization operation between the buyer and Banque de France.



Finally, for both the buyer and Banque de France, an entry was created in the Collateral list to record the details of auto-collateralization operation.

The reimbursement of the CBDC by the buyer and the corresponding return of the securities posted as collateral could be triggered either manually by the buyer or automatically at the end of the day.

Coupon payment

We selected for this experiment several OAT securities with fixed rate coupons. Dedicated smart contracts were developed to test the handling of coupon payment based on the holdings of securities tokens. Payments were subsequently prepared and executed automatically in CBDC on the blockchain platform.

The AFT created the coupon payment event details directly on the platform to share them with all the participants.

The payment of the coupon went from the AFT CBDC wallet straight to the CBDC wallets of the OAT holders, without transiting via the CBDC wallet of the CSD or other intermediaries. Under current market practices, the coupon payment would first transit via the issuer paying agent's cash account in the CSD.

Multiple types of tokens on the same blockchain

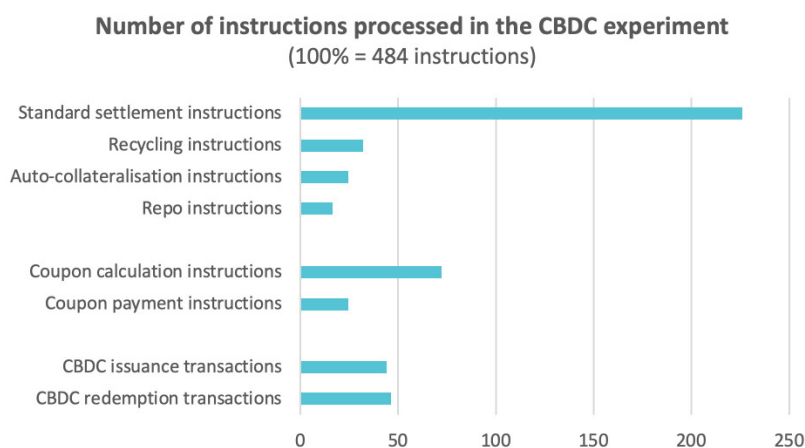
As both types of tokens, securities and CBDC, were present on the same ledger, the blockchain platform needed to be able to distinguish them. To this end, the DL3S platform supported two types of wallets: a CBDC wallet and a securities wallet.

Even though both types of tokens were on the same platform, the issuance and management of each type could be handled by different parties. In our experiment, Banque de France managed the CBDC tokens while Euroclear manages the securities tokens.

In more concrete terms, Banque de France's node was the sole node able to issue CBDC tokens and Euroclear's node was the sole node able to issue securities tokens by certifying with the ISIN code. Both had a total overview on members' wallets in their respective tokens.

Extensive test playbook

We ran an extensive playbook of test cases (almost 500 instructions) to assess the aforementioned use cases under realistic business conditions. Our experiment however did not focus on the technical scalability capabilities of a blockchain infrastructure.



2/ Conclusions

The first objective of our experiment was to assess the management of post-trade operations and functionalities on the blockchain. Based on the outcome of our experiments, we concluded that CSD functionalities can be operated on a permissioned blockchain environment while fully respecting the regulatory rules of control, confidentiality and privacy.

Before considering the use of a blockchain platform in production, we still need to execute real-life volume and performance tests. This requires further research and experimentation to allow us to quantify the efficiency gains and cost savings that a blockchain-based infrastructure could offer for the securities business.



3

VALUE OF BLOCKCHAIN FOR POST-TRADE EXECUTION

1/ More direct participants – less reconciliations

As part of the experiment, we expanded the role of the securities wallet manager by enabling the custodians to open securities wallets for their own clients. This allowed the custodians to maintain the relationship with their clients as they were the ones who decided how and when to open wallets for their clients – while abiding with the applicable KYC and regulatory rules set by the CSD. The presence of client securities wallets on the blockchain meant that securities tokens could be managed and transferred directly on the blockchain like any other securities transaction between two direct CSD participants. The resulting direct settlement flows reduced the need for reconciliation between a direct CSD participant/custodian and its clients, generating immediate benefits for custodians.

Issuers too can benefit from such a setup. Client securities wallets on the blockchain will immediately give a higher level of beneficial owner transparency towards issuers as smart contracts can be built to provide them with transparency reports. This will also facilitate the register operations for both bearer and

registered securities. Issuers, or their agents, could therefore rely on the blockchain to run the securities register and decommission their registry platforms.

