Digital Money, Claims, and Payment Systems

Bitcoin, stablecoins, a possible digital pound, and final settlement

Summer 2026

Computational Finance / FinTech Summer School

Day 8 | money, redemption, and infrastructure

Day 7 measured news about central-bank money; Day 8 asks what money is and how it moves

> A digital balance is understood only after identifying the issuer, the holder's claim, the redemption promise, and the settlement asset.

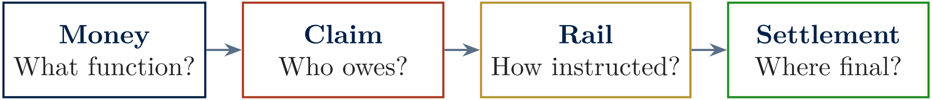
Settlement asset = the asset transferred between institutions to discharge the payment obligation finally.

The screen says GBP100, but the balance sheet asks whose liability

Displayed object	Direct issuer or governance	What the holder owns
GBP100 cash	Bank of England	central-bank liability
GBP100 deposit	commercial bank	claim on that bank
GBP100 stablecoin	private issuer	redemption claim defined by design and law
GBP100 digital pound	Bank of England, if introduced	proposed central-bank liability
GBP100 worth of Bitcoin	protocol and network	asset with no issuer redemption claim

The interface can look similar while the legal claim, conversion mechanism, and residual risk differ.

Money, claim, rail, and settlement answer different questions



- A bank deposit can move through a card, bank transfer, cheque, or direct debit.
- A ledger can record a central-bank liability, a bank liability, a private token, or an unbacked asset.
- A fast user notification need not mean that interbank settlement is already final.

The 2026 UK landscape contains existing rails, policy positions, and unresolved choices

Object	Status on 15 Aug 2026	What is not yet true
Faster Payments and CHAPS	operating payment systems	they are not forms of money
systemic sterling stablecoins	policy positions and draft rules published	final Code of Practice not yet issued
digital pound	design phase	no decision to introduce
future retail infrastructure	design consultation open	no completed replacement rail

Bank of England, 4 Mar, 22 Jun, and 25 Jun 2026; Pay.UK.

CHAPS = Clearing House Automated Payment System; the Faster Payment System is abbreviated FPS later in the lecture.

Roadmap: six questions move from monetary function to final settlement

1. **Money:** what must an object do before its technology matters?
2. **Claim:** who owes what to the holder?
3. **Bitcoin:** what changes when there is no issuer?
4. **Peg:** how does a stablecoin promise one-for-one redemption?
5. **Public:** what would a central bank digital currency change?
6. **Settle:** when does a payment become final?

Each section uses the same classification: function, issuer, claim, redemption, transfer record, and residual risk.

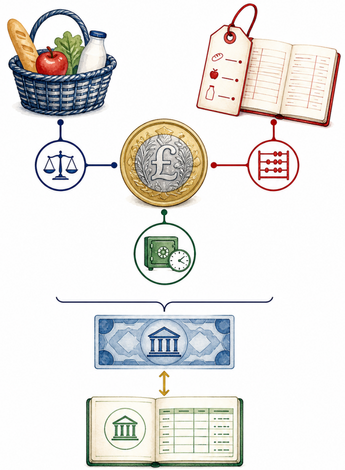
By the end, you should be able to classify a balance and trace a payment

- Distinguish money from wealth, income, a payment instrument, and a payment rail.
- Identify the issuer, holder's claim, and par-conversion mechanism for five forms of money or assets.
- Distinguish blockchain, cryptocurrency, Bitcoin, and BTC; explain the ledger, issuance, and absence of redemption.
- Read a stablecoin balance sheet and calculate peg deviation and immediate redemption coverage.
- Distinguish a stablecoin, tokenised deposit, and possible digital pound.
- Trace initiation, clearing, gross or net settlement, and finality through UK payment systems.

Test the monetary function

What must an object do before its technology matters?

Begin with economic function and general acceptability. A digital record is not money merely because it can be transferred.



Money is anything generally accepted for payment or debt repayment

> Money is an object that is generally accepted as payment for goods and services or in repayment of debts.

- The definition concerns acceptance, not whether the object is paper, metal, or digital.
- General acceptance distinguishes money from an asset accepted only by a narrow group.
- Legal tender status can support use, but economic acceptance is the operational test.

