Empirical Research on Securities Finance Transactions using Distributed Ledger Technology

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1. Background and Purpose of this Empirical Research

(1) Distributed Ledger Technology and Security Tokens

Research is taking place on distributed ledger technology (below, "DLT") in a broad range of industrial fields and a number of trials are underway with regard to its application in the securities field. In particular, these studies and trials focus on the potential for building robust ledgers (here, this indicates ledgers established on blockchain) in terms of robustness and operational continuity, as DLT operates the system across a distributed number of locations compared to operating the system with the central control mechanism located in one specific facility. In addition, other benefits in the spotlight are risk reduction by means of delivery versus payment (DVP) settlements and streamlining of operations by connecting smart contracts that automatically process this work.

The use of security tokens for utilization of DLT in securities industry is on the rise. A security token is generally understood as securities in the form of a token issued and administered electronically using DLT.

Security tokens make it possible for more advanced processing of information that is ultimately managed on ledgers using smart contracts as mentioned above. For example, when exchanging securities and funds or securities and securities, which will be discussed below, by tokenizing each and processing transaction conditions, such as period and rate, along with settlement information, such as settlement time at the start and end of transactions using smart contracts, it is possible to streamline and automate the operation required until the final ledger entry and transfer of rights, and reduce operational risk, while tokens can be exchanged at the same time to reduce settlement risk. In addition, tokens are believed to reduce operational costs related to securities redemption and dividend payments and offer potential for use in smaller trade sizes and securitization, for example. From these perspectives, trials are already underway for the issuance of security tokens in such fields as securitization products related to corporate bonds and real estate.

(2) Trends of Security Tokens and Issuance

The evaluation and issuance of security tokens is taking place actively both in Japan and abroad.

First, with regard to the issuance market, following revisions to Japan's Financial Instruments and Exchange Act implemented in May 2020, the new Act contains the concept of “Electronically Recorded Transferable Rights to Be Indicated on Securities, etc.” for security tokens, and following this impetus of legislation development, initiatives are now underway to issue actual security tokens. Specifically, with regard to Japanese government bonds (JGB) and listed stocks, since there is already efficient and robust settlement infrastructure in place, security tokens issuance is taking place centered on securities with low liquidity compared to JGBs, such as corporate bonds and securitized real estate products, among others.

Outside of Japan, research on issuance of tokenized securities is actively underway centered around the main actors of international institutions, central banks, securities exchanges, and major financial institutions.

Additionally, discussions are being held on the formation of a secondary market as a venue to facilitate trading of security tokens.

In Japan, there is a movement for conceptualizing a digital securities market and a secondary market for security tokens focused on those related to securities exchanges. Outside of Japan, securities exchanges continue exploring ways to commercialize secondary markets utilizing security tokens.

In addition, as an infrastructure for the issuance and distribution of security tokens, a DVP settlement mechanism using DLT is being studied in various countries through collaboration involving various institutions, mainly central banks. Recently, discussions have also been taking place in relation to central bank digital currencies.

(3) Purpose and Target of this Empirical Research

As described above, research on security tokens is actively underway in Japan as well, but in this empirical research, we have decided to conduct testing focused on repo transactions and securities lending and borrowing transactions (below, collectively referred to as “Securities Finance Transactions” or “SFTs”), which play a key role in providing liquidity to the market in the distribution of securities, for the following reasons.

i. Through SFTs using bonds and stocks, market participants flexibly manage their holdings and raise funds, and the securities and funds procured are used for settlement of trading in the secondary market, collateral offered to clearing institutions, etc., and daily cash flow. SFTs provide liquidity in the secondary market for securities and have become essential to the market.

ii. Looking at the actual scale of SFTs in Japan, there are about 56 trillion yen[1] worth of transactions per day, and the balance of the amount outstanding is about 295 trillion yen for bonds and about 18 trillion yen[2] for stocks, making it a large market.
iii. At present, there has been little research using DLT in Japan focusing on SFTs.

In the field of SFTs, this empirical research, for example, explored the potential benefits of utilizing DLT: (1) the transfer of securities and collateral denominated in foreign currencies, which usually involves time differences, can be executed simultaneously between parties, although not final, (2) advantages such as expanded system availability and efficiency of operational processing can be enjoyed, and (3) against the backdrop of these advantages, it is possible to use various assets, including assets with low liquidity, as collateral.

Since the subject of this empirical research is a cutting-edge field, we decided to take the following approach from the viewpoint of effective project management:

i. This empirical research focused on bilateral relationships between transaction parties, and did not aim to build exchanges or payment and settlement systems used by large numbers of participants. Therefore, it did not consider replacing the existing infrastructure for trading, clearing and settling government bonds, stocks and other securities with a new system using DLT.
ii. This empirical research focused exclusively on practical feasibility, excluding review of the related laws and regulations, specifically tokenization methods, legal structures and methods of transfer of rights, and the necessity of business licenses and registrations.[3]

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[1] Bank of Japan, *Statistics on Securities Financing Transactions in Japan,* average for December 2022

[2] Japan Securities Dealers Association, *Balance of Bond Transactions with Repurchase Agreements (by investor type), Bond Margin Loans* and *Borrowing and Lending Transactions for Share Certificates*, *etc.,* December 31, 2022

[3] The execution of a STF involves both parties concluding a basic agreement and an attached memorandum, etc. In Japan, the reference format of a basic agreement prepared by the Japan Security Dealers Association is widely used. In cross-border transactions, the international standard format of a Global Master Repurchase Agreement (GMRA) and Global Master Securities Lending Agreement (GMSLA) are used. In this basic agreement and attached memorandum, the fundamental matters and shared matters related to the

iii. When using tokens for SFTs, it is first necessary to issue tokens, and various schemes have been proposed and researched including their legal structure. Therefore, this empirical research excluded review of token issuance schemes and instead focused on transactions using tokens already issued.[4]

iv. In this empirical research, “settlement of SFTs using tokens” refers to the exchange of tokens, and does not refer to the transfer of underlying assets such as funds and securities. In order for the underlying assets to be transferred, final settlement must be made in the securities settlement system of the central securities depository and the funds settlement system of the central bank, but the time lag and settlement risk cannot be eliminated due to the time difference in these settlement locations. Here, it is assumed that the transaction party is limited to "face-to-face" participants already known each other in advance and the settlement has been completed by exchanging tokens between the parties, on the premise that underlying assets are managed robustly by the token administrator under trust, etc. contract. Then, exchanging tokens is treated as “settlement of SFTs.”

Based on this awareness, Japan Securities Finance Co., Ltd. (hereinafter, "JSF ") and Tanaka Laboratory of the Graduate School of Engineering, The University of Tokyo (hereinafter, "Tanaka Laboratory") agreed in April 2021 to conduct empirical research on whether the use of DLT can facilitate trading of tokenized securities and collateral in SFTs. The two parties have been conducting joint research since then. Specifically, JSF was mainly in charge of formulating experimental concepts and structures, investigating related market practices, and compiling this report, and Tanaka Laboratory was responsible for examining basic technical and system aspects related to data analysis and DLT. In addition, the development of DLT and smart contracts was outsourced to USD Co., Ltd. (hereinafter, "USD")[5]

STF are set out, such as ways of calculating market value or lending fee and handling in case of a collateral shortfall, etc.
This empirical research excludes any evaluation of key points regarding these contractual matters from the scope of consideration.

4 There are several options for tokenizing currencies or securities, such as using a trust with certificates of beneficial interest, for example, but the tokenization method, the method of transferring and managing underlying assets, and the necessity of business licensing and registration are also excluded from consideration. In addition, in this empirical research, currencies or securities that are the underlying assets are not placed in trusts.

5 See the Attachment for the members of each organization who participated in this empirical research.

2. About Securities Finance Transactions

This chapter provides an overview of the SFTs subject to this empirical research. While SFTs involve an extremely wide range of economic, legal and practical issues, this chapter covers only those subject to this empirical research.

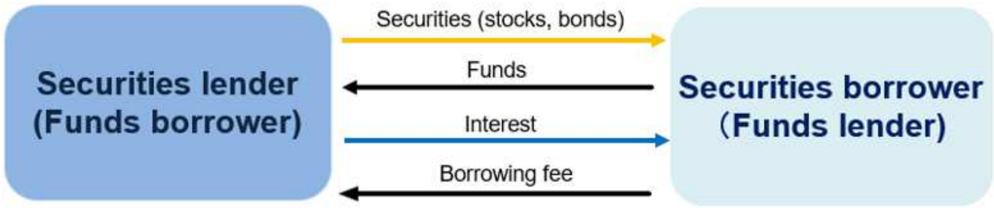
(1) Outline of Securities Finance Transactions

SFTs generally involve the exchange of funds and securities with another party, which are then returned after a predetermined period (Figure 2-1), but in recent years, this has evolved into the exchange of securities and securities (Figure 2-2), which is also actively taking place. Therefore, for the purposes of this research SFTs shall include both.

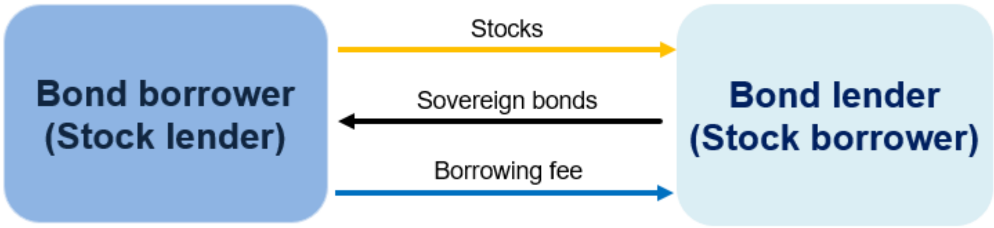
SFTs have both the qualities of lending funds and lending securities, and they can be leveraged for investing or procuring funds or they could focus on investing or procuring securities. In recent years, countries around the world have tightened financial regulations and strengthened management of settlement risks, while also pursuing monetary easing for many years, and as part of this, asset purchases driven by monetary policy have become the norm worldwide, causing elevated rarity of securities with high credit ratings such as government bonds, etc., which has given rise to transactions focused on the investment and procurement needs of securities. Against this backdrop, transactions involving the exchange of securities and securities are being conducted with the purpose of exchanging, for example, stocks with government bonds for fundraising or posting of collateral to a Central Counter Party (so-called upgraded repo transactions).

When executing transactions using securities as collateral for the investment or procurement of funds, transactions involving the lending and borrowing of funds are referred to as general collateral (GC) transactions. On the other hand, when executing transactions using funds as collateral for the investment or procurement focused on specific securities, these transactions involving the lending and borrowing of securities are referred to as special collateral (SC) transactions.