Operationally speaking, exposing the interaction capabilities via API would enable technical integration with existing customers and custodian systems and potentially allow us to automate the chain, removing the need for human intervention.



2/ Lower running costs and operational risks

Through smart automation of the workflows and greater direct participation, blockchain can offer efficiency gains and cost reduction. The automation of workflows during the experiment allowed us to streamline the trade-to-settlement process, create both legs of the repo transaction, generate beneficial owner transparency reports and facilitate direct participation of custodian clients on the blockchain platform will substantially reduce the number of tasks and reconciliation efforts in the middle and back-offices of the CSD participant.

Moreover, the dissemination of reference data like the ISIN, corporate action information and SSIs will make it very easy for any user (issuers, custodians and clients) to get the right data at the right moment, reducing the number of messages required between participants in the ecosystem. Smart contracts can be built to ensure that such data can be processed automatically without the specific intervention of the blockchain platform participants.

A token based approach removes the need to use transfer accounts to handle movements across settlement platforms, facilitating CBDC and securities transfers. As tokens are more fungible across platforms, significant reductions in cross-border reconciliation processes can be obtained. However, as interactions between different blockchain platform protocols will be inevitable, a certain level of standardisation will likely be necessary.

These features will reduce effort required by participants to manage their wallets, their positions and their transactions, and as a result reduce their operational costs and risks.

Together with more direct access by a broader range of participants (including custodian clients) costs will come down for the market as whole.



3/ Resilience – data dissemination

To avoid the single point of failure of centralised cash and securities systems, regulators and market participants have explored several ways to increase their resilience and business continuity. Almost all the solutions so far have required the duplication of data centres at the level of the CSD for securities and the Central Bank for the cash, and at several points of the chain of intermediaries.

All the transactions which took place on the DL3S blockchain platform are recorded on the ledger of several nodes. These ledgers are auditable and no participant can alter the content on a node's ledger without alerting all the other nodes. The traceability of tokenized securities throughout their lifecycle can be guaranteed from issuance until redemption. As all securities transactions are recorded there as well, securities ownership can be determined and guaranteed at any point in time. This decentralized and synchronized setup can address the data integrity requirements under CSD regulations.

In this shared data environment, data is automatically replicated and disseminated across the nodes of the participants on the blockchain platform. In case of a problem at the level of one participant, the activity can continue on the other nodes. When the problematic node is up and running again, it will be automatically synchronised with all the other nodes.

The blockchain data dissemination model therefore offers a high level of resilience without the need to replicate data centres. Nonetheless, for control, confidentiality and privacy reasons, the number of nodes validating transactions in permissioned ledgers is reduced to the nodes of the seller, buyer and CSD for securities movements and to the node of the Central Bank for CBDC movements. This reintroduces a level of systemic risk again during validation and processing, especially on the CSD and Central Bank nodes. In a 'production' configuration, particular attention must be therefore paid to the configuration and the redundancy of these nodes or alternative solutions must be considered to ensure the business continuity of those nodes.



4/ Direct process on shared data

The availability of immutable data at the level of individual nodes enables participants to directly access and leverage that data for their own consumption and processes. Each individual node is part of the internal system of the participant, directly hosted in their cloud or premises.

This setup can also help reduce the costs related to transversal services and reports, such as regulatory or standardised reports. Such report templates can be developed in full mutualisation and then run and populated independently on the node of the participants according to their own requirements.

5/ Shortened trade to settlement cycle

The current market practice is to settle securities transactions two days after the trade takes place. The time between the negotiation of a trade and its settlement is needed to allow capital market participants to reconcile their positions with intermediaries across the globe and to adjust their cash treasury positions. This time gap generates substantial costs as well as credit and market risks, which are materialised in margins calls from Central Counterparties and capital costs on balance sheets.

In 2014, the EU market moved from T+3 to T+2 and the US market is contemplating a move towards T+1. Some well-structured markets have already moved to T+1, like for

example the UK Gilts market. While the cost savings on capital and margin costs are clear, they must be balanced against costs of cash and securities reconciliation and operational process in the current production environment.