Mishkin, *The Economics of Money, Banking, and Financial Markets*, Ch. 3.

Money is a stock; income is a flow; wealth is broader

Concept	Measurement	Example
Money	stock at a date	GBP2,000 deposit balance on 15 August
Income	flow per period	GBP3,000 salary during August
Wealth	stock of all net assets	deposits, bonds, shares, property, less debt

> Bitcoin may be part of wealth even when it is not the unit in which the household writes its budget.

Stock = quantity measured at a point in time; flow = quantity measured over an interval.

Appendix A2 · Distinctions

A medium of exchange removes the double coincidence of wants

- General acceptance lowers transaction and search costs.
- Divisibility, portability, durability, and standardisation support this function.
- Lower exchange friction permits greater specialisation.

Double coincidence of wants = each barter counterparty must simultaneously want what the other offers.

A unit of account is the common language of prices and contracts

$$\text{GBP price of item } j = p_j, \qquad \text{GBP value of portfolio} = \sum_{j=1}^{n} p_j q_j .$$

- One numeraire makes unlike goods, wages, debts, and assets comparable.
- A shop can accept a card while still quoting every price in pounds.
- An asset can be transferred without becoming the economy's unit of account.

p_j = price per unit of item j in the declared unit of account; q_j = quantity. Numeraire = common unit in which values are expressed.

A store of value preserves purchasing power only imperfectly

$$\text{real purchasing-power change} = \frac{1 + r_{\text{nominal}}}{1 + \pi} - 1.$$

- Stable nominal value does not guarantee stable real purchasing power.
- Money is highly liquid, but other assets may preserve value better over long horizons.
- A payment balance should normally be retrievable at a predictable nominal amount.

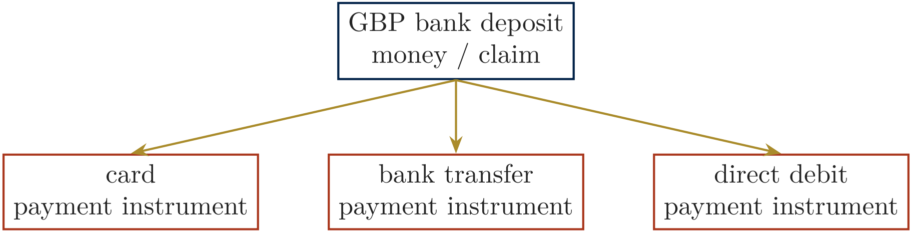
r_{nominal} = nominal holding return; π = inflation over the same period; liquidity = ability to exchange quickly with limited loss of value.

The three functions are performance tests, not a binary label

Function	Operational question	Evidence
medium of exchange	where and how often accepted?	payment share, merchant acceptance, cost
unit of account	are prices and debts denominated in it?	invoices, wages, contracts, tax
store of value	how predictable is retrievable value?	inflation, volatility, credit and liquidity risk

> An object can perform one monetary function in a niche while performing poorly on another for the wider economy.

A monetary instrument is not the payment rail that transfers it



Payment instrument = means used to initiate a transfer; payment rail = rules, messaging, clearing, and infrastructure supporting transfers.

Modern money is layered: public money anchors private claims

- Cash is public money available to the public.
- Reserves are public money held by eligible settlement institutions.
- Most everyday money is a private bank liability expected to convert at par.

Par conversion = exchange at the stated face value, such as GBP1 of deposits for GBP1 of cash.

Singleness means different claims exchange at par in the common unit

$$\pounds 1 \text{ deposit at Bank A} = \pounds 1 \text{ deposit at Bank B} = \pounds 1 \text{ central-bank money} \quad \text{at par.}$$

- Recipients need not price every pound according to the issuing bank.
- Regulation, supervision, settlement, liquidity, resolution, and protection support the equality.
- A persistent private-money discount fragments the unit of account.

BIS Annual Economic Report 2026; Bank of England, Benjamin speech, 29 Jul 2026.

Singleness of money = claims denominated in one unit remain redeemable at par with central-bank money, including under stress.

