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RESEARCH ARTICLE

New Crypto-Secured Lending System with a Two-Way Collateral Function

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Abstract. All existing secured loans, including crypto-secured loans, are provided under the condition that the collateral entrusted by the borrower is kept safe during the loan term. In other words, they use a one-way collateral function. Thus, a frequent drawback of these loans is that the collateral value increases if and only if the collateral price increases. To resolve this problem, this paper proposes a new crypto-secured lending system incorporating a new two-way collateral function. It would allow a borrower to invest proportions of their own collateral by predicting the market in both directions to make profits irrespective of whether the price of the collateral increases or decreases. This benefits the borrower since profit can be made even if the price of the collateral drops, by betting on the price decrease. This new lending system could include a new hedged portion, unlike traditional secured lending systems. As a result, larger loans can be made under this arrangement; further, this portion provides the advantage of reducing the underlying collateral price volatility risk.

1. Introduction

The use of online payments has rapidly increased with the global penetration of the internet and smartphones, as well as the advent of simple payment services. Correspondingly, the importance of cryptocurrencies such as Bitcoin (BTC) and Ethereum (ETH) as online payment methods has been growing steadily. Cryptocurrencies offer advantages over traditional payment methods: borderless and instant transactions with no intermediaries. This technology now facilitates simple financial transactions, such as online transfers and instant payments, globally.

However, a substantial hurdle of using cryptocurrencies on a daily basis is their high price volatility. Because of this, using cryptocurrencies as a medium of exchange or store of value is risky. This means that one party in a contract will most likely suffer economic disadvantages as a result of severe price volatility. For this reason, stablecoins, whose prices are pegged to fiat money such as the US Dollar or commodities such as gold, are sometimes considered the "holy grail of crypto."[1] A stablecoin is a cryptocurrency that, as the name implies, stabilizes the price to maximize usability. One can easily use them to both to pay for goods or services and hedge against market volatility. Many types of stablecoins with different price-pegging algorithms are already actively used. They can be classified into fiat-collateralized, non-collateralized, and crypto-collateralized stablecoins, depending on the type of collateral utilized in a given transaction.[1, 2]

In recent years, decentralized finance (DeFi)—the use of blockchain technologies to provide borderless financial services across nations—has been gradually spreading.[3, 4] One of the most actively used DeFi services is crypto-secured loans. These are similar to conventional loans based on fiat money, except that (as the name implies) cryptocurrencies are used as collateral. Such loans can be classified into two types. The first is a loan paid out in a different extant

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cryptocurrency, as with traditional secured loans. For example, at Compound, a loan can be provided in DAI, a stablecoin, when a borrower deposits ETH as collateral.[5] The second is a new method of lending in which stablecoins are newly issued, similar to a central bank. This was first introduced by MakerDAO.[6] Such a crypto-secured loan has certain advantages over simple cryptocurrency ownership. For example, when a cryptocurrency owner needs cash, they have to sell the cryptocurrency, thereby forfeiting any future profits accruing from price increases. This is a clear drawback. However, with a crypto-secured loan service, not only can the owner use the loan proceeds immediately, but they can also benefit from additional profits when the price of the collateral (*i.e.*, the cryptocurrency) increases over time.

2. Related Work

Today, almost all financial transactions rely on centralized custodial providers because of counterparty risk.[7] In economic transactions, these providers or intermediaries help find transaction partners, establish trust, and settle transactions.[8]

However, distributed ledger technologies (DLTs) can eliminate the need for intermediaries by implementing an immutable digital ledger system in a distributed manner.[8] DLTs can be seen as a database that includes shared and immutable records of ownership registered by participants.[9] This technology enables financial services to be distributed, innovative, interoperable, borderless, transparent, and difficult to censor.[8] For this reason, this technology is actively applied in both financial and non-financial sectors.[10, 11, 12] This can also offer easy access to financial services to individuals who otherwise would not have it, since the technology provides contract execution through a smart contract.[13, 14] Smart contracts are programmed, code-based contracts stored on blockchains that can enforce agreements among mutually non-trusting entities;[15] being coded in advance, they can effectively eliminate intermediaries such as escrow services and central counterparty clearing houses.[9] The Ethereum platform provides Turing-complete language for creating smart contracts specifically for this purpose.[16]

DeFi, also called open finance, replaces intermediaries with smart contracts, which increases the efficiency of financial services, minimizes costs, and enables borderless use.[9, 17] Smart contracts can replace traditional lenders, whose traditional contracts are enforced by the judicial system. Replacing this type of contract can considerably increase the efficiency of transactions, thus helping to turn previously infeasible business models into practicable ones.[8] Because of these potential innovations, many DeFi projects are now competing to replace or supplement traditional finance.[11, 18] As of August 19, 2020, the total amount of funds locked in DeFi was estimated at US $6.3 billion, about six times more than only three months ago.[19] DeFi mainly uses the Ethereum network, but the use of other networks is also on the rise.[20]

