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# Can on-chain lending markets carry institutional repo?

## Liquidation buffers against euro government bond risk, and on-chain borrowing rates against SOFR and €STR, 2024 to 2026

Khai Uy Pham*

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**Abstract**

We ask whether a lending protocol, the pooled and overcollateralised loan market of decentralised finance, can carry the secured funding that banks obtain through repo. Protection: on Morpho Blue the cash lender keeps a buffer of 1 − LLTV × LIF before bad debt, 1.41% of collateral value at the highest enabled loan-to-value of 98%; on ECB yield curves since 2004, it covers the 99% loss of a AAA euro zero-coupon bond of up to five years over five business days, and of ten years over one day, for price risk alone. Process: at 98% the liquidator's incentive of 0.60% is smaller than the 99% one-day loss of a ten-year bond it must hold before selling. Price: over the twelve months to October 2026, rates in current on-chain markets showed no detectable weekly relation to SOFR or €STR, moved with policy decisions in half of the cases, and euro stablecoin borrowing cost about 200 basis points over the ECB deposit facility rate. Markets that differ only by their crypto collateral charged rates within a median of 7 basis points: collateral risk enters through the loan-to-value, not the rate. No public market lending against tokenised government bonds themselves can yet be observed. An institutional market would need term rates anchored on the policy rate, committed liquidators, and cash in central bank money.

**JEL classification:** G23, E43, E44, G21, G28

**Keywords:** repo, secured funding, decentralised lending, liquidation, haircut, tokenised collateral, central bank money, interest rate formation

* Aiko Academy, research@aiko-academy.eu. Version 2.0 supersedes "On-Chain Repo Architectures and Institutional Liquidity Management", version 1.0 of 22 January 2026. The views expressed in this publication are those of the author and do not necessarily reflect those of Aiko Academy or Aiko Kapital. This publication is for information and research purposes only. It is not investment advice, nor an offer or solicitation to buy or sell any asset or service.

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**Key findings**

1. **Protection:** at the highest Morpho Blue loan-to-value (98%) the lender's buffer before bad debt is 1.41% of collateral value; 0.60% of the 2% gap goes to the liquidator.
2. **Collateral:** the 99% loss of a AAA euro zero-coupon bond is 0.22% (2 years) and 1.08% (10 years) over one business day, 0.52% and 2.60% over five; a 98% loan-to-value covers up to five years at five days, ten years at one day only.
3. **Liquidators:** at 98% the 0.60% incentive exceeds the 99% one-day loss of a two-year bond by 0.38 points but falls 0.48 points short for a ten-year bond; at 94.5% every maturity clears at one day.
4. **Benchmarks:** Eurosystem haircuts on zero-coupon government bonds (2.0% to 5.0%, 6.0% at ten years from 30 November 2026) exceed every 99% loss measured here; Aave Horizon keeps buffers of 5.1% to 9.7% at the liquidation threshold on tokenised funds.
5. **Rates:** weekly changes of on-chain rates show no detectable relation to SOFR or €STR; around nine policy decisions they moved in the policy direction in 13 of 26 cases; EURC borrowing cost 202 bps over the ECB deposit facility rate.
6. **Collateral and isolation:** in three Morpho markets with different crypto collateral and the same loan-to-value, rates stayed within a median of 5 to 7 bps of each other; in the April 2026 run the pooled Aave rates reached 14.2% (USDC) and 19.1% (EURC), isolated markets 4.6% to 8.4%.

## 1 Introduction

Repo is the main channel through which banks and other financial institutions turn securities into cash for a day or a few weeks. The 60 entities, from 52 financial groups, in the semi-annual survey of the International Capital Market Association (ICMA) held EUR 14,916 billion of repo and reverse repo on 10 June 2026 (International Capital Market Association 2026d), and SOFR, the rate of overnight Treasury repo in the United States, was computed on USD 3,086 billion of transactions on 26 October 2026 (Federal Reserve Bank of New York 2026). Two sets of changes now reach this market at once. The first keeps the legal contract and moves the ledger: Broadridge's Distributed Ledger Repo processed USD 359 billion of repo a day on average in September 2026 (Broadridge 2026b), and ICMA counts it and J.P. Morgan's Kinexys as the only two ledger-based repo platforms in regular and substantial commercial use by the end of 2025 (International Capital Market Association 2026c). The second changes the contract itself: in decentralised finance (DeFi), lending protocols such as Aave and Morpho run pooled loan markets in which borrowers post collateral to a smart contract, borrow against it up to a fixed loan-to-value, and are liquidated by any third party when they cross it. Since August 2025 a dedicated instance of Aave, Horizon, has accepted shares of tokenised Treasury bill, credit and crypto carry funds as collateral for stablecoin loans (Aave Labs 2025). And central banks are building the settlement asset these markets lack: the Eurosystem launched Pontes on 21 September 2026 to settle wholesale tokenised transactions in central bank money (European Central Bank 2026b), and the BIS Innovation Hub reported on Project Agorá, which brings tokenised deposits and central bank money onto one platform (Bank for International Settlements 2026).

This paper asks whether the second architecture, the public lending protocol, can carry institutional repo. Version 1.0 of this paper, published in January 2026, argued that it could, given modular markets, safe settlement assets and a legal wrapper. Its

argument rested on three claims we now test with data: that the loan-to-value of a lending market is the algorithmic analogue of a haircut, that margining becomes continuous, and that pricing becomes asset-based rather than relationship-based. A repo desk relies on three things, and we measure each of them. Protection: does the liquidation threshold leave the cash lender a buffer that covers the price risk of good collateral, as a haircut does? Process: will a third party actually liquidate tokenised bonds at the incentive the market pays? Price: is the rate of an on-chain secured loan a repo rate, anchored on the policy rate and reflecting the collateral?

The paper makes four contributions. First, it maps the repo lifecycle onto the primitives of an isolated lending market, corrects the statements of version 1.0 that do not hold, and derives the buffer a lender keeps before bad debt and the condition under which a liquidator acts, both as functions of the loan-to-value. Second, it measures the tail price risk of euro area government bonds over one to ten business days on the ECB yield curves since 2004, with bootstrap intervals, and turns it into the highest loan-to-value each maturity supports. Third, it compares on-chain secured borrowing rates with SOFR, €STR and the ECB deposit facility rate over a year and around nine policy decisions since 2024, and tests whether rates differ with the collateral. Fourth, it draws the conditions an institutional market would need. Every number comes from public data and the scripts listed in Appendix B.

The paper relates to three strands of work. The empirical repo literature shows how haircuts and rates depend on collateral, lenders and relationships, and how they behave in a run (Hu et al 2021; Julliard et al 2022; Gorton and Metrick 2012; Copeland et al 2014). The literature on DeFi lending describes the mechanics of lending pools and their rate models (Bartoletti et al 2021; Gudgeon et al 2020), finds that borrowing there is driven mainly by speculation and, to some extent, governance motives (Cornelli et al 2025), that wallet leverage, the ratio of assets to equity, typically ranges from 1.4 to 1.9 (Heimbach and Huang 2024), and that liquidations sell collateral at a discount, with price impact and contagion (Qin et al 2021; Lehar and Parlour 2022; Chiu et al 2023). And the work of central banks on tokenisation sees repo as a natural next setting for a ledger that holds central bank money, deposits and government bonds together (Bank for International Settlements 2025). We add measurements that connect them: the protection a lending market gives a cash lender against the price risk of government bonds, the incentive it leaves to the liquidator, and the behaviour of on-chain rates against repo benchmarks.