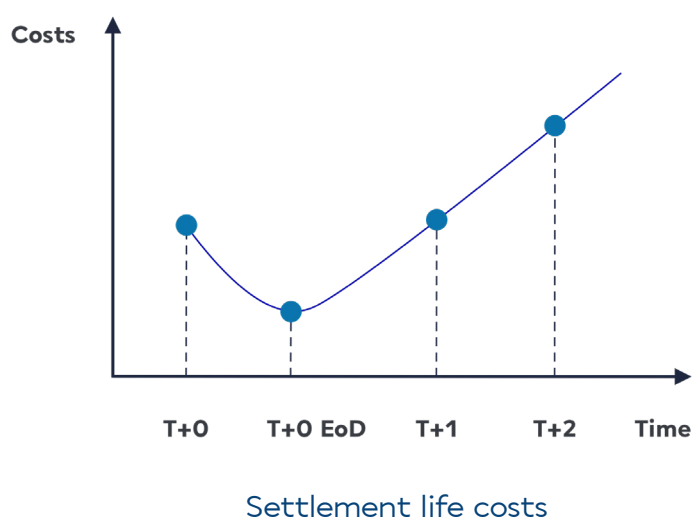
Current settlement technology used by CSDs can support a reduction of the trade to settlement cycle, even down to T+0. The current T+2 practice is not a technology issue at the level of CSDs or CCPs, but rather the result of the current market organization driven by intermediaries that have to reconcile the positions on the trades and settlement chains held on different systems.

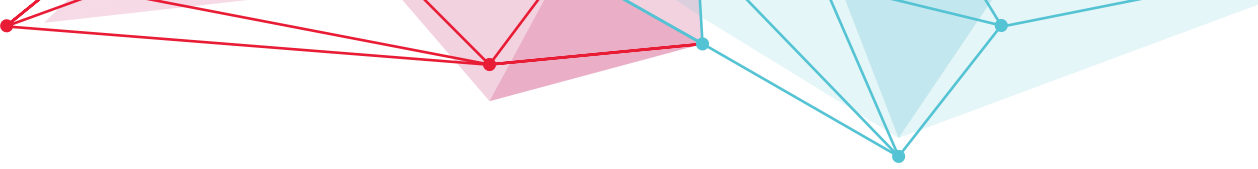
By simplifying the intermediation process and removing the need for reconciliation between systems, blockchain technology could help to reduce the trade to settlement cycle to T+1 or even T+0. A move to T+0 would mean that

cash needs to be available at the time of the trade. While this is often not an issue for the retail market, such immediate availability of cash will result in more pre-funding by the wholesale market and more intensive use of collateral to obtain funding.

Settlement life cycle

If the financial costs are the main driver to reduce the settlement life-cycle, the best time for settlement life-cycle would be T+0 end of day ("T+0 EoD"). Market participants would still be able to benefit from intra-day clearing and netting without having to bear the additional capital and margin costs for any extra day delay.





Settling securities on a blockchain platform offers the capability to attract more direct participants on the platform including the clients of the custodians which would improve their settlement efficiency and reduce their reconciliation effort.

For historical but also political reasons, there is at least one domestic CSD per market. This fragmentation of settlement activity led to the creation of cross-border links to support cross-border settlement activity.

Blockchain technology can help here as well, as the use of tokens facilitates transfers across platforms. By limiting the data carried by a token to the asset itself, transfers across various platforms becomes much easier.

By reducing/removing reconciliation processes and by facilitating cross-border transfers, blockchain technology can help the market reduce the current settlement life-cycle and its related costs.

6/ Conclusions

By reducing the entry costs for users through smart workflow automation and easier access (e.g. API, internet), blockchain platforms should attract more direct participation and connection from the market.

The opportunity for a reduction in operating costs combined with more direct participation will enable more direct settlement flows and reduce reconciliation efforts for all market participants.

The availability of immutable data at the level of individual nodes will enable participants to directly gain access to and leverage that data for their own consumption and processes.

Leveraging this accrued efficiency, blockchain could facilitate a reduction of the settlement cycle to T+1 or even T+0 end of day, which would lead to capital and margin costs reductions.

The use of blockchain for the execution of post trade operations of the wholesale business could offer substantial gains and costs savings for the capital market.



4

LOOKING FORWARD

1/ Token versus account-based model

The DL3S platform was initially developed on an account-based model, but switched to a token-based model for our experiment.

For DVP settlement within the blockchain platform, a token based approach proved to be as efficient as an account based approach. Moreover a CBDC token-based model could be more suitable to deal with cross-border movements with other blockchain or legacy platforms. Being agnostic of wallet data, the token carries less data and is easier to

manage and transfer. However this requires some protocols agreement between the platforms.

Generically speaking a token-based approach seems to be more suitable for any type of cross-platform activity.