DeFi can be broken down into five subcategories: payments, on-chain assets, decentralized exchanges (DEXs), decentralized derivatives, and crypto lending.[19] Payments and on-chain assets are fairly self-explanatory, with the latter including platforms such as SetProtocol and Melon, which provide a basket of crypto-assets.[21, 22]

DEXs are distributed ledger protocols that allow users to trade cryptocurrencies without handing the control of their private keys to an intermediary,[9] and since their trade execution is atomically processed through a smart contract, the other party's risk is reduced.[9] However, DEXs are still in an early development stage, providing higher trade latency, lower liquidity, and less-intuitive user interfaces.[23] The DEXs' counterparty discovery mechanisms, matching

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mechanisms, and transaction settlements are covered by Lindsay X. Lin in her "Deconstructing Decentralized Exchanges" (2019).[23]

Decentralized derivatives are crypto-assets whose values are determined by the performance of an underlying asset and outcome of an event.[9] Because of this, they need an oracle connected to the outside world to trace external variables.[24] Decentralized derivatives can be classified into asset-based and event-based derivative tokens.[9] The former provides various synthetic assets (synths) issued using network-locked collateral.[25, 9] The most popular protocol is Synthetix (https://synthetix.exchange), which provides various tokens that inversely follow underlying asset prices.[25] It includes Augur, which provides a prediction market.[26]

Crypto lending is a fast-growing field in the DeFi ecosystem, where participants borrow money or provide liquidity to earn interest without revealing their identity. Loans can be used to avoid temporary liquidity squeezes or for leverage. [9] In general, crypto lending refers to crypto-secured lending because the collateral is locked in smart contracts and returned after paying back the debt. This lending is completely permissionless, thus eliminating reliable traditional intermediaries, and it can be classified into collateralized debt positions (CDP) and collateralized debt markets (CDMs). [9]

MakerDAO uses CDP. [27] Borrowers generate CDP and receive newly-issued DAI stablecoins supported by collateral.[27] Because of this design, all DAIs issued are always over-collateralized. As a result, such a DAI corresponds to a fully secured loan, whereby a liquid asset is obtained through collateral; however, the risk of *forced liquidation* increases proportionally to increases in the collateral *price volatility*. This is a drawback.

CDMs use existing conventional crypto assets from other people and need to achieve a match between the borrower and lender, much like conventional secured lending.[9] Both parties are usually matched between individuals (peer to peer) and in a pool (*i.e.*, pooled matching).[9] The most popular protocols include Compound and dYdX.[5, 28] A simple review of crypto lending is provided by Binance Research in their "DeFi Series #1" (2019).[3] Interest in crypto lending is detailed on the websites defirate.com and binance.com. [29, 30] Binance also details arbitrage and carries trade strategies that take advantage of interest rate differences in "DeFi Series #2" (2019).[31]

3. Conventional Crypto-Secured Lending Systems

To better understand this lending system, we examine a MakerDAO lending protocol.[6] The protocol is structured as follows. A *borrower* provides ETH to a *collateralized debt position* (CDP, currently called *Vault)*, in a smart contract—an automated program running on the Ethereum network.[6] The CDP (or lender) receives ETH as collateral and lends the DAI. [6] This framework also includes a liquidator to facilitate the liquidation. For example, when the borrower provides ETH worth $10,000 to the CDP, the CDP locks it into the network and issues DAI worth $3,000 to lend it to the borrower (see Fig. 1).

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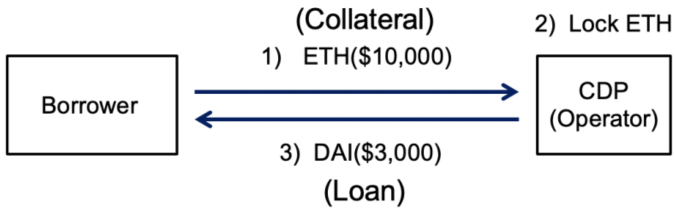

Fig. 1. Loan structure and process of a conventional crypto-secured lending system, MakerDAO. The investment of collateral is a one-way operation for freezing and safekeeping.

As shown in the figure above, DAI is a secured loan based on a *one-way collateral function*, whereby the operator CDP temporarily maintains the borrower's collateral during the loan term. This function is mandatory so the operator can use it to recover the loan amount by liquidating it should the collateral be insufficient. Consequently, every secured loan must include the potential for such forced liquidation. Additionally, the borrower is allowed the option of normal "*repayment*," wherein the borrower returns the whole loan amount to the CDP and reclaims the collateral, thereby terminating the loan. The returned DAIs are then burned or destroyed. Therefore, the value of all other circulated DAI is always maintained by over-collateralized collateral. However, when collateral is liquidated, the borrower suffers the loss caused by a fall in the collateral price and cannot gain from any future increase in the price.