The rest of the paper is organised as follows. Section 2 describes repo as it is traded and settled today. Section 3 describes lending protocols and sets them against repo. Section 4 gives the framework, Section 5 the data, Section 6 the results. Section 7 draws design implications, Section 8 states the limits, and Section 9 concludes.

## 2 Repo as it is traded today

### 2.1 Contract, settlement and margin

A repo is a sale of securities with an agreement to buy them back at a fixed price on a later date. Economically it is a secured loan: the cash lender receives the securities as collateral and the price difference as interest. Legally, a true repo transfers title to the collateral rather than creating a pledge (International Capital Market Association 2026d), which is what allows the cash lender to sell or reuse the securities and, under the Global Master Repurchase Agreement (GMRA) that governs most cross-border

repo, to close out all transactions on a default and net them into one amount. Regulators recognise that netting for capital purposes when it is supported by legal opinions, which ICMA updates each year for 75 jurisdictions (International Capital Market Association 2026a). Three features of the market matter for what follows.

Settlement is already delivery versus payment (DvP): in the euro area, T2S settles the securities and the cash simultaneously in central bank money (European Central Bank 2026d), so principal risk, the risk of delivering one leg without receiving the other, is eliminated without a blockchain (Committee on Payment and Settlement Systems and Technical Committee of the International Organization of Securities Commissions 2012). DvP does not remove the risk that a settlement fails and must be retried. Version 1.0 described repo as constrained by T+1 and T+2 settlement lags and exposed to Herstatt risk. Both statements were wrong. Herstatt risk is the risk of the two legs of a foreign exchange trade settling in different time zones, which payment versus payment addresses. And the start of a repo is negotiated: parties agree a purchase date on the day of the trade, the next business day, two or three business days later, or further forward (International Capital Market Association 2025). Repo tends to settle one business day earlier than the cash market in the same security (International Capital Market Association 2025), and the move of EU securities settlement to T+1 on 11 October 2027 exempts repo documented as a single transaction of two linked operations (European Parliament and Council of the European Union 2025). In the ICMA survey, 26.2% of outstanding repo had one day to run, 6.7% was open and 7.1% was forward-starting (International Capital Market Association 2026d). What remains true is that settlement runs on the hours of payment and settlement systems, which a ledger running at all hours could extend.

Margin is set in two steps. At the start, the haircut makes the cash smaller than the market value of the collateral; during the life of the trade, margin calls under the master agreement restore that ratio when prices move. The haircut thus protects the cash lender against the price move between two margin calls plus the time needed to sell the collateral after a default.

Terms are negotiated, but less than version 1.0 suggested. In US tri-party repo, the dispersion of haircuts and rates is large for equity and lower-grade corporate bond collateral and almost absent for Treasuries, and the lending fund families, not the dealers, drive it (Hu et al 2021). In UK bilateral repo, relationships matter: borrowers with repeated relationships receive lower or zero haircuts, and about 35% of bilateral transactions carry no haircut at all (Julliard et al 2022). Under stress, an index of average haircuts on non-Treasury repo collateral rose from zero in early 2007 to nearly 50% in late 2008 (Gorton and Metrick 2012), while tri-party margins stayed stable for most borrowers apart from Lehman Brothers (Copeland et al 2014). Rates, by contrast, are anchored on the central bank's policy rates, and SOFR is itself a measure of the cost of overnight borrowing against Treasury securities (Federal Reserve Bank of New York 2026).

### 2.2 Tokenised repo keeps the contract

The repo platforms built on distributed ledgers keep this contract and change the record. Broadridge's platform supports tokenised US Treasury collateral, intraday repo and collateral pledges (Broadridge 2026a); its volumes are turnover, the surge of the second half of 2025 was reportedly driven by sponsored repo in the United States (International Capital Market Association 2026c), and they are not comparable with

the outstanding amounts of the ICMA survey. Kinexys reports over USD 4 trillion processed since inception across its platform, about USD 7 billion a day, without a figure for repo alone (J.P. Morgan 2026). ICMA counts 34 publicised tests and transactions between 2017 and the end of 2025, describes the two platforms in production as walled gardens that serve their existing clients, and finds that legal and regulatory uncertainty about digital cash and assets still holds back production use (International Capital Market Association 2026c). Other work is still at the pilot stage, such as the cross-border intraday repo of tokenised gilts on the Canton Network in February 2026 (Digital Asset 2026). The Eurosystem decided on 27 January 2026 to accept marketable assets issued in central securities depositories using ledger-based services as collateral from 30 March 2026, while assets issued and settled entirely on a ledger were not yet eligible (European Central Bank 2026a). ICMA's Digital Assets Annex to the GMRA, published in August 2024, extends the definitions of securities and cash to platform-transferred securities and digital cash (International Capital Market Association 2024), and ICMA's Digital Bonds Annex of April 2026 covers natively issued digital bonds (International Capital Market Association 2026b); neither redefines repo (International Capital Market Association 2026c).

These platforms show that a shared ledger can shorten the cycle to intraday tenors and move collateral faster, but their participants still sign a master agreement, settle cash through the usual channels and manage default through close-out netting. They answer a question of operations, not of contract design.

## 3 Lending protocols as a repo market

### 3.1 The isolated market

A lending protocol replaces the bilateral contract with a pooled one. On Morpho Blue, which we use as the reference because its markets are isolated and its parameters are fixed at creation, a market is defined by five parameters: the loan asset, the collateral asset, a price oracle, an interest rate model and a liquidation loan-to-value (LLTV) (Gontier Delaunay et al 2023). Anyone can create a market, but the LLTV and the interest rate model must come from lists that the protocol's governance has enabled: on Ethereum, nine LLTVs (0, and eight values from 38.5% to 98%) and two rate models, the AdaptiveCurveIRM and a null model that charges no interest (Morpho Association 2023b). Lenders supply the loan asset to the market and earn the rate the model sets; borrowers deposit collateral and borrow up to the LLTV; a position whose debt exceeds LLTV times the oracle value of its collateral can be liquidated by anyone (Morpho Association 2023b).

Five differences from repo follow from this design (Table 1). The loan is open-ended: no maturity, no fixed rate; the borrower repays when it chooses and the lender withdraws when liquidity is available in the pool, which makes it closest to open repo repriced every day. The rate floats with the utilisation of the pool, the share of supplied assets that is borrowed. There is no initial margin above the maintenance threshold: the borrower may borrow up to the LLTV and is then on the edge of liquidation, and any buffer below the LLTV is the borrower's choice. The collateral is held by the contract and is not lent on, so the lender cannot reuse it. And default management is a liquidation by a third party who repays debt and receives collateral at a discount, not a close-out between the two parties.

**Table 1. Repo and an isolated lending market, feature by feature.**

| feature | repo (bilateral, tri-party or cleared) | isolated lending market (Morpho Blue) |
|---|---|---|
| legal form | sale and repurchase, title transfer under a master agreement | deposit of collateral in a contract, no title transfer to the lender; loan from a pool |
| tenor and rate | overnight to term, rate fixed for the term; open repo repriced daily | open-ended, rate floating with pool utilisation |
| counterparties | identified, bilateral or through a CCP or tri-party agent | anonymous pool; access may be permissioned |
| initial margin | haircut at the start | none above the threshold; buffer chosen by the borrower |
| variation margin | margin calls under the master agreement | none; the position is liquidated when debt exceeds LLTV times collateral |
| default | close-out netting of all trades under the agreement | liquidation by any third party at a fixed incentive |
| reuse of collateral | allowed with title transfer | not possible while the collateral sits in the market |
| settlement | DvP in a securities settlement system, on its hours | atomic on the chain, at any hour; cash is the loan token |
| pricing | negotiated; haircut and rate depend on counterparty and collateral | LLTV set per market at creation; rate the same for every borrower |

**Source:** ICMA (International Capital Market Association 2025, 2026d); Morpho Blue whitepaper and code (Gontier Delaunay et al 2023; Morpho Association 2023b).