Checkpoint: name function, claim, rail, and settlement separately

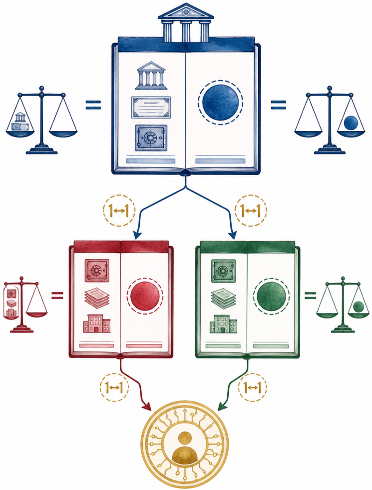
1. What monetary function is being assessed: exchange, account, or value storage?
2. Is the object a holder's asset and, if so, whose liability is it?
3. What instrument initiates the transfer and which rail carries the message?
4. What asset finally discharges obligations between institutions?
5. Which risk remains after settlement?

> The label "digital money" is incomplete until all five answers are declared.

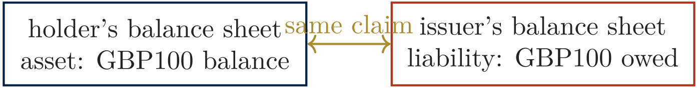
Read the balance sheet

Who owes what to the holder?

Classify the liability before examining the ledger. Similar interfaces can represent public money, bank money, a private claim, or an asset with no issuer.



A monetary balance has an asset side for the holder and usually a liability side elsewhere



- A bank deposit is simultaneously the customer's asset and the bank's liability.
- A central-bank note is the holder's asset and a central-bank liability.
- Bitcoin is the holder's asset without a matching redemption liability of an issuer.

Cash and reserves are central-bank liabilities held by different users

Public money	Typical holder	Primary role
banknotes	households and firms	retail payment and store of nominal value
reserves	banks and eligible institutions	interbank settlement and liquidity
possible retail CBDC	households and firms	digital public money for everyday use

CBDC = central bank digital currency. A UK retail CBDC would be called the digital pound; it has not been introduced.

A bank deposit is the customer's asset and the commercial bank's liability

Customer	Commercial bank
Asset: deposit +£1,000	Asset: reserves, loans, securities Liability: customer deposit +£1,000

> The customer does not own a segregated pile of reserves; the customer owns a claim on the bank.

Commercial bank = private bank that accepts deposits and extends credit under a banking licence and prudential framework.

Appendix A3 · Entries

Bank lending normally creates a matching deposit

Bank assets	Bank liabilities and equity
loan to customer +£10,000	customer's deposit +£10,000

- The bank records a loan asset and a deposit liability simultaneously.
- The borrower receives spending power and also owes the loan.
- Net wealth does not rise by GBP10,000 merely because both entries appear.

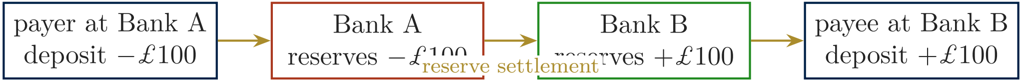
Double-entry accounting keeps total assets equal to total liabilities plus equity after every transaction.

A payment within one bank changes account names, not total deposits

$$\begin{aligned} \text{Payer deposit} &: -£100, \\ \text{Payee deposit} &: +£100, \\ \text{Bank's total deposit liabilities} &: 0 \text{ net change.} \end{aligned}$$

- The bank updates two entries on its own ledger.
- No reserve transfer between banks is required.
- The payment still changes who can spend the GBP100.

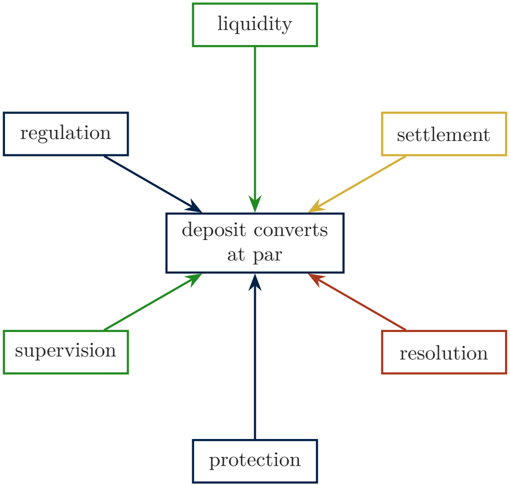
A payment across banks creates an interbank settlement obligation



The deposit transfer and the reserve settlement are related entries on different ledgers. Timing depends on the payment system.