We should note that the borrower is asked to provide high *over-collateralization* when the price volatility of collateral is high. This is because as the price volatility of the collateral increases to the same extent as over-collateralization, the risk of forced liquidation also increases proportionally. Consequently, in every secured loan, assets with low price volatility are inevitably preferred as collateral. However, the BTC price rose about 10.5 times in five months from US $1,883 on July 17, 2017 to US $19,896 on December 17, 2017, according to coinmarketcap.com. Approximately ten months later, the price dropped about 84% to US $3,228 on October 16, 2018. About eight months later, it rose again about 4.2 times to US $13,725 on June 27, 2019. The historical volatility of cryptocurrencies is clearly much greater than that of conventional collateral such as real estate and stock.[32] Because of this volatility, such secured loans inevitably require higher over-collateralization than conventional secured loans. Consequently, the average loan-to-value ratio (LTV) of crypto-secured loans is about 30%, which is much lower than that of conventional collateral assets such as real estate.[33, 34, 35] In secured loans, the loan amount is determined as the value of collateral at the time of loan multiplied by the LTV. The LTV in Fig. 1 is 30%.

3.1 Conventional One-Way Collateral Function—In most conventionally-secured loans, the borrower temporarily entrusts the collateral to the operator, the price of which changes over time, and receives a loan in return. Thus, the collateral is a form of security deposit during the loan term and is returned when the contract is terminated. Deposits are assets such as stocks and real estate that are traded in spot markets.

Thus, all secured loans, including crypto-secured loans, use a *one-way collateral function*. This function can include forced liquidation triggered by insufficient collateral. It allows the value of the collateral to increase/decrease only when the price of the collateral increases/decreases. Therefore, the borrower of conventional loans always has no choice but to

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bet on the price increases of collateral. Thus, conventionally-secured loan collateral assets contain a one-way profit structure that involves betting on the upside profit only. However, this function seriously limits the borrower's options. Let us call these conventionally-secured loans *upside loans*. Here, our questions are as follows: first, is it possible to obtain a loan that provides profit when the value of the underlying asset falls? Let us call this hypothetical loan a *downside loan*. If this is possible, a combined service of these two loans is also possible. Second, is it possible to increase the loan to a higher amount than that of the conventionally-secured loan by reducing the price volatility of collateral?

4. New Crypto-Secured Lending System

To resolve the one-way profit structure, this paper proposes a new crypto-secured lending system that incorporates a new two-way collateral function wherein a borrower can select the investment direction at their discretion.

4.1 New Two-Way Collateral Function—This new lending system provides a new *two-way collateral function* in which a borrower can choose the investment direction and ratio of collateral at their discretion, and thus gain operating profit based on this choice. With this function, a borrower can opt for a "two-way collateral ratio" at the time of the loan. This allows the borrower to increase the collateral value when the price of collateral increases or decreases. With this new function, the collateral could be any of the investment products such as margin trading, derivatives, and exchange traded funds (ETFs), which have the potential to produce profits in both directions (upward and downward) relative to the collateral price. For example, the operator receives a spot asset, such as BTC, as collateral from a borrower, pays out the loan amount, and then invests the collateral in derivative products corresponding to the two-way collateral ratio chosen by the borrower. As seen in Fig. 2, this new lending system collects collateral from a borrower and secures or invests it as two-way collateral. An investment made to increase the value of the collateral when its price increases is referred to as *upside collateral:* these are upside loans. The opposite is *downside collateral*: these are downside loans. Together, they are called *two-way collateral.* Their investments are *upside investment*, *downside investment*, and *two-way investment*, respectively. Let us call the underlying asset of two-way collateral as the "underlying collateral." Now, the borrower can execute the loan by including a combination of upside and downside collaterals or only the downside collateral. For example, if both the upside and the downside collaterals move in line with BTC, their underlying asset is BTC.

4.2 Implementation—This new lending system can be divided into lending, repayment, and forced liquidation processes.

Algorithm—A brief algorithm for this new system is shown below. In the following, $\boldsymbol{\mathcal{L}}$ is the loan amount; $\boldsymbol{P}_{entry}$, $\boldsymbol{P}_{curr}$, and $\boldsymbol{P}_{exit}$ are the entry price, current price, and forced liquidation price of collateral, respectively; $\boldsymbol{C}$ is the number of collateral; $\boldsymbol{r}_{up}$ and $\boldsymbol{r}_{dn}$ are the ratios of upside and downside collateral, respectively; $\boldsymbol{r}_{liq}$ is the (forced) liquidation ratio;

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$\boldsymbol{I_{up}}$ and $\boldsymbol{I_{dn}}$ are the upside and downside investments, respectively; and $\boldsymbol{req}$ refers to the liquidation request of the borrower.

■ **Lending**

Input: The borrower provides the operator with the collateral $(\boldsymbol{C})$, the ratios of upside and downside collateral $(\boldsymbol{r_{up}}, \boldsymbol{r_{dn}})$ and the liquidation ratio $(\boldsymbol{r_{liq}})$.

Output: The operator invests the collateral $(\boldsymbol{C})$ in upside and downside investments $(\boldsymbol{I_{up}}, \boldsymbol{I_{dn}})$ and disburses the loan to the borrower.