### 3.2 Liquidation

When a position becomes liquidatable, a liquidator repays some or all of its debt and receives collateral worth the repaid amount times a liquidation incentive factor (LIF). On Morpho Blue the factor depends only on the LLTV,

$$\mathrm{LIF}(\lambda) = \min\left(M, \frac{1}{\beta\lambda + (1-\beta)}\right), \tag{1}$$

with $\lambda$ the LLTV, a cursor $\beta = 0.3$ and a cap $M = 1.15$, which binds below an LLTV of about 56.5% (Morpho Association 2023b). The factor falls as the LLTV rises: a market that lends more against its collateral pays its liquidators less. (Morpho's documentation rounds the factor at 86% to 1.05 (Morpho Association 2026a); the code gives 1.0438.) There is no close factor: a liquidator may repay the whole debt in one call. When a liquidation exhausts the collateral of a position and debt remains, the protocol removes the remainder from the market's supplied assets, so that every lender in the market bears the loss pro rata (Morpho Association 2023b). Version 1.0 described liquidation as partial by design, restoring the health factor just above one. That is the rule of Aave, whose close factor limits a liquidation to half the debt while the health factor is above 0.95, for positions of at least USD 2,000 of collateral and of debt in current versions (Aave 2026b), and of Morpho's optional pre-liquidation contracts, not of a Morpho Blue market. Aave also separates a borrowing limit (LTV) from a liquidation threshold, which gives its markets an initial margin that Morpho Blue does not have.

### 3.3 Interest rates

The rate model used by Morpho Blue markets, AdaptiveCurveIRM, sets the borrow rate as a multiple of a rate at target that itself drifts over time (Morpho Association 2023a). With utilisation $u$, a target $u^* = 0.9$ and a steepness $k = 4$, the rate is between a quarter of the rate at target (empty pool) and four times it (full pool); while utilisation stays above target, the rate at target grows at a speed of 50 per year times the normalised gap, within bounds of 0.1% and 200% a year. At full utilisation it doubles in 5.1 days; at 95% utilisation in 10.1 days. The rate is therefore set by the balance between lenders' supply and borrowers' demand in each market, with no reference to a policy rate. Lenders in practice supply through vaults: a curator enables markets and sets supply caps, with increases delayed by a timelock, and an allocator moves the vault's funds between enabled markets within those caps (Morpho Association 2026b); in the code of MetaMorpho V1.1 and Vault V2, neither role has a function that sends depositors' assets to another address. Because the same vault can supply several markets, its reallocations can carry rates from one market to another.

### 3.4 Horizon: tokenised funds as collateral

Aave Horizon, a separate instance of Aave launched in August 2025, applies the pooled design to tokenised fund shares (Aave Labs 2025). At launch it accepted shares from Superstate (USTB, a short-term Treasury fund, and USCC, a crypto carry fund) and Centrifuge (JTRSY, Treasury bills, and JAAA, AAA-rated collateralised loan obligations), later Circle's USYC and VanEck's VBILL. Lenders supply USDC, RLUSD or GHO without permission, while only holders allowlisted by the fund issuers can post collateral and borrow, and the collateral is valued from the issuer's net asset value within bounds set by an oracle provider and a risk provider (Aave Labs 2025; Aave 2026a). Horizon is the closest live public market to on-chain repo against government securities, with two reservations: its collateral is fund shares, which add redemption, issuer and tokenisation risk to the bonds they hold, and most of the collateral supplied until April 2026 was the crypto carry fund, USD 118.4 million of USD 152.7 million on 10 April 2026 against USD 25 million for USTB (LlamaRisk 2025).

Its parameters are set by a risk provider, and they are far more conservative than the price risk of Treasury collateral. Since an update of 12 December 2025, USTB can be borrowed against up to 88% and is liquidated above 90%, with a 3% bonus to the liquidator (LlamaRisk 2025). By the arithmetic of Section 4, that leaves a buffer of 7.3% at the liquidation threshold, and 9.4% from a position borrowed to the full 88%, against a 99% five-day loss of 0.26% for a one-year US Treasury zero-coupon bond (Section 6.4). The difference prices other things: the time needed to redeem the fund shares for cash, which the risk provider measures on the fund's redemption record (for the credit fund JAAA, 63 of 93 redemptions between 10 October 2025 and 5 October 2026, USD 717.3 million in all, were paid on the day, 28 the next day and 2 after two days) (LlamaRisk 2026a), and the risk of the tokenisation structure itself.

## 4 Framework

### 4.1 The lender's buffer

Consider a position at the threshold, with debt $D = \lambda C$ against collateral of value $C$. Suppose the price of the collateral falls by a fraction $\delta$ between the moment the

position crosses the threshold and the moment a liquidator acts. The liquidator repays $D$ and receives collateral worth $\mathrm{LIF} \times D$; this is possible without loss to lenders only if the remaining collateral covers it, $C(1-\delta) \geq \mathrm{LIF}(\lambda)\,\lambda C$. The largest fall the market absorbs without bad debt is therefore

$$\delta^*(\lambda) = 1 - \lambda\,\mathrm{LIF}(\lambda). \tag{2}$$

The buffer $\delta^*$ is smaller than the apparent margin $1-\lambda$ by the incentive paid to the liquidator, $\lambda(\mathrm{LIF}-1)$. Version 1.0 stated the safety condition as $\lambda < (1-\mathrm{LIF})/(1+\delta)$; since the factor is above one, that bound is negative for every market, and it should be replaced by $\lambda\,\mathrm{LIF}(\lambda) \leq 1-\delta$, which is equation (2).

The buffer is not a haircut. A haircut is an initial margin, restored by margin calls, that protects the lender from the start of the trade; the buffer exists only for a borrower who sits at the threshold, and a borrower below it adds a margin the lender cannot require. The haircut is sized to the time a lender needs to sell after a default; the buffer must cover the time until a liquidator acts. The closest repo notion is a haircut net of the cost of close-out.

### 4.2 The liquidator's participation

Equation (2) assumes that a liquidator acts. It does so only if the incentive pays for what liquidation costs it: the loss on the collateral while it holds it before selling, and the cost of the sale itself. The liquidator repays $D$ and receives collateral worth $\mathrm{LIF} \times D$, on which both costs apply. With $q_h$ the loss of the collateral over a holding period of $h$ days at a chosen confidence level and $c$ the cost of the sale as a share of collateral value (bid-ask spread, price impact, gas, and any discount of the token to the oracle value), a liquidator that limits its loss at that confidence level participates if $(\mathrm{LIF}-1)D \geq \mathrm{LIF}\,D\,(q_h + c)$, that is

$$\frac{\mathrm{LIF}(\lambda)-1}{\mathrm{LIF}(\lambda)} \geq q_h + c. \tag{3}$$

This is a prudential condition, the one a bank acting as liquidator would apply; a liquidator that only needs a positive expected profit enters more readily, since the expected holding loss over a day is close to zero. The sale cost does not reduce the lender's buffer, since the liquidator bears it; it decides whether the liquidation happens at all. If it does not, the price keeps moving and the horizon of equation (2) lengthens. A liquidator who hedges the rate risk of the bond with futures replaces $q_h$ by the basis between the bond and the hedge, which is smaller; a liquidator who must redeem fund shares or sell a token that trades below the net asset value the oracle reads adds that discount to $c$.