Appendix A4 · Settlement audit

Deposit stability is engineered through several institutions



Deposit protection reduces losses only within its legal scope; it does not eliminate every bank, liquidity, fraud, or operational risk.

Par is an institutional achievement, not a property of digital records

$$\begin{aligned} \text{secondary-market price} &= \text{face value} - \text{expected loss} \\ &\quad - \text{liquidity and access discount} \\ &\quad \pm \text{other demand effects.} \end{aligned}$$

- A perfectly copied ledger can still record a risky claim.
- Convertibility requires assets, liquidity, legal rights, and operational access.
- Stress reveals which support was assumed but not guaranteed.

The decomposition is conceptual, not an exact additive asset-pricing identity. It organises the sources of a departure from par.

A token can record a claim, an asset, or neither

Tokenised object	Underlying economic object	Holder's claim
tokenised deposit	commercial-bank deposit	claim on bank
fiat-backed stablecoin	issuer's private liability	redemption claim on issuer
tokenised government bond	security	contractual cash flows
Bitcoin	native protocol asset	no issuer redemption claim

> The ledger format changes how ownership is recorded and transferred; it does not determine the balance-sheet claim by itself.

Five questions classify an unfamiliar form of digital money

1. **Issuer:** which institution or protocol governs creation?
2. **Liability:** does another balance sheet owe the holder a fixed amount?
3. **Redemption:** who can convert, into what, at what price, and when?
4. **Unit:** is value denominated in pounds, dollars, or its own unit?
5. **Settlement:** which ledger and asset make transfer final?

> Only after these answers should we compare speed, programmability, or user interface.

Checkpoint: the ledger tells us where ownership is recorded, not automatically what is owned

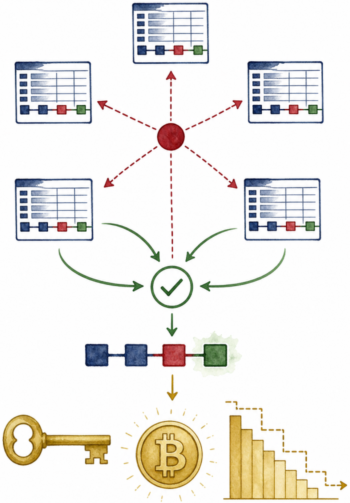
- Bank deposit: private liability expected to convert into public money at par.
- Stablecoin: private token liability whose par depends on reserves and redemption.
- CBDC: direct central-bank liability in digital form.
- Bitcoin: transferable native asset with no issuer redemption promise.

> The absence of an issuer removes issuer credit risk but also removes the promise to redeem at a fixed value.

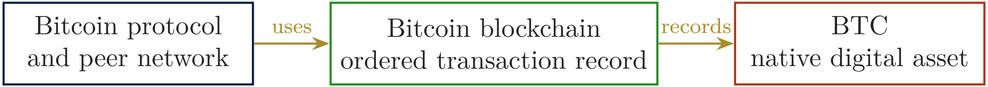
Examine Bitcoin

How can a transferable digital asset operate without an issuer or redemption promise?

Separate the asset from the ledger, recover the original payment problem, then test the design against monetary evidence.



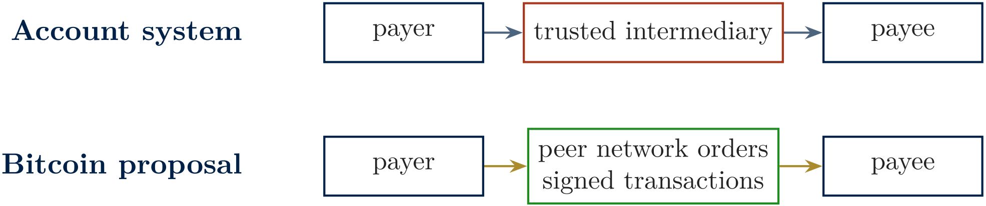
Blockchain, cryptocurrency, Bitcoin, and BTC name different objects



- **Blockchain:** ordered batches of records linked by cryptographic hashes.
- **Cryptocurrency:** a broader class of digital assets whose control and transfer rely on cryptographic keys and network rules.
- **Bitcoin:** the specific open protocol and network; **BTC** is the asset native to that system.