(Figure 2-1) Exchange of Securities and Funds



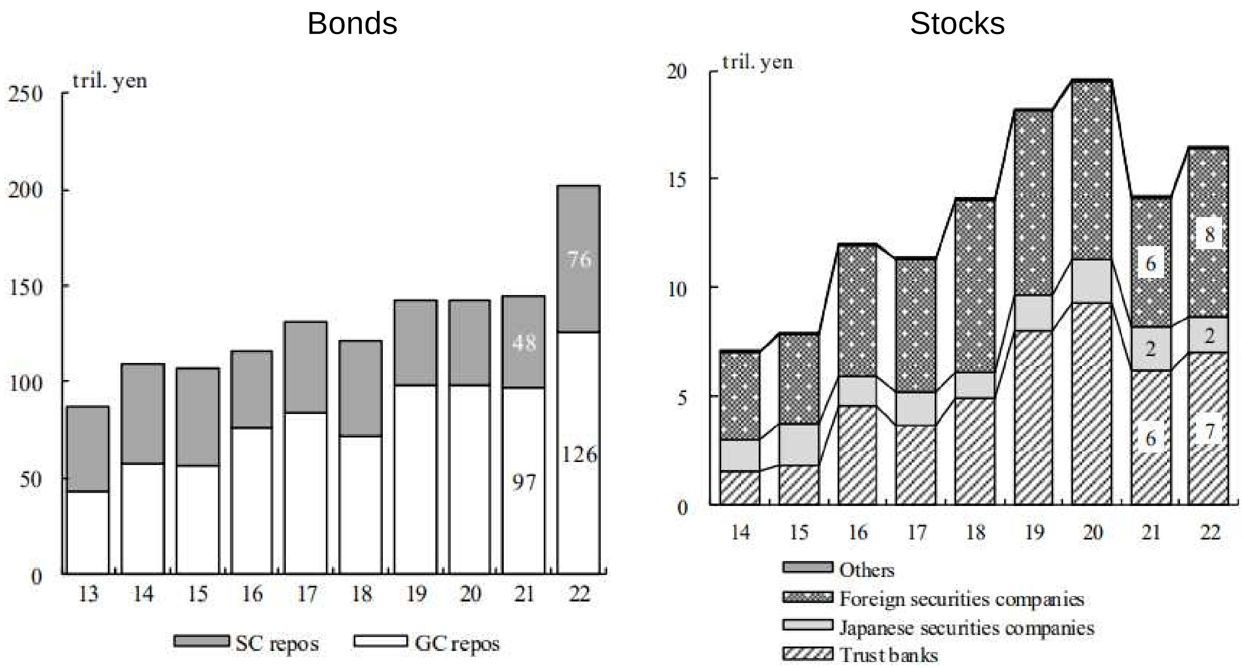
(Figure 2-2) Exchange of Securities and Securities



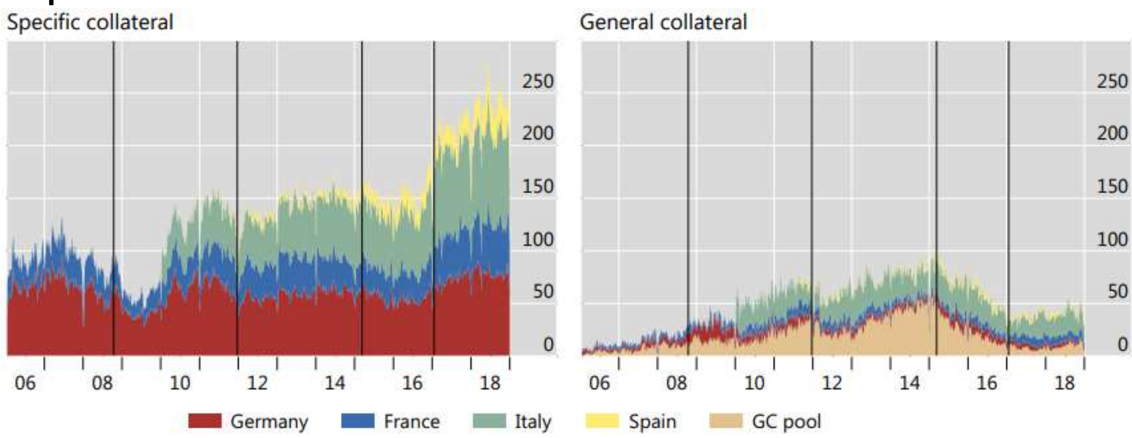
(2) Market Size

The size of the SFTs market continues to grow worldwide. In terms of fundraising, the volume of GC transactions is growing because it is possible to procure stable funds at low interest rates since these transactions are secured by collateral, and at the end of 2022, the balance of GC transactions in Japan had reached 126 trillion yen. Additionally, SC transactions with the purpose of procuring securities, including the aforementioned collateral demand, etc., are also increasing remarkably, as the balance of SC transactions in Japan stood at 76 trillion yen at the end of 2022. In this manner, the SFTs market represents an extremely important market in size for the securities and financial markets of each country.

(Figure 2-3) Trend in the Balance of Securities Finance Transactions in Japan[6]



(Figure 2-4) Trend in the Balance of Securities Finance Transactions in European Countries[7]



(3) Credit Risk Management

Since SFTs are secured transactions, credit risk is limited, but since the collateral value fluctuates according to market value, the difference between the transaction target amount and the collateral value becomes the net credit amount,

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[6] Bank of Japan, *Trends in the Money Market in Japan – Results of Tokyo Money Market Survey (August 2022)*

[7] BIS, *BIS Quarterly Review, December 2019, Euro repo market functioning: collateral is king*

and credit risk management is required. There are two main credit risk management methods as follows:

i. Haircut

In SFTs, the term haircut refers to the fact that the valuation amount is calculated by multiplying the value of the securities by a certain weighting in consideration of the price fluctuation risk of the securities and the credit risk of the transaction counterparty, and the rate used to calculate this weighting is called the haircut rate.

Since GC transactions have a character of funds lending and borrowing with securities as collateral, the haircut rate is used to prepare for the risk of a decrease in value when collateral is liquidated in the event of a default by the borrower of funds. Since SC transactions have a character of securities lending and borrowing with funds as collateral, the haircut rate can be viewed as preparation for an increase in the cost of repurchasing securities in the event of a default by the borrower of the securities, and as a result, the haircut rate of SC transactions is smaller than GC transactions, and in some cases, it may be negative (exceed the transaction amount).

ii. Margin call

At the start of a SFT, funds or other securities are exchanged for the value of the securities considering the above haircut, but due to price fluctuations during the transaction period, there is a discrepancy between the value of the funds or securities initially offered to the counterparty and the value of the funds or securities received from the counterparty (calculating this discrepancy known as marking to market). At this time, credit risk management is carried out by charging the other party for the surplus or shortfall and reducing the net credit amount as much as possible. This is called a margin call.

Marking to market is generally based on the closing price of the securities on the day. A margin call is made for the surplus or shortfall found as a result of marking to market, but if a certain threshold is set and this amount is within that range, an agreement not to make a margin call may be made between the transaction parties. In the event of a margin call, the counterparty confirms the details and pledges additional funds or securities.

For standard transactions, margin calls are also standardized; for example, as for JGB repo transactions, the counterparty pledges the necessary funds on the day of the margin call in the case of conditional repurchase and resale transactions (transactions with repurchase agreement; “Gensaki transactions”) and on the next day of the margin call in the case of cash-backed bond lending and borrowing transactions (“Gentan transactions”).

On the other hand, in cross-border transactions, due to the exchange of funds and securities through local custodians[8] and the time difference, it may take several days, including intermediate confirmation with the counterparty, from the time of the margin call to the actual delivery of funds or securities. In order to mitigate this burden, in a tri-party repo, a tri-party agent[9] manages transactions and collateral on behalf of the parties to the transaction.

The margin call structure used in this empirical research assumes a bilateral structure between the transaction parties as described above, but for SFTs of which obligations are assumed by a Central Counter Party, the margin call is also made collectively by the Central Counter Party between all the transaction parties.[10]

(4) Settlement Risk Management

With regard to standard transactions, settlement risks associated with SFTs are

[8] The custodian stores, administers and settles securities based on requests from customers. In addition to these basic services, the custodian often provides additional services such as receipt of interest and dividends, exercising of voting rights, and response to corporate actions.
In cross-border transactions, funds and securities are settled by the Central Counter Party with legal jurisdiction; thus, settlements of securities in foreign currencies or in foreign countries requires an account be setup at a local Central Counter Party. As a result, settlements are entrusted to a custodian with an account at the local Central Counter Party. The custodian settles funds and securities as a proxy of the customer.
On occasion a global custodian may enter between a customer and custodians located in each country. A global custodian has an established network with custodians located in each country and handles the storage and settlement of customer securities in bulk. By using a global custodian, customers do not need to conclude deals with individual custodians in each country because the global custodian can manage all securities they have invested in around the world.

[9] In SFTs, there are cases where a third party enters between the transaction parties to carry out the transaction and manage collateral (typically this third party is a custodian). This format is known as a tri-party repo. This third party is referred to as a tri-party agent. The tri-party agent automatically receives necessary collateral between the account of the collateral provider opened within the company and the account of the collateral recipient according to various conditions instructed. In this manner, the custodian plays a roll in mitigating the burden related to collateral management of the transaction parties.

[10] A Central Counter Party stands between transaction parties to acquire and receive both receivables and payables becoming the settlement counterparty. By having the Central Counter Party as a go between, participants can reduce risk related to delivery with transaction counterparties and can perform netting where positions of receivables/payables are offset to settle only the difference of net owing, which can reduce the number of settlements and can lower settlement costs.

addressed using settlement institutions and clearing institutions, while transactions that are not necessarily standardized, such as cross-border transactions, are addressed using tri-party agents to mitigate such risks.

In addition, if there is a lag in the timing of receipt due to time differences, etc. in the settlement of the exchange of funds and securities, there is a risk that one of the transaction parties delivered the securities but the other party did not receive the funds for the consideration. In order to reduce such risks, it is important to have a mechanism that simultaneously settles funds and securities (delivery versus payment, or DVP). Such mechanisms have been established in major countries, including Japan, and in some cases, they are connected across borders.

In contrast, in cross-border transactions where such standardization has not been established, it is necessary to settle funds and securities through Central Counter Parties around the world with different settlement times. Thus, there are many cases where these transactions are strictly accompanied by time differences.

(5) Structure of Securities Finance Transactions in this Empirical Research

Based on the above, the basic workflow of SFTs considered in this empirical research is as follows:

i. Deal

After negotiations and coordination between the front office departments of the transaction parties regarding transaction conditions such as amount, securities issue, transaction rate, and period, a deal is concluded. Negotiations widely use chat tools of information vendors, and may also be conducted by telephone or e-mail.

ii. Reconciliation

After the deal is concluded, the middle and back office departments of the transaction parties reconcile to confirm the matters agreed at the deal stage. Reconciliation may be carried out individually using e-mail or fax, or centralized settlement reconciliation systems provided by Central Counter Parties or central securities depositories (CSDs)[11] may be used.