### 4.3 Collateral price risk

For a zero-coupon government bond of maturity $m$ years, with the continuously compounded spot rate $y_t$ of the ECB yield curve, the loss over $h$ business days at constant maturity is

$$L_t(m,h) = 1 - \exp\left(-m\left(y_{t+h} - y_t\right)\right). \tag{4}$$

We take the 99% and 99.9% quantiles and the expected shortfall at 99% of $L$ over all overlapping windows, the 90% interval of the 99% quantile by a circular moving

block bootstrap (blocks of 20 days for one-day losses and 60 days for five-day losses, 1,000 draws), and the highest LLTV whose buffer covers the loss, $\lambda^{\max}$ such that $\delta^*(\lambda^{\max}) = q$. When the collateral is denominated in a currency other than the loan, its value in the loan currency combines the bond and the exchange rate; for dollar collateral against euro debt the loss is $1 - e^{-m\Delta y} X_t / X_{t+h}$, with $X$ the dollars per euro, computed jointly on each date.

### 4.4 Rates on a money market basis

Protocols report an annual percentage yield (APY), the effective annual rate of interest that accrues every second. SOFR, €STR and the deposit facility rate are overnight rates quoted on an actual/360 basis. We convert each APY to the overnight rate that, compounded over 365 days, gives the same effective yield, quoted on that basis: $r = 360\left((1 + \mathrm{APY})^{1/365} - 1\right)$. The spread is the converted borrow rate minus the benchmark of the same day (the last fixing on weekends and holidays). For a policy decision, the pass-through is the change of the 30-day mean of the on-chain rate after the decision against the 30 days before, divided by the change of the policy rate.

## 5 Data and methods

### 5.1 Sources

**Table 2. Data sources.**

| data | coverage | source |
|---|---|---|
| euro area government spot rates, AAA issuers and all issuers, 1, 2, 5 and 10 years | daily, 6 Sep 2004 to 26 Oct 2026 | ECB Data Portal, yield curves (YC) |
| euro reference rates for USD, SGD and CHF | daily, from 6 Sep 2004 | ECB Data Portal (EXR) |
| €STR and deposit facility rate (DFR) | daily, to 26 and 28 Oct 2026 | ECB Data Portal (EST, FM) |
| SOFR, US Treasury constant maturity yields (1, 2, 10 years), federal funds target upper bound | daily, to 27 Oct 2026 | FRED, Federal Reserve Bank of St. Louis |
| Aave v3 borrow rates: core market USDC and EURC, Horizon USDC, RLUSD and GHO | daily average, 29 Oct 2025 to 28 Oct 2026 | Aave API |
| Morpho Blue USDC markets with cbBTC, WBTC and wstETH collateral (LLTV 86%) | daily, from creation (Jan and Sep 2024) to 28 Oct 2026 | Morpho API |
| protocol constants | as deployed | Morpho Blue and AdaptiveCurveIRM code, Aave documentation |

**Source:** fetched on 28 October 2026 by `fetch_data.py`; sizes and SHA-256 fingerprints in `data/MANIFEST.json`.

### 5.2 Definitions and choices

The ECB curves are fitted with the Nelson-Siegel-Svensson model to euro area central government bonds, and the spot rates are continuously compounded (European Central Bank 2025); the AAA curve uses AAA-rated issuers, the second curve all issuers. A constant-maturity zero-coupon loss ignores roll-down and coupons and overstates the risk of a coupon bond of the same maturity, whose duration is shorter. The US constant maturity yields are par yields, which we treat as zero-coupon rates; the difference is small for the one- and two-year points. Horizons are in business days of the curve, so a Friday to Monday change counts as one day, which is the relevant horizon when a tokenised bond's oracle stops over the weekend. The three Morpho

markets share the loan asset (USDC), the LLTV (86%) and the rate model, and differ only by collateral. The rates of the Aave API are daily averages of the variable borrow rate. All rates are gross: we do not observe incentive payments, which would lower the borrower's net cost, so the spreads we report are upper bounds of what borrowers paid.

## 6 Results

### 6.1 The buffer by loan-to-value

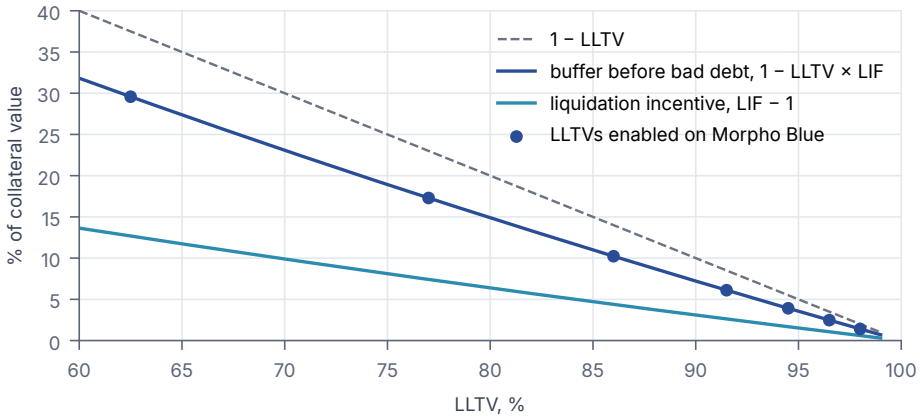
The buffer shrinks quickly as the LLTV rises (Table 3, Figure 1). At 86%, the most common LLTV for crypto collateral, the liquidator receives 4.38% and the lender keeps a buffer of 10.23%. At 98%, the highest enabled value, the liquidator receives 0.60% and the buffer is 1.41%: of the 2% between the loan and the collateral, almost a third pays for liquidation.

**Table 3. Liquidation incentive and lender's buffer for the LLTVs enabled on Morpho Blue.**

| LLTV | LIF | incentive, LIF − 1 | buffer, 1 − LLTV × LIF | 1 − LLTV |
|---|---|---|---|---|
| 38.5% | 1.1500 | 15.00% | 55.73% | 61.5% |
| 62.5% | 1.1268 | 12.68% | 29.58% | 37.5% |
| 77.0% | 1.0741 | 7.41% | 17.29% | 23.0% |
| 86.0% | 1.0438 | 4.38% | 10.23% | 14.0% |
| 91.5% | 1.0262 | 2.62% | 6.11% | 8.5% |
| 94.5% | 1.0168 | 1.68% | 3.91% | 5.5% |
| 96.5% | 1.0106 | 1.06% | 2.48% | 3.5% |
| 98.0% | 1.0060 | 0.60% | 1.41% | 2.0% |

**Source:** equations (1) and (2) with the constants of the Morpho Blue code; author's calculations.

**Figure 1. Lender's buffer before bad debt and liquidation incentive, as a share of collateral value, against the LLTV.**




**Source:** equations (1) and (2); author's calculations.

### 6.2 Collateral risk and the loan-to-value it supports

Government bonds of short maturity carry little price risk over a few days (Table 4, Figure 2). The 99% loss of a AAA zero-coupon bond over one business day is 0.08% at one year, 0.22% at two years, 0.57% at five years and 1.08% at ten years; over five business days it is 0.19%, 0.52%, 1.31% and 2.60%. In yields, the one-day quantiles are rises of 8 to 11 bps. The largest one-day rises in the sample were 27 bps at two years (14 March 2023) and 26 and 24 bps at five and ten years (5 March 2025). The quantiles are estimated precisely: the 90% bootstrap interval of the one-day 99% loss at ten years runs from 1.00% to 1.12%, and of the five-day loss from 2.22% to 2.91%. Since 2022, a period that includes the rise in euro rates of 2022 and 2023, the one-day quantiles are higher, at 0.12%, 0.29%, 0.68% and 1.31%. The curve of all issuers adds little at short maturities and about 0.06 to 0.23 percentage points at ten years.