Protocol = agreed operating rules. A blockchain is a record structure, not a synonym for Bitcoin, cryptocurrency, or money.

The white paper proposed online payments without a trusted intermediary



- **Problem:** digital signatures authorise instructions but cannot alone prevent double spending.
- **Mechanism:** a peer network timestamps and orders valid transactions under proof of work.
- **Scope:** no promise of stable fiat value, legal tender status, reversibility, or consumer protection.

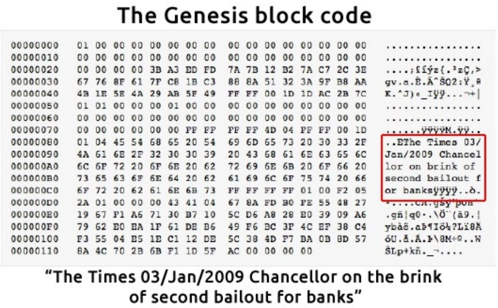
Nakamoto (2008), abstract and section 1.

Trusted intermediary = institution maintaining the authoritative record. Peer-to-peer = participants communicate without one central operator.

Bitcoin's launch joined a technical experiment to a crisis-era monetary debate

- **31 Oct 2008:** the white paper circulated.
- **3 Jan 2009:** the genesis block fixed the first entry in Bitcoin's history.
- **9 Jan 2009:** the first public software release followed.

"The Times 03/Jan/2009 Chancellor on brink of second bailout for banks."

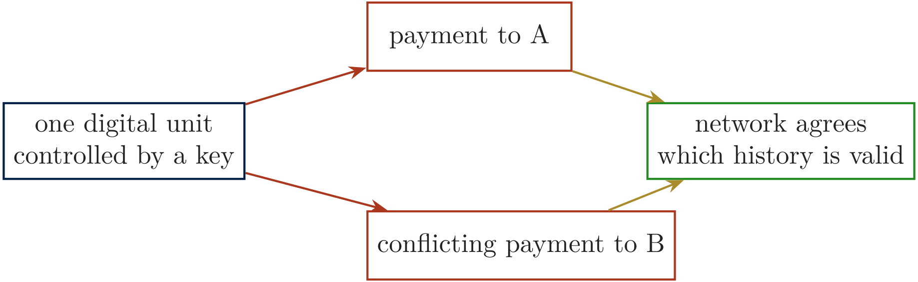


The headline encoded in the genesis block's coinbase data.

Bitcoin genesis-block coinbase input; *The Times*, 3 Jan 2009; Nakamoto (2008).

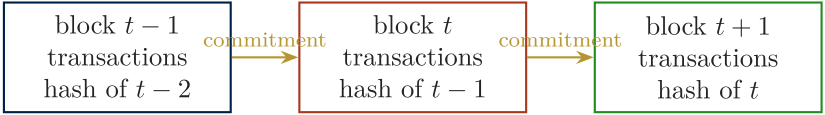
The headline establishes that the block was not created before that newspaper date. Reading it as criticism of bank bailouts is plausible historical interpretation, not a protocol result.

The core design problem is double spending without a central account keeper



Double spending = attempting to use the same digital unit in two incompatible transfers. A decentralised system needs a shared ordering rule.

Hash links make past changes visible; consensus selects the history to extend



- Changing an earlier block changes its hash and breaks every later commitment.
- Nodes independently verify transactions, hash links, and proof-of-work rules.
- Competing valid histories can exist briefly; accumulated work determines which one the network extends.

Hash = fixed-length digital fingerprint of data. Hash linking provides tamper evidence; it does not guarantee that an external statement entered into a ledger is true.

A Bitcoin transaction moves through broadcast, validation, ordering, and confirmation

> Confirmation is probabilistic: additional accepted blocks make reversal increasingly costly, rather than creating legal redemption by an issuer.

Mining combines block production, proof of work, and compensation

> miner revenue from an accepted block = block subsidy + transaction fees.