2/ Permissioned (private) versus public blockchain platform

As our experiment concerns exclusively settlement of security token with CBDC, we believe that permissioned blockchain makes it easier to implement controls and does not call into question the trust which participants give to the platform, since each of them is identified. This is of particular importance for the capital markets which are heavily regulated.

At this stage of the analysis, it does not seem possible yet to combine the current regulatory requirements around securities settlements and payments with the concept

of a public blockchain. KYC checks on parties and scrutiny controls on transactions flows at all-time require a continuous and overall view on user accesses and activity management which does not seem possible at this time with current public blockchain design and model.

This should lead to a greater adoption of permissioned ledgers by the capital market at least in the short term and fuel the public-versus-permissioned debate between blockchain experts.



3/ Post-market restructuring

Leveraging the distributed features of blockchain while fulfilling the obligation of Banque de France and Euroclear to control respectively the cash and securities transactions, we looked at ways to provide more autonomy to the direct participants on the blockchain platform.

The ability for issuers to directly create and distribute securities tokens on the platform and for custodians to open and manage securities wallets for their clients were the most concrete cases of increased autonomy that we observed during our experiment.

The ability to provide more autonomy to capital market participants while keeping the control imposed by the regulators is made possible on a blockchain platform through the use of smart contracts.

Smart contracts can execute specific operations in a well-defined context based on controlled and immutable data. An issuer could for instance request the creation of a security based on the specific conditions set

in a smart contract. If the conditions were met, there would be no need to ask for an additional validation by an operator and the process could be executed automatically.

However, to ensure that all business and regulatory rules were respected, the definition and the implementation of smart contracts would need to be fully controlled and handled by organizations which had the rights and the obligations to supervise this activity. This means that smart contracts on CBDC and securities must be handled and/or validated by trusted and regulated FMIs like CSDs or platforms operated by Central Banks.

A blockchain platform of CBDC securities settlement would facilitate direct management of portfolio and transactions by all parties leading to an overall increase to the autonomy of market participants.



4/ Co-existence with legacy systems

The design of the experiment included the issuance of CBDC tokens based on the blocking of cash on a Banque de France escrow account in T2 and the simulated pledging of securities in T2S.

The workflows in the blockchain platform included the implementation of smart contracts which issue CBDC tokens conditional to the pledge of securities in T2S.

5/ Regulatory frameworks

As demonstrated during the experiment, blockchain technology allows for an easy distribution of various roles amongst the participants on the permissioned blockchain.

The responsibility dimensions have not been fully analysed during the experiment. Today, Banque de France and Euroclear are responsible for the good execution of the central bank money activity and of the securities activity respectively. We should however analyse more in depth which entity on the blockchain platform would be held legally and financially liable in case something goes wrong with the network while for instance a DvP transaction,

a corporate action or a CBDC transfer is taking place.

A deeper analysis is required to determine how the underlying responsibilities would be re-distributed (or not) amongst the participants and to which extent such a re-distribution is compatible (or not) with the current regulatory frameworks. This being said, based on our experiment, it seems that custodians could play an active role and take the corresponding responsibilities to manage their client activity (e.g. KYC, management of wallets and management of keys).

4. Conclusions

The Euroclear CBDC securities settlement experiment was a success. It offered the consortium valuable insight into how post-trade operations could take place using CBDC as well as a greater understanding of the potential value that blockchain technology and CBDC would bring to these operations..

Our CBDC experiment indicated that Blockchain can be a suitable technology for the management of post trade market operations. It showed that CBDC can be effectively used to support the settlement of securities in central bank money and that it is possible to run post trade operations for an activity as critical for the capital markets as the management of OATs. A permissioned blockchain approach would allow participants to benefit from blockchain features while ensuring market operators (CSD and Central Banks) can continue to run the required controls.

Our experiment indicated that the value of blockchain technology does not lie in replicating ‘as is’ the management of

securities settlement operations. Rather it lies in the opportunity for the market to change the way it organised so as to reduce trade to settlement cycles, increased direct market participation and reduce reconciliation efforts. The experiment also showed the capacity of blockchain platforms to coexist and interoperate with existing settlement infrastructures.

By attracting more direct market participants on a common ledger for post trade operations, blockchain could also reduce the overall cost and increase the efficiency of the capital markets.

We are well aware that there are still challenges that need to be overcome before we can envisage the implementation of blockchain platforms in a ‘production’ environment. But, the trend is positive and analysis continues across the market to come up with solutions. We are proud that our CBDC experiment has contributed to the journey that will eventually bring blockchain to the capital markets.

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