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[11] CSD operates a system for storing, managing and settling securities. CSD concentrates on

iii. Settlement at transaction start

For transactions that have been reconciled, settlement is made by exchanging and delivering funds and securities on the agreed date. Since government bonds and listed stocks are centrally managed by the CSD, the transaction parties instruct the CSD to transfer the securities.

iv. Margin calls

During the transaction period, due to fluctuations in the price of securities and exchange rates, the value of funds or securities initially offered to the counterparty and the value of funds or securities received from the counterparty will experience a surplus or shortfall. As a result, mark to market and margin calls are made to eliminate such surplus or shortfall.

v. Settlement at transaction end

On the business day before the transaction ends, the middle and back office departments of the transaction parties reconcile the settlement details, and on the end date, funds and securities are received (settled) between the transaction parties. The settlement practice is the same as in (3).

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management of securities and provides settlements of securities (transfer settlements) using book entry. Transaction parties open an account at CSD each to manage securities and transfer securities as well as entrust settlements to the custodian with an account at CSD.
In addition to basic services such as storage, management and settlement of securities, CSD often provides additional services such as system provision related to reconciliation and settlements, provision of securities lending and borrowing services, and cross-border settlements by links with other CSD.

3. Structure of Empirical Research and Blockchain Smart Contracts

In this chapter, we first set out the structure of SFTs in this empirical research when tokenizing securities or funds for the SFTs subject to this empirical research as examined in the previous chapter. On top of this, we explain about the composition of the blockchain and smart contracts in order to execute these transactions.

(1) Structure of Securities Finance Transactions in this Empirical Research

The structure for executing SFTs subject to this empirical research indicated in section (5) of the previous chapter are assumed to be the following when using tokens for execution.

i. Subject of tokenization

Security token (ST): government bonds and listed stocks of Japan, the United States, and Germany

Cash token (CT): denominated in each currency including Japanese yen, US dollars and Euro

ii. Calculation method of token's market value

ST: Calculation of market value in the currency of each country after acquiring the closing price of each market on daily basis.

CT: Same for the currency of each country.

iii. Calculation of net credit amount

Based on the market value of each ST and CT calculated above, in the case of transactions of tokens denominated in different currencies, the net credit amount of all SFTs was calculated by using the exchange rate of those currency to the base currency (specified by the counterparties in advance) after the close of the US market on the day. The exchange rate is acquired and currency conversion is conducted before the start of trading on the Japan market the next day. If there was any excess or shortage, a margin call was made (however, in case a threshold for a margin call is set in advance, the margin call is only made after this threshold is exceeded).

iv. Transaction workflow

The workflow of executing the transactions described in section (5) of the previous chapter using tokens is comprised of the following. Details regarding blockchain records in the transaction process are discussed in section (4) of this chapter.

- Transaction parties receive issuance of tokens from the token administrator (the issuance process is excluded from this system as discussed above).
- After a deal is made between the transaction parties (the matching function is out of scope), one transaction party enters the transaction information (issue, quantity, rate, transaction period, etc.) into the system, and the other party approves it (equivalent to the current reconciliation). It is also possible to bundle different STs and CTs into a pool for both legs of the transaction.
- For transactions that have been approved, when the transaction start time (including immediate) recorded above arrives, the information is included in the initiation transaction processing[12] that the service server periodically requests the blockchain to execute, the smart contract is activated, and the settlement, i.e. the transfer of tokens, is recorded in the ledger. At this time, if a transaction party does not hold the number of tokens required for settlement, the settlement itself is not made and the other party's tokens are not transferred.
- During the trading period, mark to market and margin calls are made every business day following fluctuations in the market price of ST and CT. For margin calls, a certain threshold (amount) can be set, thereby margin calls could be made only when the threshold is exceeded. In addition to CT, margin calls could also be made by multiple ST pools.
- Upon the transaction end date, the transaction is automatically terminated, and the smart contract automatically delivers the token borrowed from one party to the other party, returns the loaned token, and records the result in the ledger. Even in this case, if either of the transaction parties does not have the tokens to be repaid, the settlement related to the repayment is not executed.
- Furthermore, although it is systematically possible to receive loan fees and collateral interest by CT using smart contracts, it was excluded from the

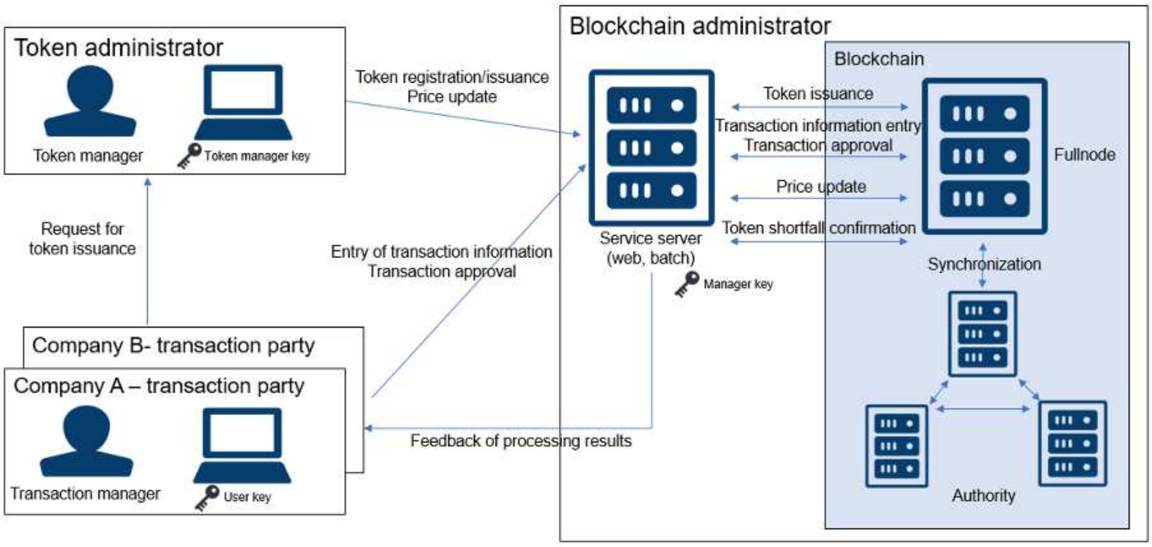
[12] Transaction processing refers to the indivisible series of information processing for executing transactions within the system. It is processed in the blockchain in this case.

scope of this empirical research from the viewpoint of simplifying system requirements.

(2) Composition of Overall System

To conduct tests based on the above structure, we developed a system composed of a structure as shown in Figure 3-1. Each actor comprising this system is responsible for the following functions.

(Figure 3-1) System Composition



(The distinction between Fullnode and Authority within the blockchain is discussed below.)

i. Token administrator

- The token administrator instructs the blockchain administrator to issue the tokens (ST or CT) based on the request of the transaction parties (Company A and Company B) and the token is issued.[13]
- After token issuance, the token administrator obtains market value information of the token's underlying assets on a daily basis and gives instructions to update the price of the tokens in the blockchain.

ii. Transaction parties (Company A and Company B)

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[13] Conventionally, there is a need to manage the linkage of tokens and the underlying assets of the token, but this process was excluded from the scope of development as discussed above.

- Following the token issuance from the token administrator, the transaction parties enter transaction information and their approval in the system, and then execute the transaction involving the token exchange.

iii. Blockchain administrator

- The blockchain administrator manages both the service server and blockchain.
- The service server receives the information sent from the token administrator and transaction parties, and processes the transaction on the blockchain. In addition, it informs the token administrator and the transaction parties of the results of processing on the blockchain. The token administrator and transaction parties are unable to directly access the blockchain and must do so via the service server.
- The blockchain uses smart contracts based on the instructions received from the service server to process the transaction, form blocks and record the transaction.

(3) Structure of Blockchain

i. Blockchain functions

The blockchain builds smart contracts on the blockchain. The smart contract records the market value of the token, the balance of the quantity and amount by owner, and transaction information (information on borrower, lender, collateral [issues, quantities, etc.,] and transaction conditions [period, haircuts, rates, etc.,]).

This information is updated in a way that maintains the history when there is a transaction processing (i.e., instructions on the price of a new token) from the token administrator or transaction party via the service server. In turn, the collateral value is recalculated and margin calls are performed.

ii. Blockchain platform

Ethereum was used as the blockchain platform. Ethereum is the most widely used blockchain platform in the world at the time of empirical research on blockchain on which smart contracts can be implemented, and Tanaka Laboratory at The University of Tokyo has experience using it in past empirical research.

iii. Node assignment

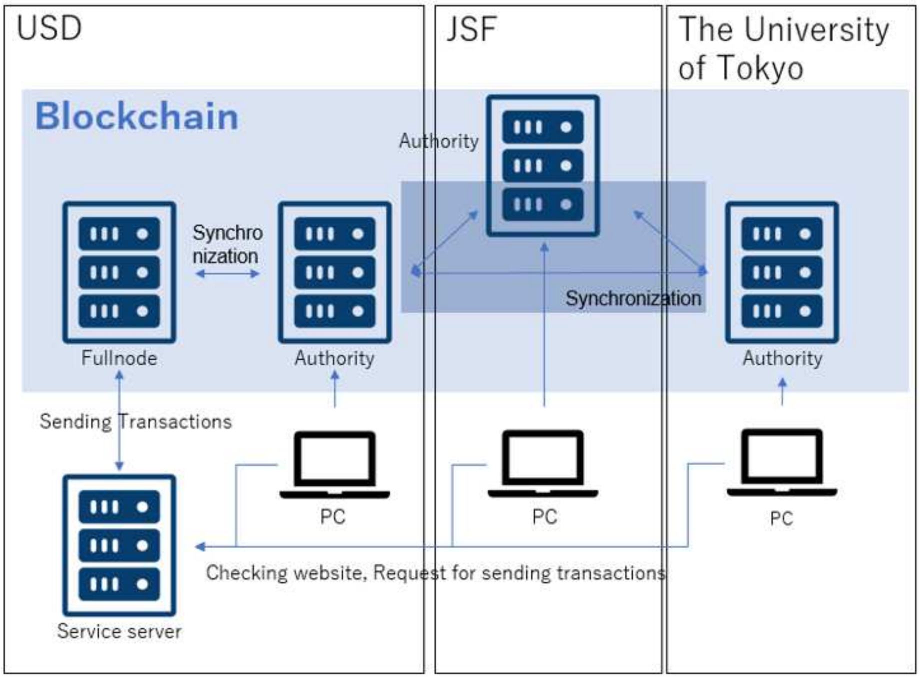
For this empirical research, we built a blockchain network as shown in Figure 3-2. The University of Tokyo, USD, and JSF built a server and set up nodes to synchronize the blockchain that recorded the contents, balance, market value, etc. of tokens.

The reasons for using three nodes are based on a comprehensive consideration of the following: 1. from the viewpoint of fault tolerance, it is better to have a large number of nodes, 2. a project management perspective is also necessary, 3. an odd number is desirable when dealing with the majority rule problem (when the blockchain branches out, the long chain takes precedence, but if a chain of the same length occurs, it is difficult to decide which one to prioritize if there is an even number).