Operator ← $\boldsymbol{C}$;
Calculate the entry price and the forced liquidation price $(\boldsymbol{P_{entry}}, \boldsymbol{P_{exit}})$;
$\boldsymbol{I_{up}}, \boldsymbol{I_{dn}}$ with $\boldsymbol{r_{up}} \& \boldsymbol{r_{dn}} \leftarrow \boldsymbol{C}$;
Calculate the loan amount $(\boldsymbol{\mathcal{L}})$
Borrower ← $\boldsymbol{\mathcal{L}}$;
$\boldsymbol{req}$ = false;

■ **Repayment**

Input: Check the liquidation request of borrower ($\boldsymbol{req}$ == true).

Output: The borrower returns the loan amount to the operator and receives the investment profit of the collateral.

if ($\boldsymbol{req}$) then
Operator ← $\boldsymbol{\mathcal{L}}$;
$\boldsymbol{C} \leftarrow \boldsymbol{I_{up}}, \boldsymbol{I_{dn}}$ & Borrower ← $\boldsymbol{C}$;

■ **Forced liquidation**

Input: The current price $(\boldsymbol{P_{curr}})$ has reached the forced liquidation price $(\boldsymbol{P_{exit}})$.

Output: The upside and the downside investments are liquidated.

if ($\boldsymbol{P_{curr}} == \boldsymbol{P_{exit}}$) then
All investments $(\boldsymbol{I_{up}}, \boldsymbol{I_{dn}})$ are withdrawn and liquidated.

Loan Amount and Forced Liquidation—MakerDAO's service pays out the loan after locking collateral of 150% or more in CDP, which is the minimum collateral-to-debt ratio.[6] Forced liquidation occurs when the residual value of the collateral is less than this ratio. For reference, if the collateral-to-debt ratio is 150%, the LTV is 66.7% and the two are in a reciprocal relationship. The borrower can apply for a loan through Oasis, a MakerDAO app and non-custodial exchange. However, because the loan amount is calculated by the Oasis collateral-to-debt ratio, it is difficult for the borrower to keep track of the price at which the forced liquidation occurs.

In contrast, we have introduced a new liquidation ratio $(\boldsymbol{r_{liq}})$ so that the forced liquidation will be determined by this ratio chosen by the borrower in the new lending system. The forced liquidation price $(\boldsymbol{P_{exit}})$ is calculated directly from the liquidation ratio $(\boldsymbol{r_{liq}})$, as shown in Eq. (1) below. The forced liquidation is executed at this price in the new lending system. The "main investment direction" is the direction of the profit-generating price and corresponds to the

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direction of 50% or more in the ratio of the two-way collateral; the opposite of this is the "opposite investment direction." For example, if the liquidation ratio is 70% (the upside collateral and the downside collateral are 70:30), the main investment direction is the direction of the upside collateral; that is, the direction of increasing price. Therefore, forced liquidation occurs when the price of underlying collateral falls because the forced liquidation occurs when the market moves in the opposite investment direction.

$$\boldsymbol{P}_{exit} = \begin{cases} \boldsymbol{P}_{entry}(1 - \boldsymbol{r}_{liq} \,/\, 100), & \boldsymbol{r}_{up} \geq 0.5 \\ \boldsymbol{P}_{entry}(\mathbf{1} + \boldsymbol{r}_{liq} \,/\, 100), & \boldsymbol{r}_{up} < 0.5 \end{cases} \tag{1}$$

The loan amount ($\boldsymbol{\mathcal{L}}$) is determined by the residual value of collateral when the current price of the underlying collateral reaches the forced liquidation price, as expressed in Eq. (2). This equation can be easily obtained from Table 1 below.

$$\boldsymbol{\mathcal{L}} = \begin{cases} \boldsymbol{P}_{entry}\,\boldsymbol{C}\,(\boldsymbol{r}_{up}(1 - \boldsymbol{r}_{liq}) + \boldsymbol{r}_{dn}(1 + \boldsymbol{r}_{liq})), & \boldsymbol{r}_{up} \geq 0.5 \\ \boldsymbol{P}_{entry}\boldsymbol{C}(\boldsymbol{r}_{up}(1 + \boldsymbol{r}_{liq}) + \boldsymbol{r}_{dn}(1 - \boldsymbol{r}_{liq})), & \boldsymbol{r}_{up} < 0.5 \end{cases} \tag{2}$$

However, it should be noted that the new forced liquidation that did not exist before can also occur in the profit-generating main investment direction because this new lending system includes two-way collateral. Let us call this the "forced liquidation by profit" while calling conventional forced liquidation the "forced liquidation by loss." The latter occurs when the residual value of the underlying collateral is at risk of being smaller than the loan amount, as mentioned earlier. However, the former occurs when the value of investment in the opposite investment direction among the two-way collateral is due to the risk of being negative. This problem occurs only when the ratio of upside collateral ($\boldsymbol{r}_{up}$) is smaller than 50% because the price of underlying collateral is open infinitely in the upward direction but limited to zero in the downward direction. Nevertheless, if leverage tokens are included as two-way collateral, this situation can occur more easily.