**Table 4. Loss of a euro area AAA zero-coupon government bond over $h$ business days, and the highest LLTV whose buffer covers it.**

| maturity | horizon | 99% loss | 99.9% loss | expected shortfall 99% | 99% loss since 2022 | highest LLTV at 99% | highest enabled LLTV at 99% | at 99.9% |
|---|---|---|---|---|---|---|---|---|
| 1 year | 1 day | 0.08% | 0.16% | 0.11% | 0.12% | 99.9% | 98% | 98% |
| 1 year | 5 days | 0.19% | 0.38% | 0.27% | 0.32% | 99.7% | 98% | 98% |
| 2 years | 1 day | 0.22% | 0.37% | 0.29% | 0.29% | 99.7% | 98% | 98% |
| 2 years | 5 days | 0.52% | 0.81% | 0.65% | 0.72% | 99.3% | 98% | 98% |
| 5 years | 1 day | 0.57% | 0.84% | 0.70% | 0.68% | 99.2% | 98% | 98% |
| 5 years | 5 days | 1.31% | 2.02% | 1.64% | 1.78% | 98.1% | 98% | 96.5% |
| 10 years | 1 day | 1.08% | 1.77% | 1.38% | 1.31% | 98.5% | 98% | 96.5% |
| 10 years | 2 days | 1.55% | 2.32% | 1.93% | 1.80% | 97.8% | 96.5% | 96.5% |
| 10 years | 5 days | 2.60% | 4.25% | 3.33% | 3.41% | 96.3% | 94.5% | 91.5% |

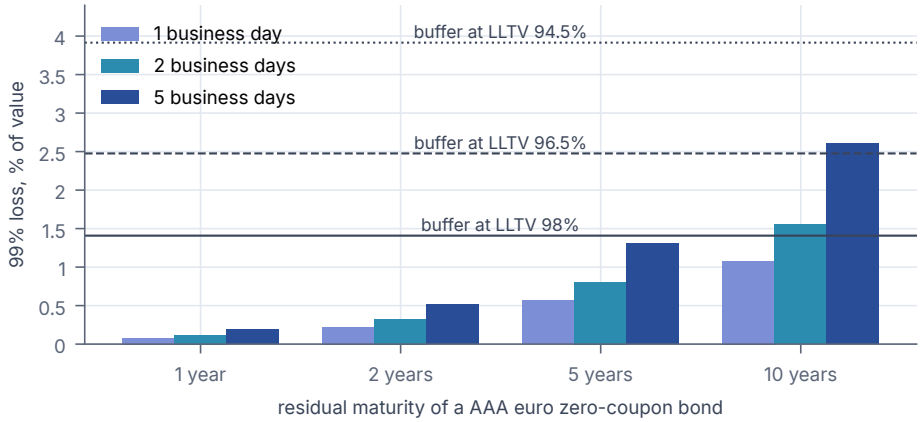
**Note:** Losses by equation (4) on overlapping windows, 6 September 2004 to 26 October 2026 (5,655 to 5,659 windows). The highest LLTV solves equation (2) for the loss; the enabled values are those of Table 3. Source: ECB yield curves; author's calculations.

Turned into loan-to-values, the numbers say that the highest enabled LLTV of 98% covers AAA bonds up to five years over five business days at the 99% level, and ten-year bonds over one day only. At the 99.9% level, five-year bonds over five days and ten-year bonds over one day need 96.5%, and ten-year bonds over five days need 91.5%.

### 6.3 Who liquidates

The buffer protects the lender only if a liquidator acts, and at high LLTVs the incentive is thin (Table 5). At 98%, the incentive of 0.60% of the collateral received leaves a margin of 0.52 percentage points over the 99% one-day loss of a one-year bond and 0.38 points for a two-year bond, from which the sale cost must still be paid; it leaves 0.03 points for a five-year bond and is 0.48 points short for a ten-year bond. A liquidator who holds for two days before selling is short at five years as well. At 96.5%, only the ten-year bond fails at one day; at 94.5%, every maturity clears at one day, with 0.57

**Figure 2. 99% loss of a AAA euro zero-coupon government bond by maturity and horizon, against the buffers at three enabled LLTVs.**




**Source:** ECB yield curves; author's calculations.

**Table 5. Liquidator's margin: incentive per unit of collateral, (LIF − 1)/LIF, minus the 99% loss over the holding period, percentage points, AAA euro zero-coupon bonds.**

| LLTV | incentive per unit of collateral | holding period | 1 year | 2 years | 5 years | 10 years |
|---|---|---|---|---|---|---|
| 98.0% | 0.60% | 1 day | 0.52 | 0.38 | 0.03 | −0.48 |
| 98.0% | 0.60% | 2 days | 0.48 | 0.27 | −0.21 | −0.95 |
| 96.5% | 1.05% | 1 day | 0.97 | 0.83 | 0.48 | −0.03 |
| 96.5% | 1.05% | 2 days | 0.93 | 0.72 | 0.24 | −0.50 |
| 94.5% | 1.65% | 1 day | 1.57 | 1.43 | 1.08 | 0.57 |
| 94.5% | 1.65% | 2 days | 1.53 | 1.32 | 0.84 | 0.10 |

**Note:** Equation (3) with $c = 0$, for a liquidator that limits its loss at the 99% level and does not hedge: a positive margin is what is left to pay the sale cost. Source: ECB yield curves; author's calculations.

points to spare at ten years. A market at 98% against long bonds therefore depends on liquidators who hedge the rate risk or accept a tail loss, and the sale cost, unknown for tokenised bonds today, comes on top.

### 6.4 Two benchmarks for prudence

The Eurosystem and Horizon's risk provider both ask for more (Table 6). The Eurosystem's haircuts on zero-coupon central government bonds are 2.0% for one to three years, 3.0% for five to seven years and 5.0% for ten to fifteen years in the schedule applied since 29 June 2023, rising to 6.0% for ten to fifteen years from 30 November 2026 (European Central Bank 2023, 2026c). A haircut is an initial margin restored by margin calls, not a buffer at a liquidation threshold, so the two are not substitutes; set side by side, the haircuts exceed every 99% loss of Table 4 and the 99% ten-day loss, and they exceed or sit close to the 99.9% ten-day loss (3.0% against 2.90% at five years, 5.0% against 5.18% at ten). We do not reproduce the Eurosystem's calibration: its haircuts serve a central bank lending to all its counterparties and also cover valuation, liquidity and other risks that a price quantile does not measure. Horizon's risk provider is more prudent still, with buffers at the liquidation threshold of 5.1% to 9.7% on tokenised fund shares under the parameters of 12 December 2025, against a 99%

**Table 6. Eurosystem haircuts on zero-coupon central government bonds against the losses of a AAA euro zero-coupon bond.**

| residual maturity | haircut since 29 June 2023 | haircut from 30 November 2026 | 99% five-day loss | 99% ten-day loss | 99.9% ten-day loss |
|---|---|---|---|---|---|
| 1 year (bucket 1 to 3) | 2.0% | 2.0% | 0.19% | 0.30% | 0.65% |
| 2 years (bucket 1 to 3) | 2.0% | 2.0% | 0.52% | 0.74% | 1.37% |
| 5 years (bucket 5 to 7) | 3.0% | 3.0% | 1.31% | 1.93% | 2.90% |
| 10 years (bucket 10 to 15) | 5.0% | 6.0% | 2.60% | 3.82% | 5.18% |

**Note:** Haircuts of liquidity category I (central governments), credit quality steps 1 and 2, zero coupon; a haircut is an initial margin, not a buffer at a liquidation threshold. Source: ECB Guideline (EU) 2016/65 as amended by Guideline (EU) 2023/832, and Guideline ECB/2026/27; ECB yield curves; author's calculations.

five-day loss of 0.26% for a one-year US Treasury zero-coupon bond; these buffers reflect redemption time and tokenisation risk rather than price risk (Section 3.4).