In building nodes, in order to distribute the load, the blockchain nodes are divided into two parts: Fullnode and Authority. The former performs transaction processing related to deals received from the service server, mark to market, etc., and the latter creates blocks and writes data. Of these, Fullnode was installed only in USD, and Authority was installed in all three parties.

Furthermore, block creation was performed every five seconds, which is the default in OpenEthereum.

(Figure 3-2) Blockchain Network



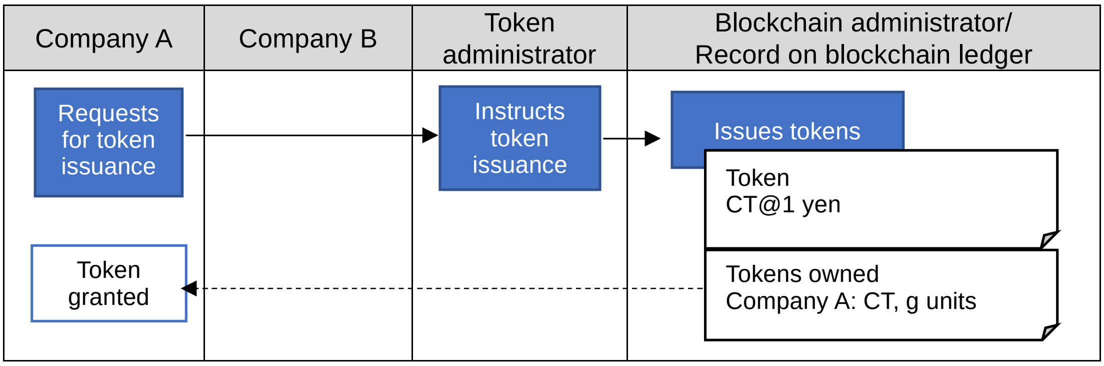
(4) Records on the Blockchain

Records on the blockchain are made as follows based on the basic workflow of the transaction described in (1) above.

i. Token issuance

- The token administrator orders the issuance of tokens with indicating the target token, recipient, and issuance amount on the blockchain based on the request from the transaction party (Company A).
- The token name and quantity are recorded on the blockchain as the balance of Company A.

Workflow of Token Issuance



ii. Transaction deal, recording and approval

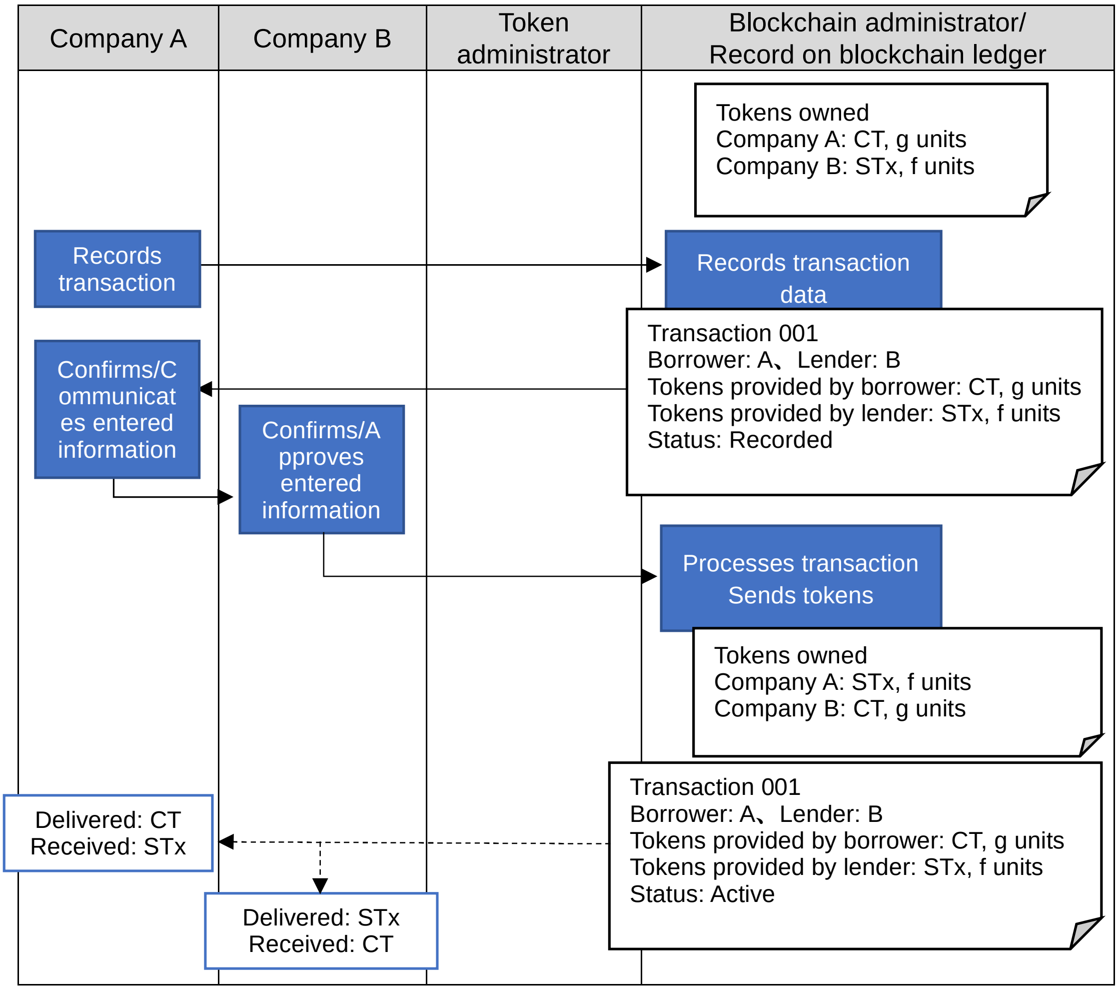
- The transaction parties conclude a deal for a transaction to exchange tokens on the blockchain after they receive the tokens issued from the token administrator.
- Based on the details of the transaction deal, one of the transaction parties (Company A) records the transaction information on the blockchain (including deliverables, quantity, receivables, and transaction conditions [deal start date, deal end date, haircut, currency, threshold for margin call]).
- Transaction information recorded by Company A on the blockchain is recorded in the “recorded” status. At this stage, the tokens owned by Company A and Company B are not transferred.
- After Company A enters the above transaction information, the other transaction party (Company B) checks the transaction information recorded on the blockchain through the service server and then approves the transaction.
- Once Company B approves, the status of the transaction changes to

"active" in the blockchain and then the transaction settlement (transfer of tokens) takes place.

iii. Transaction settlement

- Upon transaction approval and the designated transaction start date, following the transaction details, the tokens owned by Company A are transferred to Company B and the tokens owned by Company B are transferred to Company A on the blockchain.
- Since the blockchain itself does not have a function to automatically process transactions at a specific time, the blockchain administrator automatically and regularly verifies on the service server the presence of a transaction for which the transaction start date has arrived, and processes transactions for settlements of transactions that have begun, automatically starting the transaction.
- Although the transaction is recorded and approved, if one transaction party's (Company A) token has an insufficient balance at the start of the transaction, transaction settlement is not carried out. In this case, the tokens of Company B are not delivered to Company A.
- For transactions that are not settled, the shortfall of tokens by Company A is remedied by requesting new issuance from the token administrator, and once the balance required for settlement is fulfilled, a smart contract is activated and the transaction is settled automatically including the information for transaction processing at the start of the transaction sent regularly by the service server to the blockchain.
- If Company A's balance insufficiency is not remedied, all transactions with Company A as a transaction party are stopped. Thereafter, it is believed that depending on the situation, proceedings move on to damage claims or preservation procedures. However, this is outside the scope of this empirical research.

Workflow from Transaction Recording to Settlement



iv. Token transaction denominated in different currencies

- As described above, an environment was established where transactions can be executed involving the exchange of tokens whose underlying assets are from different jurisdictions assuming that these underlying assets could be currencies, government bonds and listed stocks of not only Japan, but also the United States and Germany. For example, a transaction of tokens whose underlying assets are US Treasury bonds and Japanese yen will be transferred simultaneously after automatic settlement on the designated transaction start date.
- The token administrator acquires the market value and foreign exchange rate of the underlying securities of each country on a daily basis and records it on the blockchain, including the value converted into the base currency (Japanese yen, US dollar or Euro).
- The transaction parties, when executing transactions involving assets

denominated in different currencies, designate a base currency (Japanese yen, US dollar or Euro) for each transaction. The collateral price is converted to the base currency based on the foreign exchange rate updated daily, and during the transaction period, mark to market and margin calls are performed in the base currency.

v. Updating of token price

- The token administrator obtains the closing price of the stock price, securities price or foreign exchange rate for each type of underlying asset and instructs the blockchain to update the price of the token.
- The token price recorded in the smart contract is updated in the blockchain based on the price of the underlying asset instructed from the token administrator.