4.3 A-COIN Stablecoin—In this new lending system, the *A-COIN stablecoin*—with its value pegged to US $1.00, similar to DAI—is newly issued for the loan amounts and is burned at repayment—again, similar to DAI. In this case, a market exchange is added to the structure of the conventional secured loan for two-way collateral, as shown in Fig. 2. Therefore, two-way collateral is used as an investment and not simply for collateral.

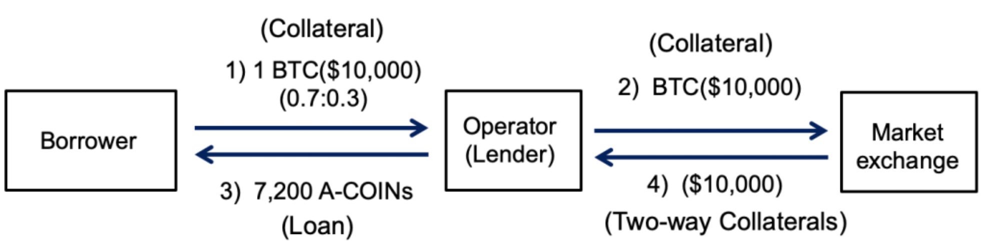

Fig. 2. An A-COIN loan process (the two-way collateral ratio is 70:30).

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Fig. 2 illustrates this new lending process. In this example, the borrower chooses 70:30 as the two-way collateral ratio at the time of the loan, and thus provides 1 BTC valued at US $10,000 as collateral to the operator. In other words, the borrower chooses to invest 0.7 BTC as the upside collateral and 0.3 BTC as the downside collateral. The operator then invests 1 BTC in market exchange products according to this two-way collateral ratio. Furthermore, the operator issues the A-COIN of US $7,200 and pays it out to the borrower as the loan amount, thereby completing the issuance process. The arrows and numbers in Figs. 2 and 3 indicate the direction and sequence of the process, respectively. However, unlike the figure below, the two-way collateral can be stored in the operator's account in the exchange.

Fig. 3 illustrates the repayment process for this new lending system. The operator of a new lending system cancels the contract for the two-way collateral invested in the market exchange according to the given two-way collateral ratios, and returns them to the borrower on the loan's repayment. This process is as follows: the loan is repaid when the borrower returns 7,200 A-COINs, the loan amount, to the operator, as shown in Fig. 3. Then, the operator burns all A-COIN received from the borrower and recovers all two-way collateral invested on the market exchange, and returns it as investment profit to the borrower, thereby completing the repayment process. Unlike in Figs. 2 and 3, the collateral and the repayable amount can be delivered to their final destinations without going through the operator. Furthermore, because the A-COIN issued in the loan process is burned at repayment, these two processes have no impact on the total A-COIN issuance volume.

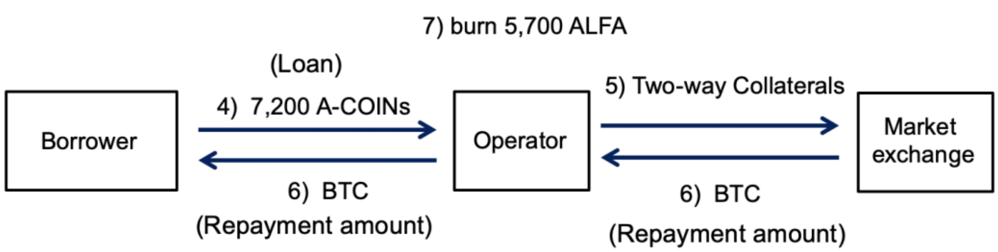

Fig. 3. The repayment process of A-COIN (the investments are withdrawn from the market exchange and returned to the borrower on repayment).

4.4 Market Exchange—Two-way collateral can utilize margin trading or derivatives of the cryptocurrency market exchange. At present, many centralized exchanges capable of providing the two-way collateral function exist. In December 2017, the Chicago Mercantile Exchange (CME) and the Chicago Board of Trade (CBOT) commenced trading in Bitcoin futures.[36] In addition, centralized market exchanges, such as BitMEX, FTX, OKEx, and Binance, provide sufficient volumes of derivatives or margin trading with BTC as an underlying asset.

Furthermore, the new lending system can be operated in a decentralized exchange (DEX) for two-way collateral if it meets the market conditions. For example, the operator in Figs. 2 and 3 can be turned into smart contracts to provide a fully-decentralized secured lending system. If the two-way collateral function is implemented on DEX, anyone can transparently check the issuance volume of A-COIN and the status of the collateral on the blockchains. Currently, however, the trading volume is generally insufficient for DEXs where derivatives of cryptocurrencies are traded. Examples of DEXs supporting ETH include the dYdX exchange and the Synthetix Exchange. At present, iBTC, iETH, *etc.*, of the Synthetix Exchange can be

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used as downside collateral.[25] Another way to utilize the two-way collateral function is to use "leverage tokens," which are similar to ETF. The Ethereum-based "leverage tokens" on FTX.com are a good example.[37] If diverse ETFs tracking a Bitcoin index or leverage are commercialized in the near future, two-way collateral functions will be utilized more efficiently with them.