### 6.5 Collateral in another currency

When the collateral and the loan are in different currencies, the exchange rate dominates the risk of short bonds (Table 7). For a US Treasury zero-coupon bond held against euro debt, the joint 99% one-day loss is 1.42% at one year, 1.45% at two years and 2.02% at ten years, against 0.11% to 1.39% for the bond alone; over five days it is 2.9% to 4.1%. Such a market supports 96.5% at one day and 94.5% (91.5% at ten years) at five days. The exchange rate alone gives a 99% one-day loss of 1.06% for Singapore dollar and 0.99% for Swiss franc collateral against euro debt. Tails are heavy: the largest one-day losses in the sample were 3.96% for dollar collateral on 19 March 2009 and 7.69% for franc collateral on 6 September 2011.

**Table 7. US Treasury zero-coupon bond held against euro debt: 99% loss and the highest enabled LLTV.**

| maturity | bond alone, 1 day | joint, 1 day | joint, 5 days | highest enabled LLTV, 1 day | highest enabled LLTV, 5 days |
|---|---|---|---|---|---|
| 1 year | 0.11% | 1.42% | 2.88% | 96.5% | 94.5% |
| 2 years | 0.30% | 1.45% | 2.92% | 96.5% | 94.5% |
| 10 years | 1.39% | 2.02% | 4.05% | 96.5% | 91.5% |

**Note:** Joint loss of the bond in dollars and the dollar against the euro on the same dates, 5,476 to 5,480 windows from September 2004. US constant maturity yields treated as zero-coupon rates, which overstates the bond leg at ten years, where a coupon bond has a shorter duration. Source: FRED, ECB; author's calculations.

### 6.6 Rates are not anchored on repo or policy rates

Over the twelve months to 28 October 2026, borrowing rates in current on-chain markets differed from the repo benchmarks in level and in dynamics (Table 8, Figure 3). The Aave core market lent USDC at 4.47% on average against SOFR at 3.71%, a mean spread of 76 bps with a standard deviation of 124 bps; the three Morpho markets were closer to SOFR, at 33 to 37 bps on average, with a standard deviation of 68 to 75 bps. Euro borrowing was the most expensive: EURC on the Aave core market cost 4.14%, 209 bps above €STR, which is unsecured, and 202 bps above the ECB deposit facility rate, the policy rate that anchors euro overnight rates; it was more than 100 bps above

the deposit facility rate on 97% of days. We had no freely available euro repo index to compare with.

Dynamics are not anchored either. The correlation between weekly changes of each on-chain rate and of its benchmark is between −0.19 and 0.09, and every 95% interval includes zero; with 52 weeks the test has little power, so moderate co-movement of about 0.3 in either direction cannot be excluded, and the rates are not demonstrably anchored. Around policy decisions the picture is the same. Over the nine policy decisions since January 2024 that our series cover on both sides, seven of the Federal Reserve and two of the ECB, the 30-day mean of the on-chain rates moved in the direction of the policy rate in 13 of 26 market and decision pairs, half of them, which is what no relation would produce (the pairs share decisions, so the count is descriptive, not a test), by between −66 and +332 bps against policy moves of 25 or 50 bps. After the Federal Reserve's cut that took effect on 8 November 2024, the three Morpho rates rose by 300 to 332 bps; after the ECB's two increases of 2026, EURC rose by 51 bps the first time and 1 bp the second. Over the longer Morpho window, monthly averages co-move with SOFR (correlation 0.36 to 0.60), with a slope of 1.4 to 2.3, which reflects the crypto credit cycle as much as monetary policy.

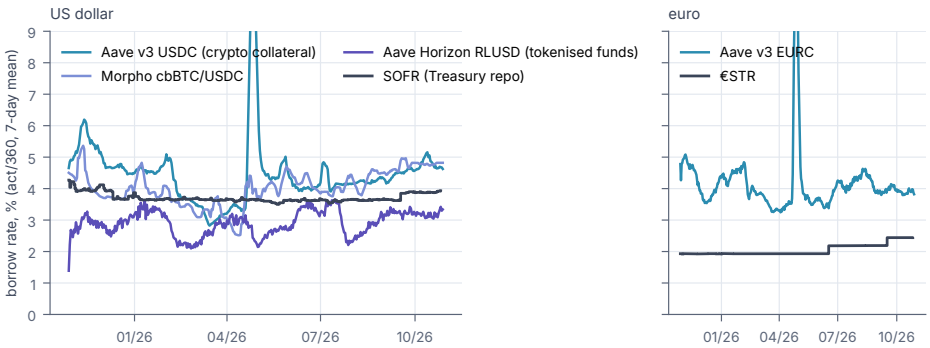
**Table 8. On-chain borrowing rates against SOFR (dollar) and €STR (euro), money market basis, 29 October 2025 to 28 October 2026.**

| market | collateral | mean rate | benchmark | mean spread, bps | median | standard deviation | 5th to 95th percentile | days below benchmark | weekly change correlation |
|---|---|---|---|---|---|---|---|---|---|
| Aave core, USDC | crypto assets | 4.47% | 3.71% | 76 | 65 | 124 | −46 to 204 | 17% | −0.04 |
| Morpho, USDC | cbBTC | 4.04% | 3.71% | 33 | 23 | 68 | −65 to 121 | 29% | 0.09 |
| Morpho, USDC | WBTC | 4.08% | 3.71% | 37 | 25 | 75 | −64 to 137 | 27% | 0.04 |
| Morpho, USDC | wstETH | 4.05% | 3.71% | 34 | 24 | 72 | −65 to 111 | 27% | 0.02 |
| Aave Horizon, RLUSD | tokenised funds | 2.92% | 3.71% | −79 | −80 | 73 | −197 to 47 | 88% | −0.16 |
| Aave Horizon, GHO | tokenised funds | 3.36% | 3.71% | −35 | −58 | 64 | −115 to 55 | 65% | 0.03 |
| Aave Horizon, USDC | tokenised funds | 5.89% | 3.71% | 217 | 176 | 175 | 37 to 504 | 2% | −0.19 |
| Aave core, EURC | crypto assets | 4.14% | 2.05% | 209 | 184 | 138 | 118 to 317 | 0% | 0.04 |

**Note:** Borrow rates converted from APY to overnight act/360, before incentives. Benchmark SOFR for dollar stablecoins, €STR for EURC (against the deposit facility rate, the EURC spread is 202 bps on average), last fixing carried over weekends. Weekly change correlation: weekly means, first differences, 52 weeks. Source: Aave API, Morpho API, FRED, ECB; author's calculations.