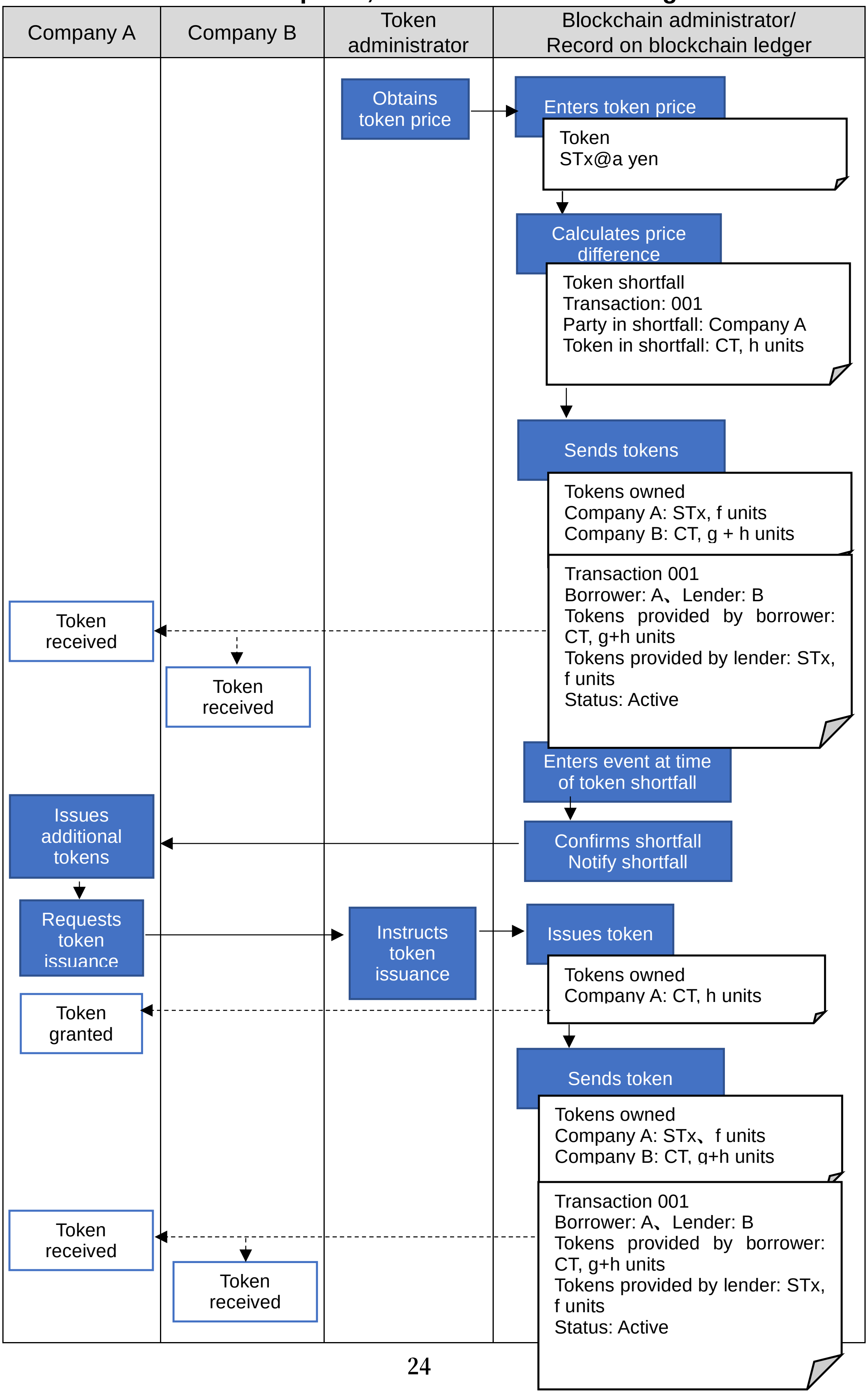
vi. Mark to market and margin calls

- Once per day (prior to the market opening in Tokyo time), the smart contract is automatically activated so that the transaction is marked to market and margin calls are made.
- Within the blockchain, the price of the token of each transaction is recalculated (marked to market) based on the token price updated in the “Updating of Token Price” process in (5) above, and after marked to market, the token price of both transaction parties is compared.
- The smart contact automatically performs the operation to cancel out any difference in token price once detected. At the start of the transaction, it is agreed which tokens of the transaction party to make the margin call, and if a margin call is made with the token provided by Company A and the value of the token provided by Company A is large compared to the value of the token provided by Company B, the surplus tokens of Company A are withdrawn from Company B.
- In this example, if Company A pledges multiple tokens, considerations are made to flexibly establish collateral as to which token surplus or shortfall to adjust. For example, when procuring a certain value of CT as collateral for multiple ST (using a GC transaction), adjustment can be made using these multiple ST, and alternatively, when procuring specific ST for collateral of CT (using a SC transaction), adjustment can be made using CT. Additionally, when procuring multiple ST using multiple ST as collateral, adjustment can

be made using multiple ST of either side of the designated ST for the collateral or transaction.

- If a threshold is set for margin calls, no margin call is made when the difference between the price of the ST or CT of the lender and borrower after marking to market does not exceed the threshold.
- The handling when the balance is insufficient at the time of a margin call is the same as settlement in (3) above.

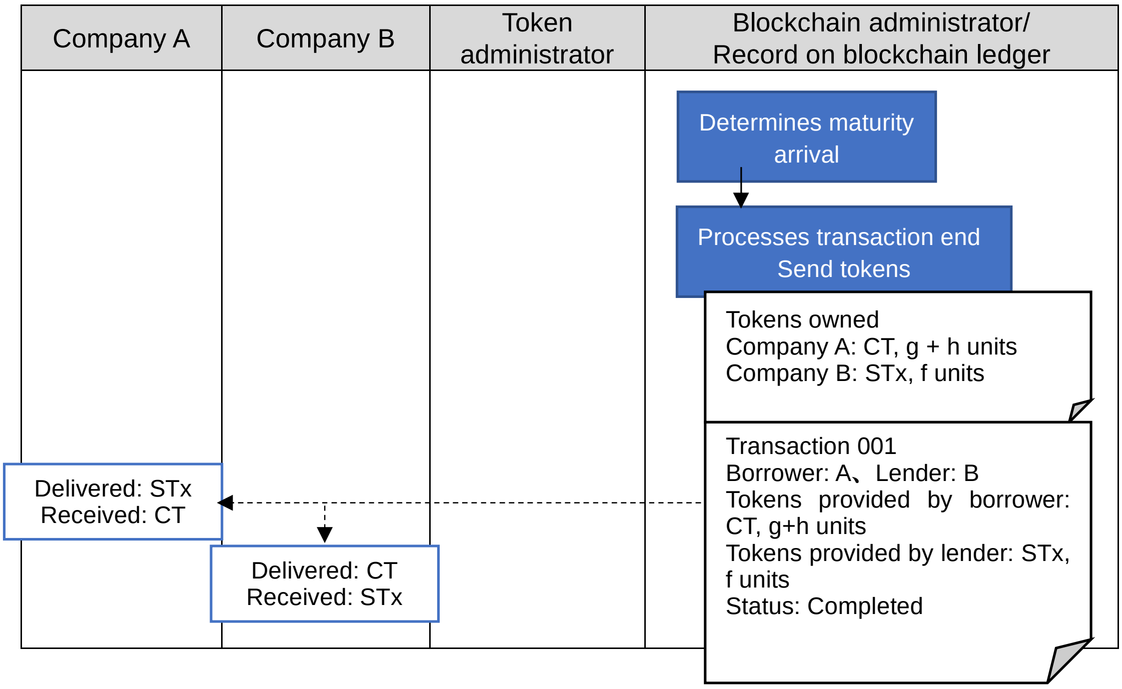
Workflow for Token Price Update, Mark to Market and Margin Call



vii. End of transaction

- Upon the transaction end date, the transaction in the smart contract changes in status to "completed," the borrowed tokens are delivered to the other party, and the lended tokens are automatically returned. The handling in case of shortfall is the same as (3) above.

Workflow at Transaction End



viii. Cancellation of tokens

- The token administrator instructs the blockchain to cancel the tokens (target token, cancelling party, number issued) based on the request from the transaction party (Company A).[14]
- The name of the token and quantity canceled is reduced from the balance of Company A on the blockchain.

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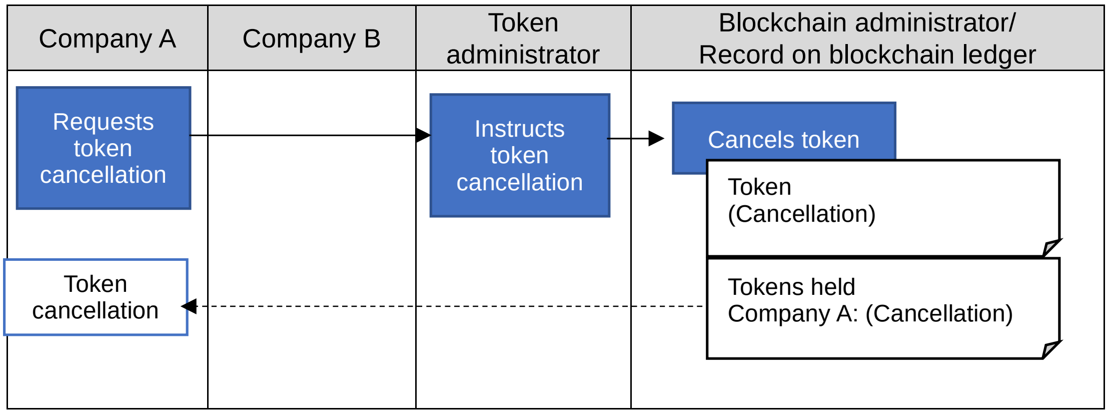
[14] Token cancellation assumes that tokens are cancelled in exchange for the underlying currency or securities deposited at the time of token issuance.

Workflow of Token Cancellation



4. Evaluation Results

(1) Feasibility of Securities Finance Transactions Execution

First, we evaluated whether it is possible to execute each token-based SFTs using blockchain. The results of this evaluation are as follows:

i. Types of Transactions Evaluated

The following types of transactions (samples) were executed between Company A and Company B.

a. Transactions involving the exchange of securities and funds of the same currency
   - Transactions involving the procurement of Japanese yen CT collateralized by Japanese stock ST or Japanese Government Bond ST and the inverse transaction (transactions involving procurement of ST collateralized by CT).
   - Transactions involving the procurement of US dollar CT collateralized by US stock ST or US Treasury Bond ST and the inverse transaction
   - Transactions involving the procurement of Euro CT collateralized by German stock ST or German Bund ST and the inverse transaction

b. Transactions involving the exchange of securities and funds of different currency
   - Transactions involving the procurement of US dollar CT collateralized by Japanese Government Bond ST
   - Transactions involving the procurement of Euro CT collateralized by US stock ST
   - Transactions involving the procurement of Japanese yen CT collateralized by German Bund ST

c. Transactions involving the exchange of securities and securities of the same currency
   - Transactions involving the procurement of Japanese Government Bond ST collateralized by Japanese stock ST
   - Transactions involving the procurement of US Treasury Bond ST collateralized by US stock ST
   - Transactions involving the procurement of German Bund ST collateralized by German stock ST

d. Transactions involving the exchange of securities and securities of different currency

- Transactions involving the procurement of US Treasury Bond ST collateralized by Japanese stock ST
- Transactions involving the procurement of German Bund ST collateralized by US stock ST
- Transactions involving the procurement of Japanese Government Bond ST collateralized by German stock ST

ii. Transaction Period

The above types of transactions involving margin calls were executed according to the following period from start to end dates.

Intraday, overnight, three days, one week, two weeks, and three weeks (carrying over to the next month)

iii. Evaluation Results

a. Start of transaction

At the start of the transaction, when Company A first registered the transaction, the transaction information was recorded on the blockchain, and the same transaction information was displayed on the screen of the other party (Company B), and Company B confirmed that it can be approved. Recording and approval were completed in about a few seconds.

b. Margin calls during the transaction period

By obtaining the price of the token's underlying asset from the outside and recording it on the blockchain, the smart contract could link it with the pre-recorded transaction information, calculate the collateral value of both parties for each transaction, and automatically transfer tokens to adjust the difference between the two.

Specifically, in the case of a transaction between Company A and Company B to procure ST (German bund) using the aforementioned ST (US stock) as collateral started on Wednesday, April 19, 2023 under the conditions in Figure 4-1, the price of ST (German bund) is automatically acquired and recorded on the blockchain when the closing price on April 19 was available. The closing price of 98.811 on April 18 was changed to the closing price of 98.759 on April 19. After that, the price of ST (US stock) was automatically acquired and recorded on the blockchain when the closing price was available, and the closing price of 161.01 on April 18 was changed to the closing price of 162.53 on April 19.