In general, the collateral of the borrower and two-way collateral are the same in the new system. This means that if the collateral of the borrower is BTC, then the two-way collateral uses derivatives that follow BTC as the underlying asset as well. However, in a departure from this process, in the new lending system, the collateral and the two-way collateral may be different. Simply put, the borrower may select two-way collateral from a basket of possibilities containing various investment products. For example, if the borrower deposits BTC as collateral and chooses BTC (30%) and ETH (70%) for upside and downside collateral assets, respectively, then the operator can execute the investments accordingly.

5. Results

Not only can the new lending system pay out a larger loan amount than the traditional lending systems under the same forced liquidation condition, but it can also reduce the price variation risk of collateral (low-risk variation). Let us examine this point.

5.1 Larger Loan Amounts—The new lending system can provide larger loan amounts than conventional secured loans, with the same forced liquidation conditions. This advantage becomes possible because of the system's hedged portion, which does not exist in conventional secured loans, but is now included because of the new two-way collateral function. To fully understand this, let us examine how the loan amount is determined.

Table 1. The loan amount calculated using the conventional method (liquidation ratio: 70%)

Two-way Collateral Ratio (Upside % : Downside %)	Bitcoin spikes at 70%			Bitcoin tanks at 70%			Loan Amount	LTV
	Upside collateral	Downside Collateral	Two-way Collaterals	Upside Collateral	Downside Collateral	Two-way Collaterals		
100%:0% (Conventional)	$17,000	$0	$17,000	*$3,000*	*$0*	*$3,000*	$3,000	30%
90% : 10%	$15,300	$300	$15,600	*$2,700*	*$1,700*	*$4,400*	$4,400	44%
80% : 20%	$13,600	$600	$14,200	*$2,400*	*$3,400*	*$5,800*	$5,800	58%
70% : 30%	$11,900	$900	$12,800	*$2,100*	*$5,100*	*$7,200*	$7,200	72%
60% : 40%	$10,200	$1,200	$11,400	*$1,800*	*$6,800*	*$8,600*	$8,600	86%
50% : 50%	$8,500	$1,500	$10,000	$1,500	$8,500	$10,000	$10,000	100%
40% : 60%	*$6,800*	*$1,800*	*$8,600*	$1,200	$10,200	$11,400	$8,600	86%
30% : 70%	*$5,100*	*$2,100*	*$7,200*	$900	$11,900	$12,800	$7,200	72%
20% : 10%	*$3,400*	*$2,400*	*$5,800*	$600	$13,600	$14,200	$5,800	58%
10% : 90%	*$1,700*	*$2,700*	*$4,400*	$300	$15,300	$15,600	$4,400	44%
0% : 100%	*$0*	*$3,000*	*$3,000*	$0	$17,000	$17,000	$3,000	30%

Note: Collateral = 1 BTC; the prices of Bitcoin, upside collateral, and downside collateral at the time of loan commitment = $10,000; Upside and downside collateral area (1x) long position and (-1x) short position, respectively. The two-way collateral ratio of 100:0 corresponds to a conventional secured loan.

ISSN 2379-5980 (online)
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Table 1 shows the calculation process for the loan amount in this new lending system. In all tables in this paper, we assume the borrower deposits 1 BTC as collateral, and the operator uses the collateral to make the upside and the downside collateral assets in a product having a (1x) long position and a (-1x) short position, which follow exactly one time in the upward and downward directions, respectively, based on the price of Bitcoin (or underlying collateral). Therefore, in the upside collateral, the collateral is safekept "as-is" in the wallet of the operator. Additionally, an ideal scenario is assumed in which the price of Bitcoin, upside collateral, and downside collateral at the time of the loan are all $10,000, with no commission fee. Furthermore, the liquidation ratio ($\boldsymbol{r}_{liq}$) is set at 70% in all the tables of this paper. The total value of the upside and downside collaterals is calculated directly from this liquidation ratio. In other words, as shown in the table, when the liquidation ratio is 70%; that is, when the BTC price changes ±70%, the value of the two collaterals is calculated from various two-way collateral ratios. It should be noted that the numbers shown in italics in Table 1 correspond to the opposite investment direction, and forced liquidation by loss occurs in this direction. For example, with a 70:30 collateral ratio because the upside collateral (70%) is larger than the downside collateral (30%), the main investment direction is the direction in which the price increases more than the BTC price at the time of loan commitment. Therefore, forced liquidation by loss occurs when the BTC price falls.

It is very important that the new *hedged portion* is newly introduced, with part of the two-way collateral being hedged by the two-way collateral ratio. Conventional secured lending systems cannot include this hedged portion. With a 70:30 collateral ratio, for example, 30% of the two-way collateral in both the upside and downside collateral (*i.e.*, a total of 60%) is completely hedged against each other. Therefore, this portion always maintains the same value as at the time of the loan provision, irrespective of price changes of Bitcoin after the loan commitment. This represents a "stable portion" of two-way collateral, in which the value of the two-way collateral does not change during a loan period. The remaining 40% is the *unhedged portion* because the value of this portion changes with the price fluctuation of Bitcoin. This represents an "unstable portion" of two-way collateral. In this case, therefore, the two-way collateral's hedged and unhedged portions equal 0.6 BTC and 0.4 BTC, respectively.