Horizon, the market whose collateral is closest to repo, shows that the rate belongs to the loan asset. Its RLUSD rate sat below SOFR on 88% of days and its USDC rate above it on 98% of days; lent against the same pool of collateral, the two dollar stablecoins were priced 297 bps apart on average. We do not observe who supplies RLUSD or whether incentives outside the rate compensate them, so the level below SOFR may

**Figure 3. Borrowing rates of on-chain secured loans and the repo benchmarks, seven-day means, October 2025 to October 2026.**




**Source:** Aave API, Morpho API, FRED, ECB; author's calculations.

reflect issuer or programme supply; and most of Horizon's collateral was a crypto carry fund rather than Treasuries (Section 3.4). What the evidence shows is that, in these markets, the rate does not transmit the price of Treasury repo; for the euro, where no repo index was available, the evidence concerns the policy and unsecured rates only. No public market lending against tokenised government bonds themselves has a record long enough to test; the closed ledger-based repo platforms of Section 2.2 publish no rates; the results describe the public on-chain markets that exist.

### 6.7 Rates move together across collateral

Repo prices collateral in the rate and the haircut together: a desk pays a different rate against government bonds than against equities. In the three Morpho markets, collateral risk is priced in quantity, through the LLTV, and the rate follows the cash side. Bitcoin held through two different custodial wrappers and staked ether are not the same risk, yet from October 2024 to October 2026 the daily borrow rates of the three markets were within a median of 5 to 7 bps of each other, and within 50 bps on 85% to 86% of the 758 days (Table 9). The three markets have the same LLTV, the same rate model and overlapping suppliers; their median utilisations, 88.7% to 89.3%, sit just below the target of the rate model. The evidence is descriptive: with the same LLTV and common suppliers, aligned rates are what the design predicts, and three collaterals of broadly similar risk cannot show how far the rate would move for a very different one. In the terms of version 1.0, pricing is asset-based for the threshold and pool-based for the rate.

**Table 9. Dispersion of borrow rates across collateral, Morpho Blue USDC markets with LLTV 86%, 1 October 2024 to 28 October 2026 (758 days).**

| pair of collateral | mean absolute difference, bps | median, bps | days within 50 bps |
|---|---|---|---|
| cbBTC and WBTC | 36 | 7 | 85% |
| cbBTC and wstETH | 38 | 5 | 85% |
| WBTC and wstETH | 33 | 6 | 86% |

**Source:** Morpho API; author's calculations.

### 6.8 Isolation in a run

On 18 April 2026 an attacker exploited the bridge route of Kelp's restaked ether token, rsETH, released 116,500 rsETH from the bridge adapter without a matching burn on the source chain, and deposited 89,567 of them as collateral on Aave (LlamaRisk 2026b). The incident report of Aave's service providers concludes that the protocol's contracts, oracles and liquidations worked as designed; the stress showed in liquidity. Depositors withdrew from the Aave core market and the rate model pushed borrowing rates to the top of their curves (Table 10). The core USDC rate rose from 3.39% in the two weeks before to 14.15% on 23 April and stayed above 10% for five days; EURC peaked at 19.06%. The isolated markets moved far less: the three Morpho markets peaked at 6.46% to 8.36% on 19 April and Horizon RLUSD at 4.62%, and none crossed 10%. The comparison is observational: the Aave core market held the compromised collateral and the isolated markets did not, which is what isolation means in practice. It also shows what a lender in a pooled market holds: a claim it can withdraw only if borrowers repay, which at full utilisation they need not do. A repo lender holds a claim with a maturity date.

**Table 10. Borrow rates in the run of April 2026, percent, money market basis.**

| market | mean, 3 to 17 April | peak, 18 April to 2 May | date of peak | days above 10% |
|---|---|---|---|---|
| Aave core, USDC | 3.39 | 14.15 | 23 April | 5 |
| Aave core, EURC | 3.46 | 19.06 | 23 April | 4 |
| Aave Horizon, RLUSD | 3.05 | 4.62 | 19 April | 0 |
| Aave Horizon, USDC | 4.51 | 6.47 | 27 April | 0 |
| Morpho, cbBTC/USDC | 2.85 | 6.46 | 19 April | 0 |
| Morpho, WBTC/USDC | 2.87 | 8.02 | 19 April | 0 |
| Morpho, wstETH/USDC | 2.84 | 8.36 | 19 April | 0 |

**Source:** Aave API, Morpho API; author's calculations.

## 7 Design implications

### 7.1 Parameters by maturity, horizon and liquidator

A market for tokenised euro government bonds can run at a high LLTV if its parameters follow the collateral and the liquidator. Tables 4 and 5 give a rule, before the sale cost: 98% for AAA bonds up to two years, where both the buffer and the liquidator's margin hold at five and two days; 96.5% for five-year bonds; 94.5% or less for ten-year bonds; lower again for the curve of all issuers at long maturities and for collateral in another currency. One market per maturity bucket, rather than one market per issuer, keeps the oracle simple and the buffer matched to duration. The list of enabled LLTVs is coarse at the top (94.5%, 96.5%, 98%), so some markets will hold more buffer than their collateral needs.

### 7.2 Oracles and market hours

The buffer covers the price move until liquidation, and for tokenised bonds that time is set off-chain. A tokenised fund share on Horizon is valued from the net asset value

its issuer publishes, within bounds checked by the oracle (Aave 2026a); a tokenised bond is valued from a market that closes in the evening and at weekends. A chain that runs every second does not make margining continuous when the price it reads changes once a day: version 1.0's "invariant verified block by block" is true of the arithmetic, not of the risk. The liquidation horizon in Table 4 should be read as the time from the last price the oracle could publish to the moment a liquidator has sold the collateral, and an oracle that reads a net asset value while the token trades below it shifts the gap to the liquidator, through the sale cost of equation (3).

### 7.3 Committed liquidators

At 98%, a liquidator earns 0.60% for buying a tokenised bond, holding it and selling it. That covers a bid-ask spread of a few basis points in a liquid government bond market and the one-day risk of a short bond, but only if the liquidator can reach that market: it needs an account where the tokenised bond can be redeemed or sold for cash, futures to hedge it, and a balance sheet to carry it meanwhile. Without such a route the incentive buys nothing, and the buffer is a promise without a buyer. An institutional market would need named liquidators with committed lines, or a redemption window with the issuer, which brings back the identified counterparties that the pooled design removed.

### 7.4 Rates anchored on the policy rate

A repo desk lends at a fixed rate for a term, close to the policy rate. A utilisation curve that doubles its rate in five days when the pool is full, and that moved with policy decisions in only half of the cases, is not a funding rate a treasurer can plan on. This is a requirement for adoption by banks rather than a defect of the protocols, which were built to clear a pool. Two designs address it: fixed-rate, fixed-term markets in which lenders and borrowers match at a quoted rate, or a rate model whose target follows an oracle of the policy rate. Either changes the economics for lenders, who today are paid for the risk of runs that Table 10 illustrates.

### 7.5 Cash in central bank money

The loan asset in today's markets is a stablecoin. Its price risk enters the lender's buffer: a fall of the loan token against its peg lowers the debt in euro terms, a rise raises it, and the issuer's credit risk sits with every lender. A loan in tokenised central bank money, settled through a link such as Pontes, would remove that term and give the cash leg the settlement finality that a bank's risk committee requires (European Central Bank 2026b). Cross-currency repo adds a conversion leg: our companion paper measures 14 to 20 bps for tickets of 25,000 to 120,000 USD through an automated market maker on EURC/USDC, before on- and off-ramps (Pham 2026), and Table 7 shows that the exchange rate, not the bond, sets the LLTV of such a market.