The exchange rate (EUR/USD in the case of this transaction) was automatically acquired and recorded on the blockchain after the close of the US market, changing the closing price of 1.09253 on April 18 to the closing price of 1.09753 on April 19.

Thereafter, the market value of tokens held by both counterparties was calculated once a day (before the start of trading on the next business day Tokyo time) to eliminate the difference in transaction value. In the example in Figure 4-1, before the start of trading on Thursday, April 20, the number of shares of ST (US stock) as collateral was automatically calculated to be 333,450 shares to match the market value of ST (German bund) based on the closing price on Wednesday, April 19 (EUR 50,000,000 x 98.7590 EUR ÷ 100 x 1.09753 = 54,195,483 USD). The difference between the number of shares currently accepted as collateral (335 240 shares - 333,450 shares = 1,790 units) was automatically returned from Company A to Company B.

Figure 4-1 Transaction Examples Involving ST (US Stocks) and ST (German Bunds)

	19 April 2023 (start of transaction)		20 April 2023 (after margin call)	
	B borrows	A accepts	B borrows	A accepts
	ST (German Bund)	ST (US Stock)	ST (German Bund)	ST (US Stock)
Unit	50,000,000	335,240	50,000,000	333,450
Price	98.8110	161.01	98.7590	162.53
EURUSD	1.09253	–	1.09753	–
Market value (USD)	**53,976,991**	**53,976,992**	**54,195,483**	**54,195,629**

※German Bund price is per 100 Euro face value

c. End of transaction

Regarding the end of the transaction, no additional operation was required according to the transaction information recorded in the smart contract, and the end settlement (exchange of the transaction subject and collateral) could be automatically executed upon the transaction start date and time.

iv. Simultaneous execution of token exchange

In repo and securities transactions, if there is a time lag in the receipt of funds or securities of both parties, there is a risk that one party does not receive the consideration even though it has been delivered.

In this empirical research, when the deal, registration, and approval were completed, the settlement was automatically performed by the smart contract, and the tokens of both transaction parties were automatically transferred to the other party's account. At this time, if one of the transaction parties could not prepare a token to be delivered to the other party, the settlement would not be carried out and the other party's token would not be delivered as well.

For example, if there was a shortfall of CT at the start of a transaction between ST of Japanese stocks and CT of Japanese yen, neither ST nor CT was settled, and Company A requested the token administrator to issue the necessary CT, and ST and CT were settled promptly after this issuance. In addition, the settlement itself was carried out without problem in about a few seconds in various cases, such as not only ST and CT transactions, but also ST and ST transactions and transactions between tokens denominated in different currencies.

v. Collateral management using multiple types of tokens

We evaluated whether it was possible to use the function of smart contracts to conduct multiple types of token transactions and collateral management.

Specifically, in a transaction where Company B pledges multiple ST pools as collateral and borrows ST or CT from Company A, if a margin call becomes necessary due to fluctuations in the value of ST including foreign exchange rates, Company B attempted to implement a margin call by adding or returning one or more types of ST from among the multiple types of ST pools that Company B had pledged. For example, when it borrowed US dollar CT from Company A, Company B began the transaction on Thursday, April 20, 2023 in which it pledged ST of Japanese stocks and ST of Japanese government bonds as collateral and made a margin call on these stocks shown as in Figure 4-2.

After that, on Thursday, April 20, the closing price was 4,125.0 yen for ST (Japanese stock), 97.32 yen for ST (Japanese government bonds), and 134.70 yen for USD/JPY. Based on these data, at 8 a.m. on Friday, April 21, the collateral ST (Japanese stock) was automatically calculated to be 1,000,000 shares and ST (Japanese government bonds) 2,682,079,223 units so that it matched the market value of CT (US dollar) (50,000,000 units x 134.70 = 6,735,199,500). The difference between the number of units currently accepted as collateral for ST (Japanese government bonds) of 2,633,730,485 units - 2,682,079,223 units = 48,348,738 units was automatically pledged from Company B to Company A.

Figure 4-2 Transaction Examples Involving CT (US dollar) and ST (Japanese stocks or Japanese government bonds)

20 April 2023 (start of transaction)

	B borrows	A accepts	
	CT(USD)	ST(JP Stock)	ST(JGB)
Unit	50,000,000	1,000,000	2,633,730,485
Price	1	4,138.0	97.36
USDJPY	134.04	–	–
Market value (JPY)	**6,702,200,000**	4,138,000,000	2,564,200,000
		6,702,200,000	

21 April 2023 (after margin call)

	B borrows	A accepts	
	CT(USD)	ST(JP Stock)	ST(JGB)
Unit	50,000,000	1,000,000	2,682,079,223
Price	1	4,125.0	97.32
USDJPY	134.70	–	–
Market value (JPY)	**6,735,199,500**	4,125,000,000	2,610,199,500
		6,735,199,500	

※JGB price is per 100 Yen face value

In this case, Company A registered the ST that may be offered in the future in addition to the STs to be actually offered at the start of the transaction. If there was a shortage of collateral during the transaction period, the smart contract automatically secured additional collateral from the ST registered in advance. For ST as collateral, an algorithm was set up that automatically selects the securities, accepts the securities with the lowest market value among the collateral already in the collateral pool. The contents of the collateral pool were set so that the collateral securities and their market value are diversified as much as possible.

The borrowing of other assets using such a pool of multiple ST as collateral references the fund raising mechanism by utilizing a deposit receipt scheme, which is used to raise funds in the short-term money market by the securities finance company in Japan (JSF). The securities finance company deposits various stocks it holds to the stock exchange (TSE), receives deposit receipts from the stock exchange, and use these as collateral when raising call money in the money market.

vi. Suspension of transaction

This empirical research was designed so that all transactions executed by a specific party can be suspended under the authority of the blockchain administrator.

In this case, new transactions, transaction repayment, and margin calls, etc. are not implemented for transactions executed by a specific party.

In addition, for transactions conducted by specific parties, the transaction amount and collateral value could be calculated promptly for each transaction party.

In SFTs, if one party defaults, liquidation procedures are carried out such as canceling individual transactions and consolidating receivables and payables through bulk liquidation netting. With this handling in mind, this function systematically suspends transactions of specific parties and calculates the transaction amount in case of an emergency.

In the environment of this empirical research, we attempted to suspend the above transactions and calculate the transaction amount in a situation where 80,000 transactions were executed in the performance evaluation of (2) below, and it was confirmed that it functioned correctly.

(2) System Performance when Processing Transactions in Market-Wide Scale

In the test in (1) above, the feasibility of individual bilateral transactions was evaluated, but in this section, after estimating the market-wide scale of SFTs based on certain assumptions, transactions that occur in the entire market were input into the system and their performance was evaluated.

This evaluation was carried out from the following two perspectives.

First, transactions may be concentrated for a short period of time, such as during market stress or when a system that has stopped due to a failure is restored. This evaluated how resilient the developed system is in case of high concentration of transactions during market stress or recovery from system interruptions.

Second, while individual transactions are not concentrated in a short period of time under normal circumstances, in the case of SFTs, marking to market every business day and margin calls based on the results were always generated for all transactions during the transaction period, and the processing burden on the system is heavy. Therefore, this evaluated how resilient it is to the anticipated large system workload when marking to market and implementing margin calls every business day.

Furthermore, an external cloud service with specifications of virtual CPU cores: 2 and memory: 8 GB was used as the machine.

i. Evaluation details and method

As for the details of the evaluation, the performance was measured in two points: new transaction recording/approval as well as mark to market and margin call processing.

Performance was measured by processing time. The processing time was measured as the difference between the time when a transaction order was sent and the time when the processing related to the transaction order was executed and the result was recorded in a block. Since a block was created every five seconds, the processing time was up to a five-second error.[15]

Furthermore, assuming that 20 companies execute these transactions as the main participants in SFTs in Japan, we evaluated that each company was granted sufficient tokens so that there would be no shortfall.

ii. Evaluation of transaction recording and approval

Regarding recording and approval at the start of transactions, we divided the degree of concentration of transactions into three stages, and experimented with the processing time required for transaction recording and approval for each. The number of transactions was set with reference to the market-wide scale of SFTs in Japan (see reference for details of settings).

The measured time was the difference between the data input start time and the completion time of recording on the blockchain for the transaction recording and approval process of data input every minute.

The evaluation results were as follows:

Figure 4-3 Processing Time and Calculation Amounts for Transaction Recording and Approval

Transactions/minute	Processing time (seconds)		Calculation amount (Mgas)	
	Recording	Approval	Recording	Approval
400	4.09	7.86	358	285
200	5.86	7.98	149	113
100	5.85	3.10	87	76

Here, 200 transactions per minute is assumed to be the number of daily market-wide transactions in the Japan are concentrated in one hour, with 400 transactions assumed to be twice that number during market stress. As the

[15] This is because, for example, when sent immediately after Block T creation or when sent immediately prior to the following Block T+1, the transaction is deemed as recorded in Block T+1 at the same time irrespective of the upwards of five second difference.

number of transactions increased, the number of transactions recorded in the block increased, so the calculation amount in the blockchain increased in proportion to the increase in the number of transactions.

On the other hand, in terms of processing time, regardless of the number of transactions, transaction recording and approval were completed within about 8 seconds. The reason why it is not necessarily proportional to the computational complexity is that the system developed in this empirical research has a specification that creates blocks every five seconds, so a measurement error of up to five seconds occurred when recording transactions on the blockchain. Taking this into account, there was no significant difference in the actual processing time for any of the transactions within 400 transactions.

Both are the results of evaluation in this empirical research environment. These are considered to be greatly influenced by the specifications of the machine.

iii. Evaluation of mark-to-market and margin call processing

Regarding mark-to-market and margin call processing, the transaction volume (number of transactions) during the transaction period (end yet to arrive) was divided into three stages, and the processing time when mark-to-market and margin call processing were performed for all these transactions was evaluated. The number of transactions was set based on the actual (partially estimated) market size of SFTs in Japan (see reference for details of the setting method).

The measured time was the difference between the time when the mark to market of the collateral value of each transaction was started based on the updated market value and exchange rate of the underlying asset, and the time when the transfer of necessary tokens (margin call settlement) was recorded on the blockchain.

The evaluation results were as follows:

Figure 4-4 Processing Time and Calculation Amount of Mark-to-market and Margin Call Processing

Transactions	Processing time (seconds)	Calculation amount (Mgas)
80,000	2,628	21,025
40,000	362	10,485
20,000	151	5,246

Here, "80,000 transactions" in the top-left cell is the number of margin calls processed assuming that one-third of market-wide active SFTs in Japan are concentrated in one blockchain administrator.

It took 151 seconds to process 20,000 transactions, 362 seconds (about 6 minutes) to process 40,000 transactions, and 2,628 seconds (about 44 minutes) to process 80,000 transactions. Although the processing of 80,000 transactions case took a certain amount of time (although this is considered shorter than the time expected for normal batch processing), the processing itself was able to be carried out to the end.