Fig. 4 shows what the LTV looks like where the two-way ratio changes in Table 1. The major advantage of this new lending system is that the loan amount increases greatly as the two-way collateral ratio approaches 50:50. This means that a borrower can get up to 100% LTV because of the new price-stable hedged portion, although doing so would have no benefit over simply selling the BTC at market rates and not taking out a loan at all. Because the value of the two-way collateral's hedged portion does not change, the maximum value of this portion's value can be paid out as the loan amount in ideal conditions. In this case, a lack of this value does not occur, and in Table 2, the loan amount is paid out maximally. Therefore, LTV becomes 100% for the table's 50:50 collateral ratio. This table thus demonstrates that the collateral ratio (100:0), containing only the upward collateral, corresponds to a conventional secured lending system. Therefore, in the table, the conventional system corresponds to a case in which only the upside collateral is included among various two-way collateral ratios of the new lending system. Additionally, its LTV (30%) is the smallest among the various collateral ratios. This is because conventional secured loans include only an unhedged portion. Here, it is easy to see that as the liquidation ratio decreases, the LTVs in most of the two-way collateral ratios in Table 1 increase the loan amount. This is because forced liquidation occurs, even if the price of the underlying

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collateral fluctuates less widely. In other words, this causes the residual value to increase when forced liquidation occurs.

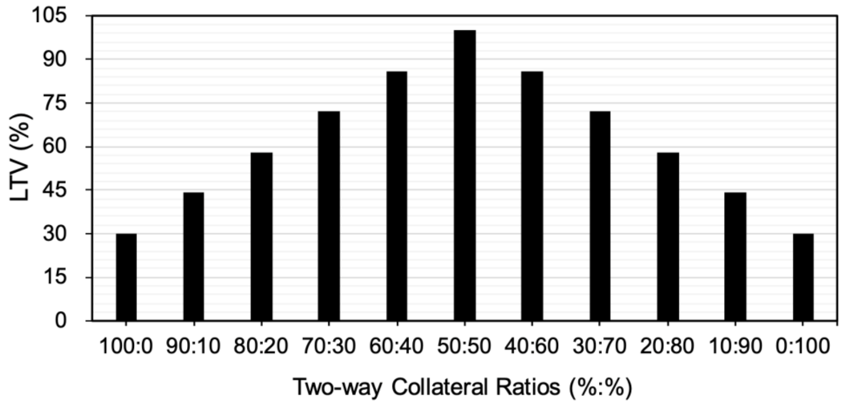

Fig. 4 LTV ratios by two-way collateral ratios in Table 1.

In sum, the loan amounts in this table are different under the same forced liquidation condition (*i.e.*, the same liquidation ratio) because the hedged part, in which the collateral value remains constant, can be newly included. As the proportion of the hedged section increases in the two-way collateral due to the two-way collateral ratio, the loan amount increases proportionally. Therefore, the substantive advantage of this new lending system is that larger loan amounts can be paid out at the cost of potential gain due to upward price of collateral.

5.2 Lower Risk Variation—Now, let us examine this advantage with repayment scenarios. To do this, let us consider Table 2 to examine the borrower's profit and loss (PNL) ratio at repayment. Let us assume that a Bitcoin price is $10,000 at the time of loan commitment and the price is changed by ±50% at the time of repayment, so the two-way collateral is settled at US $15,000 and US $5,000, respectively. The calculation conditions for this table are the same as those listed in Table 1.

Let us look at the borrower's PNL at the time of repayment when the collateral ratio is 70:30. In this case, if the two-way collateral is all liquidated after the Bitcoin price increases by 50%, the borrower receives 0.8 BTC and loses 0.2 BTC, as the table shows, but the profit, calculated in dollars, is 20%. However, if the Bitcoin price drops by 50% under identical conditions, the borrower receives 1.6 BTC, gaining 0.6 BTC, but the final dollar profit is -20%. In sum, the dollar PNL is ±20% in this case. However, notably, the PNL ratio of conventional secured loans under the same conditions is ±50%, which is the same as the fluctuation range of the Bitcoin price. Therefore, in Table 2, the two-way collateral ratio of 100:0 corresponds to a conventional secured loan (*i.e.*, upside loans), that of 0:100 is new downside loans, and the rest is a combination of the two. What is most important to note is that as the two-way collateral ratio approaches 50:50 in the table, the PNL ratio calculated in dollars decreases significantly. It decreases from ±50% to 0%. It is calculated at a condition where the Bitcoin price changes by ±50% identically. This means that in the new lending system, the dollar PNL ratio can reduce the risk induced by the collateral price change. In sum, the new lending system has the

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advantage that the borrower can include the hedged portion to reduce the risk caused by the collateral price change. Naturally, this is an advantage provided by the new hedged portion.