### 7.6 Legal and prudential recognition

The liquidation of a position is final against the smart contract, but that is not legal or settlement finality: a bank needs it to be effective in insolvency, with the ownership of the collateral established, and recognised for its capital treatment. Three facts frame what remains open. First, the legal work on repo has extended the GMRA, not replaced it: ICMA's annexes bring tokenised securities, digital bonds and digital cash into the master agreement, its 2026 legal opinions cover the Digital Assets Annex in

eight jurisdictions against 75 for netting under the agreement itself, and ICMA takes it as axiomatic that a ledger does not change the legal character of repo (International Capital Market Association 2024, 2026b, 2026a, 2026c). A position in a public lending protocol is not a GMRA repo: the collateral is not transferred to the lender and the default is not a close-out between two parties, so these opinions do not reach it unless the protocol is wrapped in an agreement that brings it under the GMRA. ESMA's call for evidence of October 2026 on tokenised collateral at central counterparties still asks whether a transfer of tokenised collateral is a transfer of ownership, a security interest or the transfer of a representation without proprietary rights (European Securities and Markets Authority 2026). Second, the Basel Committee's standard treats tokenised traditional assets like the underlying asset (Group 1a) only if they confer the same rights and risks and the network meets risk management conditions (Basel Committee on Banking Supervision 2022). For cryptoassets on permissionless blockchains, the Committee concluded in December 2023 that the risks cannot be sufficiently mitigated at present and kept the existing treatment (Basel Committee on Banking Supervision 2023); it agreed in November 2025 to expedite a review of targeted elements of the standard, which its Secretary General said would include permissionless blockchains, and expects an update by the end of 2026 (Basel Committee on Banking Supervision 2025, 2026; Esho 2025). Whether a tokenised government bond on a public chain counts like the bond itself for capital is therefore still open. Third, the EU's DLT Pilot Regime caps the market value of instruments on a ledger infrastructure at EUR 6 billion; the Commission proposed in December 2025 to raise it to EUR 100 billion (European Parliament and Council of the European Union 2022; European Commission 2025), and the Council's working text of September 2026 carries different thresholds (Council of the European Union 2026).

## 8 Limitations

The price risk is that of constant-maturity zero-coupon bonds on a fitted curve; actual tokenised bonds carry coupons, issuer spreads, liquidity premia and the risk of the tokenisation structure itself (custody, redemption, smart contract), none of which the curve measures. The quantiles are historical over one long sample; the bootstrap intervals account for the overlap of the windows, but a stressed calibration would weight crises more. The horizons of one, two, five and ten days are scenarios: the time from the last oracle price to a completed sale of a tokenised bond is not observed, and close-to-close changes of a fitted curve do not follow oracle publication times. The liquidator's margin leaves the sale cost unmeasured, because no tokenised government bond has a liquid on-chain market from which to measure it, and ignores hedging, which would reduce the holding risk. The rate comparison covers one year for Aave and two to three years for Morpho, a handful of markets on one chain, and rates before incentives; Horizon's USDC market is small and its collateral was mostly a crypto carry fund. The pass-through results rest on nine policy decisions. The test of collateral pricing uses three crypto collaterals of similar risk with the same LLTV and common suppliers, so it describes how these markets price, not what a market of government bonds would do. The comparison of the April 2026 run is observational. The paper does not test the legal claims; it states their status from primary sources.

## 9 Conclusion

An isolated lending market can hold the price risk of short government collateral at a high loan-to-value: the buffer of a 98% market, 1.41% of collateral value, covers the 99% price loss of a AAA euro zero-coupon bond of up to five years over five business days, before the risks of the tokenised instrument itself. What it cannot do by itself is the rest of what makes repo a funding market. Its buffer depends on a liquidator whose incentive, at 98%, does not cover the one-day risk of a ten-year bond, and who must buy collateral that trades on another market's hours; its rate follows the utilisation of a pool, not the policy rate, and does not price the collateral; and its lender holds a claim without a maturity date, which a run turns into a locked deposit. Version 1.0 saw modular markets, safe settlement assets and a legal wrapper as the conditions for institutional use. The evidence keeps the first, with numbers, and adds three: term rates anchored on the policy rate, committed liquidators, and cash in central bank money. Each of them brings back a part of the repo market that the protocol had removed, which suggests that an institutional on-chain repo market will look more like a tokenised repo platform with a programmable default procedure than like a pool.

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## Appendix A Notation

**Table A1. Notation, and the nearest term on a repo desk.**

| symbol | meaning | repo desk term |
|---|---|---|
| $\lambda$ | liquidation loan-to-value (LLTV) | maximum cash to collateral ratio before default management |
| $\mathrm{LIF}$ | liquidation incentive factor | discount at which collateral is sold on default |
| $\delta^*$ | buffer before bad debt, $1-\lambda\,\mathrm{LIF}$ | haircut net of the cost of close-out |
| $q_h$, $c$ | collateral loss over the liquidator's holding period; cost of the sale | close-out risk and cost |
| $L(m,h)$ | loss of a zero-coupon bond of maturity $m$ over $h$ business days | price move over the margin period of risk |
| $u$, $u^*$ | utilisation of the pool and its target | none (repo rates do not depend on a pool) |
| APY | annual percentage yield, the effective annual rate | none; converted to an overnight act/360 rate |

## Appendix B Reproducibility

Data: ECB Data Portal (yield curves, reference rates, €STR, deposit facility rate), FRED (SOFR, US Treasury yields, federal funds target), Aave API, Morpho API, all public and without a key. Code: `fetch_data.py` downloads every series and records its URL, time and SHA-256 fingerprint in `data/MANIFEST.json`; `repo_results.py` computes every number of Sections 3 to 6, including the bootstrap intervals (fixed seed), and writes `results/repo_results.md`; `figures.py` draws Figures 1 to 3 from the same functions. A rerun with the stored raw files reproduces every quoted figure; a new fetch extends the series and changes the last decimals.

# Appendix C Changes from version 1.0

**Table C1. Changes from version 1.0.**

| item | version 1.0 (January 2026) | version 2.0 (October 2026) |
|---|---|---|
| repo settlement | constrained by T+1 and T+2 lags, exposed to Herstatt risk | DvP already eliminates principal risk; Herstatt risk concerns FX; start dates are negotiated, same day included, and EU T+1 exempts documented repo |
| safety condition | LLTV < (1 − LIF) / (1 + δ), negative for every market | LLTV × LIF ≤ 1 − δ, equation (2), with the buffer by LLTV in Table 3, and the liquidator's participation, equation (3) |
| LLTV as haircut | LLTV = 1 − haircut | the lender's buffer is 1 − LLTV × LIF, smaller by the liquidator's incentive; no initial margin above the threshold |
| liquidation | partial by design, restoring the health factor above one | no close factor on Morpho Blue; partial liquidation is Aave's rule and Morpho's optional pre-liquidation |
| continuous margining | invariant verified block by block | checked at each action and at each oracle update; for tokenised bonds the price changes once a day |
| settlement asset and LVR | central bank money lowers loss-versus-rebalancing in repo | LVR is a cost of AMM liquidity, relevant to the FX leg only; central bank money removes the loan token's price and credit risk |
| pricing | asset-based instead of relationship-based | LLTV is set by asset; the rate is set by the pool, does not price the collateral and is not anchored on SOFR, €STR or the deposit facility rate |
| use cases | LLTV of 98% and 95% asserted | LLTV by maturity, horizon and liquidator margin from ECB yield curves, Tables 4 and 5; cross-currency from joint US Treasury and FX losses, Table 7 |
| evidence | none | ECB curves 2004 to 2026; US Treasury and FX joint losses; Aave and Morpho rates 2024 to 2026; nine policy decisions; the April 2026 run |

## ABOUT

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## CONTACT

research@aiko-academy.eu
www.aiko-academy.eu/publications



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