The smart contract for marking to market and margin calls, (1) searches for transactions to be marked to market from the transaction list during the transaction period, (2) searches the token information used in the acquired transaction from the token list, (3) calculates the market value of the tokens of both parties, and (4) performs settlement processing to compensate for the surplus or shortfall resulted from these calculations. In this empirical research, this workflow was implemented for each transaction, but in addition to this rather complicated calculation process, the search process increased as the number of outstanding transactions increased, especially in (1), and it took a high system load and time to find the corresponding transactions. Again, performance is considered to depend largely on the specifications of the machine.

iv. Summary of performance evaluation results

In summary, the following results were obtained by performance evaluation.

- With regard to the start of transactions, the recording and approval process was carried out smoothly even in times of market stress when the daily market-wide transactions were concentrated in one hour or doubled.

- Mark-to-market and margin call processing were possible to process although it took a certain period of time even when assuming that one-third of outstanding transactions (end yet to arrive) that exist in the entire market are concentrated in a single blockchain administrator.
- While the processing of start or end of transactions did not cause concentration in normal times other than market stress, marking to market and margin calls always present a heavy workload to process because they occur every business day during the transaction period. This point is considered to depend on the specification of the machine.

(3) Impact of Collateralized Securities Diversification and Threshold Setting for Margin Call on Net Credit Amount and Necessary Liquidity, Including the Evaluation upon Market Turmoil

We conducted the following simulations to determine how the number of tokens for collateral and whether or not to set a threshold when making a margin call would affect the net credit amount and necessary liquidity.[16]

i. Models established

We assumed that CT of currencies and ST of stock as collateral were exchanged, and collateral adjustment (margin call) was carried out by the ST of stock. Evaluation was conducted about the following six models for four scenarios using the actual stock price data before and after the collapse of Lehman Brothers (October 2008 to August 2009).

・Scenarios

Scenario 1. No material change in collateralized asset value (normal times) (62-day period from July 1, 2009 to August 31, 2009)

Scenario 2. Rapid decline in collateralized asset value (62-day period from October 1, 2008 to December 1, 2008)

Scenario 3. Rapid increase in collateralized asset value (62-day period from March 1, 2009 to May 1, 2009)

Scenario 4. High volatility of collateralized asset value (62-day period from November 1, 2008 to January 1, 2009)

・Models

Model 1-1. Transactions involving the exchange of a single ST and CT

Model 2-1. Transactions involving the exchange of multiple (five securities) ST and CT (margin calls made for one of five securities)

Model 3-1. Transactions involving the exchange of multiple (five securities) ST and CT (margin calls made to ensure that the five securities of ST always maintained the same value)

Models 1 to 3-2. The threshold for margin call in each of the above models

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[16] The following analysis is based on *Blockchain Platform Research for Automation of Collateral Value Adjustments in Securities Lending and Borrowing Transactions* by Kento Maruoka (March 2023).

was set at 2%

Based on the above models and scenarios, the following items were evaluated.

- Daily net credit amount before margin call
- Number of margin calls
- Margin call amount
- Number of tokens replaced

ii. Evaluation Results

The evaluation results were as follows. The figures for each scenario were indexed with the results of Model 1-1 set at 1.000.

Scenario 1. Normal times	Model1-1	Model2-1	Model3-1	Model1-2	Model2-2	Model3-2
Net credit amount	1.00	0.96	0.96	1.23	1.11	1.14
Number of margin calls	1.00	1.00	1.00	0.21	0.20	0.20
Margin call amount	1.00	0.96	1.23	0.65	0.64	0.71
Number of tokens replaced	1.00	0.95	0.56	0.65	0.65	0.37

Scenario 2. Sharp decrease	Model1-1	Model2-1	Model3-1	Model1-2	Model2-2	Model3-2
Net credit amount	1.00	0.94	0.95	0.99	0.95	0.97
Number of margin calls	1.00	1.00	1.00	0.49	0.54	0.56
Margin call amount	1.00	0.94	1.02	0.91	0.92	0.98
Number of tokens replaced	1.00	0.93	0.61	0.91	0.90	0.60

Scenario 3. Sharp increase	Model1-1	Model2-1	Model3-1	Model1-2	Model2-2	Model3-2
Net credit amount	1.00	0.81	0.78	1.06	0.90	0.82
Number of margin calls	1.00	1.00	1.00	0.44	0.39	0.36
Margin call amount	1.00	0.81	0.99	0.90	0.70	0.72
Number of tokens replaced	1.00	0.78	0.49	0.91	0.67	0.38

Scenario 4. High volatility	Model1-1	Model2-1	Model3-1	Model1-2	Model2-2	Model3-2
Net credit amount	1.00	0.84	0.84	1.04	0.92	0.91
Number of margin calls	1.00	1.00	1.00	0.43	0.43	0.44
Margin call amount	1.00	0.84	0.96	0.85	0.78	0.86
Number of tokens replaced	1.00	0.84	0.56	0.85	0.77	0.52

a. Normal times

a-1 Cases without a threshold during normal times

First, looking at the case of Scenario 1, where no threshold is set for normal times, the amount of net credit decreased by about 4% for Model 2-1 and 3-1, which have five securities as collateral, compared to Model 1-1, which had one security as collateral. This is believed to be attributed to the diversification effect.

The number of margin calls was not different as each model basically made a margin call every business day because margin calls were made immediately when even a small net credit occurred.

The margin call amount in the case of collateral diversification should theoretically decrease if the fluctuation of net credit amount is suppressed by collateral diversification, and in fact, the margin call amount in Model 2-1 is about 4% lower than in Model 1-1. In Model 3-1, however, the increase was about 20%, which is thought to be due to an increase in the executed amount of margin calls in gross because when margin calls are made so that multiple collateral securities maintain the same amount, it is necessary to adjust each security individually because it is not possible to offset the securities that have risen in market value and those that have fallen.

The number of tokens replaced decreased in Model 2-1, which has five securities as collateral but adjusted collateral using only one of them compared to Model 1-1, which has one security as collateral. This is believed to be attributed to the diversification effect and the suppression of collateral price fluctuations. Comparing Model 2-1, which adjusts collateral with a single security, and Model 3-1, which adjusts collateral with multiple issues, the latter has a smaller number of tokens replaced, but this is because the market value of a single security used for collateral adjustment in Model 2-1 is small, and it took a large number of tokens to adjust a certain amount. Model 3-1 was adjusted to include securities with high market prices, so the number of tokens decreased.

a-2 Cases with a threshold during normal times

On the other hand, when a threshold was set, the net credit amount increased by 10 to 20% compared to none, indicating that it took several days for the net credit amount to reach the threshold and the margin call to be made.

The number of margin calls that occurred in Models 1-2, 2-2, and 3-2 was contained at about 20% compared to no threshold.

The margin call amount was lower for each model when a threshold was set.

The number of tokens replaced also declined in every model when a threshold was set.

b. Market turmoil

The following analysis was carried out as to how findings changed during times of market turmoil based on the diversification of collateralized securities and the threshold set had the effects as noted above during normal times.

b-1 Cases without a threshold during market turmoil

Net credit amount decreased by about 5% by implementing margin calls even when the value of collateral plummeted. It is naturally intuitive for net credit to decrease by about 20% when the value of collateral rises, and even in the event of volatility, the net credit amount decreased relatively significantly.

The number of margin calls was the same for every model, which was the same as normal times.

In the case of Model 2-1, the margin call amount was generally the same as the net credit amount, with a decrease of about 5% in the case of a sharp decline, about 20% in the case of a sharp rise, and about 16% in the middle in the case of volatility. In the case where the collateral securities of Model 3-1 were diversified, the reason for the increase in the executed amount of margin calls is believed to be the same as in normal times described above.

In Model 2-1, the number of tokens replaced decreased slightly from normal times even in the case of a sharp decline, but decreased more clearly in the case of rapid increases and volatility, which is considered to be almost the same as the amount of net credit and the margin call amount. In addition, Model 3-1 had a significant decrease, but the reason for was likely the same as in normal times.

b-2 Cases with a threshold during market turmoil

When a threshold was set, the amount of net credit increased in normal times, but decreased even when the collateral value plummeted. In particular, Model 2-2 showed a decrease of about 5% due to the securities diversification effect. This is because of the fact that the amount of net credit exceeded the threshold in a shorter time than in normal times due to sudden market fluctuations, and margin calls were often implemented.

In fact, although the number of margin calls decreased, the number fell to about 20% in normal times, but only to 50% in times of market turmoil.

In addition, the margin call amount also declined significantly in normal times, but during sudden market changes, especially in the case of a sharp decline, it was almost at the same level as in cases where no threshold was set. The number of tokens replaced showed a similar trend.

In other words, in the event of a market turmoil, even if a threshold was set, the credit risk management function of the margin call was exercised to reduce the net credit amount, and if the securities diversification effect is added, the margin call amount, i.e., liquidity on the margin call provision side, can be sufficiently saved.

iii. Observations

In SFTs, from the perspective of collateral receiving party, it is desirable that the collateral securities are as diversified as possible from the viewpoint of improving liquidity and reducing net credit amount. On the other hand, the larger the number of collateral securities the greater the increase in operational burden of evaluation, management, and collateral replacement increases in the current operational flow.

In the case of tokens, these issues are avoided because all of these processes are automated, and appropriate combination of securities diversification effects and threshold setting as described above, may create the possibility of efficiently and effectively controlling net credit amount and liquidity requirements.

In addition, although these effects can be obtained during normal times and market turmoil, the effects of combining thresholds and securities diversification on reducing credit risk and economized liquidity can be especially seen during market turmoil.

5. Implications Obtained from This Empirical Research

The implications obtained from this empirical research were as follows.

(1) Transaction Feasibility

We confirmed that various types of SFTs, including those involving the exchange of assets denominated in different currencies and security tokens to security tokens, can be smoothly implemented from the start of transactions through margin calls to the end of the transaction period with various transaction periods.

(2) Reduction of Settlement Risks and Simultaneous Execution of Transactions Denominated in Different Currencies

Blockchain technology can be utilized to exchange tokens for tokens simultaneously without time difference. In the case of exchanges involving foreign currencies or foreign securities, the transfer of funds and securities must be executed during local time at the local transfer institution. For this reason, generally a time difference occurs until completion of transaction settlement or completion of margin call. For example, when a Japanese financial institution borrows US Treasury bonds, after concluding a transaction agreement and reconciliation, settlement is carried out on the next business day United States time or late at night Japan time; thus the Japanese financial institution is able to confirm the settlement in the morning of the next business day after that. As for margin calls, for example, when settlement takes place in a foreign currency, settlement is carried out local time overseas, meaning the Japanese financial institution is only able to confirm the settlement either at night or in the next morning Japan time.

In this empirical research, even if the underlying assets are denominated in different currencies, upon recording and approval of the transaction on the blockchain after deal, the exchange of tokens for tokens on the blockchain was able to be executed simultaneously in real time. Also, margin calls can be automatically implemented after updating the daily market value without the need for operations by the transaction parties.