Table 2. PNL ratio of borrower at various two-way collateral ratios when Bitcoin price changes ± 50%

Two-way Collateral Ratio (Upside % : Downside %)	Unhedged Protion of Collateral	Hedged Portion of Collateral	Bitcoin price spikes at 50%			Bitcoin price tanks at 50%		
			Value of Collateral	Value of Collateral	Dollar PNL	Value of Collateral	Value of Collateral	Dollar PNL
100% : 0% (Conventional)	1.0 BTC	0.0 BTC	$15,000	1.00 BTC	50%	$5,000	1.00 BTC	-50%
90% : 10%	0.8 BTC	0.2 BTC	$14,000	0.93 BTC	40%	$6,000	1.20 BTC	-40%
80% : 20%	0.6 BTC	0.4 BTC	$13,000	0.87 BTC	30%	$7,000	1.40 BTC	-30%
70% : 30%	0.4 BTC	0.6 BTC	$12,000	0.80 BTC	20%	$8,000	1.60 BTC	-20%
60% : 40%	0.2 BTC	0.8 BTC	$11,000	0.73 BTC	10%	$9,000	1.80 BTC	-10%
50% : 50%	0.0 BTC	1.0 BTC	$10,000	0.67 BTC	0%	$10,000	2.00 BTC	0%
40% : 60%	0.2 BTC	0.8 BTC	$9,000	0.60 BTC	-10%	$11,000	2.20 BTC	10%
30% : 70%	0.4 BTC	0.6 BTC	$8,000	0.53 BTC	-20%	$12,000	2.40 BTC	20%
20% : 10%	0.6 BTC	0.4 BTC	$7,000	0.47 BTC	-30%	$13,000	2.60 BTC	30%
10% : 90%	0.8 BTC	0.2 BTC	$6,000	0.40 BTC	-40%	$14,000	2.80 BTC	40%
0% : 100%	1.0 BTC	0.0 BTC	$5,000	0.33 BTC	-50%	$15,000	3.00 BTC	50%

Note: Collateral = 1 BTC; the prices of Bitcoin, upside collateral, and downside collateral at the time of loan commitment = $10,000; Upside and downside collateral assets are a (1x) long position and (-1x) short position, respectively. The two-way collateral ratio of 100:0 corresponds to a conventional secured loan.

5.3 Advantages of New Lending System—The most important advantage of the new lending system is that, unlike a conventional secured loan, the borrower can use the new two-way collateral function to include the new hedged portion in the loan amount. The advantages of the new lending system proposed in this paper are summarized as follows.

(1) **New Two-way Collateral Function**. The borrower can invest in both the price increase and the price decrease of underlying collateral according to his/her investment propensities. Therefore, a borrower gains by increasing the proportion of the downside collateral in the collateral, even if the price of underlying collateral drops.
(2) **Larger Loan Amount**. Larger loan amounts can be paid compared to conventional secured loans. In other words, a borrower can receive a larger loan amount by including more of the new hedged portion.
(3) **Lower Risk Variation**. This new lending system can reduce the risk caused by the price volatility of the underlying collateral. The borrower can increase the new hedged portion to reduce the risk of the collateral's price volatility.
(4) **Scalability**. The new lending system can be applied to all fiat-money-based secured loans, which facilitate the two-way collateral function. In other words, this new crypto lending can be applied to *any* arbitrary asset or product that facilitates the two-way collateral function.
(5) **Leverage**. The borrowers of DAI, a traditional crypto-secured loan, are already taking advantage of leverage. They use leverage to borrow repeatedly by repurchasing ETH, the collateral, using the loan proceeds; they use leverage by gradually decreasing the loan amount. Borrowers can use the same leveraging method in the new lending system. However, the new crypto lending system allows borrowers to leverage collateral by investing in derivative products. For example, if a borrower selects a three-time (x3)

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leverage, the operator invests the two-way collateral in a corresponding derivative product, thereby providing borrower leverage.

6. Conclusion

In traditional secured loans (*i.e.*, upside loans), the value of the collateral must be exposed to risk derived from market volatility, and a borrower has no choice but to face it since there is no hedging strategy. A borrower cannot choose the investment direction of collateral according to the current market environment. To address and resolve this issue, this paper introduces a crypto lending system with a new two-way collateral function, in which borrowers can use new downside loans, alone or in combination with standard upside loans. This has the advantage of providing borrowers with the option of betting on price increases and decreases of the underlying collateral by predicting the market direction, which can thus increase the underlying collateral's value. The borrower can use this function to make a profit even if the price of the underlying collateral drops. An additional advantage of this system is that the loan includes a hedged portion against opposite price movements, unlike conventional secured loans. This new portion not only allows greater loan amounts than that of conventional secured loans, but also provides a method to reduce the risk of the underlying collateral's price volatility.

Although we have introduced the two-way collateral function as an answer to our questions, we have also shown the disadvantage of two-way collateral, which may cause forced liquidation in both directions. Consequently, more research is required to avoid this problem.

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