(3) Reduction of Credit Risk and Flexibility in Economizing Liquidity

We confirmed that automation of margin calls using blockchain technology reduces operational burden, making it easier to make margin calls, and as a result, this can also reduce credit risk.

It is also possible for automation to nearly eliminate operational burden on diversification of collateralized securities tokens and adjusting multiple collaterals in margin calls. As a result, this reduces fluctuations in not only collateral value but also net credit amount, having a positive effect on credit risk management. In cases where a threshold is set in order to reduce operational burden associated with margin calls, relief of operational burden itself is possible already by the automation via blockchain and smart contracts; thus, it is believed that threshold setting also provides benefit of controlling system burden following an increase in the number of margin calls.

Since threshold setting allows the occurrence of net credit within that range, the amount of net credit increases to that extent. We confirmed that this effect can be mitigated or offset by diversifying the collateral securities and securities used for collateral adjustment.

Furthermore, the credit risk reduction effect and liquidity economizing effect gained through such combination of threshold and collateralized securities diversification effect proved to be particularly effective during market turmoil.

(4) Streamlining of Operation

Using blockchain in SFTs enables automated execution without manual intervention following the predetermined conditions in the smart contract with regard to settlements related to the start and end of the transaction and margin calls during the transaction period upon recording and approval of the transaction on the blockchain after deal.

These results suggest that the use of blockchain can make it possible for straight through processing (STP), improving the efficiency of SFTs operation and managing operational risk. In particular, this has the potential to significantly reduce the operation and its time required to exchange transaction information and check status with counterparties located in foreign countries, thereby improving the efficiency of transactions.

(5) Utilization of Assets with Low Liquidity

There are cases where the transfer of the rights of certain securities with low liquidity, such as unlisted shares, require an operational burden and associated time as the actual certificate must be transferred or changes must be made to the registry.

It will become easier to transfer rights of low-liquidity assets by tokenization.

This provides potential to not only hold these low-liquidity assets, but also utilize them as collateral in SFTs.

For example, as with the evaluation of this research, ST to be exchanged for CT can be issued after placing low-liquidity assets under the management of token administrators using trust scheme or other means.

In addition to ST, CT can be used for SFTs by using the following method to fix the value of CT at 1 CT = 1 yen, etc., after using the asset pool including low-liquidity assets as the underlying asset. By constantly managing the value of the pool of underlying assets, including low-liquidity assets, so that it always exceeds 1 using a certain weighting, the value of CT can be fixed at 1 yen without a one-to-one correspondence between the valuation of individual low-liquidity assets and CT (the same structure as the above-mentioned deposit receipt scheme).

Furthermore, it is believed that increasing the usage as collateral in this manner has the potential to increase the valuation of the underlying asset.

In this empirical research, we found that there are various applications by utilizing blockchain to SFTs. Although many key points were left out of this research from the perspective of project management, going forward we intend to continue researching this area further while paying close attention to the latest technological advancements in Japan and abroad.

END

Reference

The daily volume of SFTs, mark-to-market and margin call processing used in the performance evaluation were estimated as follows based on publicly available data and the Company's transaction results.

1. Daily number of SFTs

(Stock)

・The share of clearing and non-clearing transactions is 70% and 30%[17]

Unit: 100 million yen

	Balance	Share
Centrally cleared transactions	67,983	70%
Not centrally cleared transactions	29,316	30%
Total	96,534	100%

※Equities vs Cash, Month end average of securities in (average of January 2019 to December 2021)

・Based on the number of cases of 3,726,272 and the share of centrally cleared and not centrally cleared transactions in FY2021 in obligation assumption (stock lending) in JASDEC DVP clearing corporation, the number of cases of not cleared transactions was estimated to be 1,606,863, and by dividing this by business days and adding it up, the average number of cases transacted per day was estimated to be 21,857.[18]

	Yearly total			Daily average		
	Number of cases	Volume (million shares)	(100million yen)	Number of cases	Volume (million shares)	(100million yen)
Centrally cleared transactions FY2021	3,726,272	49,858	1,236,846	15,272	204	5,069
Not centrally cleared transactions FY2021 (estimation)	1,606,863	21,500	533,359	6,586	88	2,186
Total (estimation)	5,333,135	71,358	1,770,205	**21,857**	292	7,255

※Number of cases, volume and value relating to the 'Execution of DVP Book-Entries "(book-entry transfer of securities from Delivering DVP participants to JDCC).

Business days： 244

・The ratio of GC and SC transactions is 48% and 52%[19]

Unit: 100 million yen

	GC	SC	Total
Balance	47,469	50,615	98,084
Share	48%	52%	100%

※Equities vs Cash, Month end average of securities in (average of January 2019 to December 2021)

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[17] Bank of Japan, *Quantitative Analysis of Haircuts: Evidence from the Japanese Repo and Securities Lending Markets,* Table VII

[18] JASDEC, *DVP Settlement Services for NETDs (3) Obligation assumption (stock lending) (1),* FY2021

[19] Bank of Japan, op. cit. (footnote 17), Table VII

- The average number of issues per GC and SC transaction deal is 24.55 and 4.05 based on JSF actual results (April 2022 to September 2022)
- The ratio of foreign currency and Japanese yen transactions is 2% and 98%[20]
- Based on these figures, we arrived at the following estimates:
  - The daily number of GC in stock SFTs = 21,857 securities x 48% ÷ 24.55 securities x (98% + 2%) ÷ 98% = 436
  - The daily number of SC in stock SFTs = 21,857 securities x 52% ÷ 4.05 securities x (98% + 2%) ÷ 98% = 2,864

(Bonds)

- The daily number of Gensaki transactions (Japanese yen) is 5,237[21]
- The daily number of Gensaki transactions (foreign currency) is 5,237 x 12% ÷ 88% = 714 when the share is 88% for Japanese yen and 12% for foreign currencies[22]
- The ratio of Gensaki transactions and securities lending and borrowing transactions is 70% and 30%[23]
- Securities lending and borrowing transactions (Japanese yen) total 5,237 x 30%/70% = 2,244
- Securities lending and borrowing transactions (foreign currencies) total 2,244 x 17%/83% = 460 when the share is 83% for Japanese yen and 17%[24] for foreign currencies

- Combining the above, daily bond SFTs totals 5,237 + 714 + 2,244 + 460 = 8,655

- Totaling stocks and bonds, the daily number of SFTs is estimated to total 436 + 2,864 + 8,655 = 11,955 (approximately 12,000)

- Assuming that these transactions are intensively executed over an hour, in which case the number of transactions executed per minute is 12,000 ÷ 60 minutes = 200. Based on these 200 cases, three patterns, including doubling

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[20] Ibid. Table VII.
[21] Bank of Japan, *Statistics on Securities Financing Transactions in Japan,* the peak until August 31, 2022.
[22] Bank of Japan, op.cit. (footnote 17), Table IV and Table V.
[23] Bank of Japan, op.cit. (footnote 21) .
[24] Bank of Japan, op.cit. (footnote 17), Table IV and Table V.

to 400 during market stress and halving to 100, were established to evaluate the performance of this empirical research.

2. Daily mark-to-market and margin call processing of SFTs

(Stocks)

- After calculating[25] the distribution ratio of the loan period as follows, dividing the 436 daily GC of stock SFTs based on the distribution of loan periods and multiplying them by the average number of times of marking to market (= days) of each, the daily number of GC of stock SFTs subject to mark-to-market and margin call processing was estimated to be 6,012.

	Overnight	2 days or more	More than 1 week	More than 1 month	More than 3 months	Open-end	Total
Share	1%	3%	7%	2%	5%	81%	
Daily number of transactions (A)	5	13	32	10	22	353	436
Average number of times of marking to market (B)	0	4	19	60	180	2	
(A)×(B)	0	50	609	623	4,023	706	6,012

- Similarly, if the 2,864 daily SC of stock SFTs are divided based on the distribution of loan periods and multiplied by the average number of days for each, the daily number of SC of stock SFTs subject to mark-to-market and margin call processing was estimated to be 39,489.

	Overnight	2 days or more	More than 1 week	More than 1 month	More than 3 months	Open-end	Total
Share	1%	3%	7%	2%	5%	81%	
Daily number of transactions (A)	36	82	210	68	147	2,320	2,864
Average number of times of marking to market (B)	0	4	19	60	180	2	
(A)×(B)	0	330	3,998	4,093	26,428	4,641	39,489

(Bonds)

- After calculating[26] the distribution ratio of the loan period as follows, the daily number of bond SFTs subject to mark-to-market and margin call processing was estimated to be 189,563 when dividing the bond 8,655 SFTs by the distribution of loan periods and multiplying by the average number of days for

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25 Ibid. Table VII.
26 Ibid. Table IV, Table V and Table VI.

each.

	Overnight	2 days or more	More than 1 week	More than 1 month	More than 3 months	Total
Share	37%	15%	29%	15%	4%	
Daily number of transactions (A)	3,201	1,300	2,505	1,336	315	8,655
Average number of times of marking to market (B)	0	4	19	60	180	
(A)×(B)	0	5,198	47,587	80,139	56,639	189,563

- Totaling these, the daily number of SFTs subject to mark-to-market and margin call processing was estimated to be 6,012 + 39,489 + 189,563 = 235,064 (approximately 240,000 transactions).

- Three patterns were used for the performance evaluation of this empirical research: 1/3 (80,000 transactions), 1/6 (40,000 transactions), and 1/12 (20,000 transactions) of the approximately 240,000 transactions subject to mark-to-market and margin call processing per day.

Appendix

Members of Each Organization who Participated in this Empirical Research

(Job titles are as of present or during their involvement in this empirical research)

1. Japan Securities Finance Co., Ltd.

Yutaka Okada (Senior Managing Executive Officer)

Morikuni Shimoyamada (Senior Managing Executive Officer; at the time: Executive Officer and General Manager of Business Development Department)

Yuji Yoshimoto (Corporate Officer, at the time: Corporate Officer and General Manager of Business Development Department)

Kenji Ishiyama (General Manager of Business Development Department)

Tetsuya Onodera (Deputy General Manager of Institutional Sales Department, at the time: Deputy General Manager of Business Development Department)

Yusuke Tamai (Deputy General Manager of Business Development Department)

Takumi Ishiyama (Settlement & Custody Department)

2. Tanaka Laboratory, Graduate School of Engineering, The University of Tokyo

Kenji Tanaka (Associate Professor, Department of Technology Management for Innovation, Graduate School of Engineering, The University of Tokyo)

Ryota Suzuki (Project Academic Specialist, Department of Technology Management for Innovation, Graduate School of Engineering, The University of Tokyo)

Kento Maruoka (Department of Technology Management for Innovation, Graduate School of Engineering, The University of Tokyo)

Hirofumi Matsushita (Department of Systems Innovation, Graduate School of Engineering, The University of Tokyo)

3. USD Co., Ltd.

Masashi Uehara (President)

Yuto Yamazaki (Engineer)

Hiromu Oki (Engineer)