- Miners assemble valid transactions and compete to produce a qualifying proof of work.
- Nodes verify the proposed block and normally extend the valid history with greatest accumulated work.
- The subsidy issues new BTC; transaction fees compensate miners using existing BTC.
- Rewriting old history requires rebuilding its work and overtaking the continuing network.

Miner = specialised block producer. Proof of work = resource-intensive search whose result is comparatively cheap for other nodes to verify.

The issuance schedule is protocol-constrained rather than elastically supplied

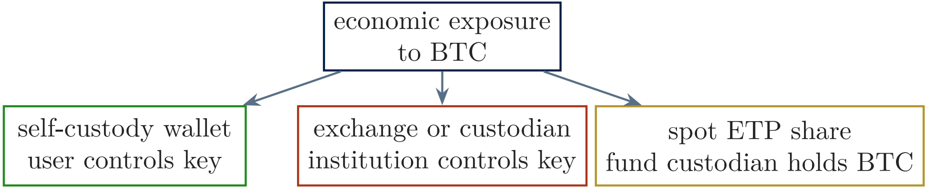
$$\text{new BTC per block after halving } h = 50 \times 2^{-h}, \qquad \text{eventual cap} \approx 21 \text{ million BTC.}$$

- New units reward block production under a declining schedule.
- A halving reduces the block subsidy approximately every 210,000 blocks.
- Supply does not expand to satisfy a sudden rise in settlement-liquidity demand.

BTC = Bitcoin's native unit. Elastic supply = capacity to expand liquidity when payment demand or stress rises.

Appendix A5 · Supply arithmetic

Access routes can reintroduce intermediaries



- Self-custody removes custodian default risk but places key loss and security on the user.
- An exchange account depends on institutional custody and records; an ETP investor owns a fund share.
- Protocol decentralisation and access decentralisation are different questions.

US Securities and Exchange Commission, 10 Jan 2024 and 29 Jul 2025.

Wallet = software for keys and transaction data. ETP = exchange-traded product. US spot listings began in Jan 2024; in-kind creation and redemption by authorised participants followed in Jul 2025.

Bitcoin gives the holder no redemption claim on an issuer

Object	Holder can demand	Value anchor
bank deposit	par cash or transfer	bank assets and institutional support
fiat-backed stablecoin	redemption under issuer terms	reserves, law, access, liquidity
Bitcoin	no fixed redemption from issuer	market demand relative to constrained supply

> Removing the issuer removes issuer default on a redemption promise because no such promise exists; it does not stabilise the market price.

Bitcoin's design choices create paired capabilities and limitations

Design choice	Capability	Limitation or risk
no issuer	no issuer redemption default or discretionary balance-sheet expansion	no par anchor, lender of last resort, or issuer-funded reversal
constrained issuance	predictable native-unit supply path	demand shocks are absorbed mainly through price
open global network	direct transfer and independent verification	variable fees, confirmation delay, compliance and capacity constraints
self-custody option	holder can control the spending key	key loss, theft, and security burden fall on the holder

The same feature can be valuable for one use and costly for another. Architecture alone does not establish stable purchasing power, universal acceptance, or legal finality.

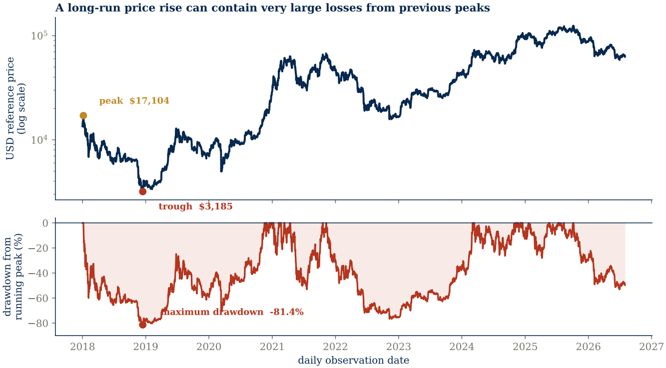
Nakamoto (2008), *Bitcoin: A Peer-to-Peer Electronic Cash System.*

Bitcoin can perform monetary functions, but performance depends on context

Function	Evidence in favour	Limitation for broad everyday money
medium of exchange	transferable globally; accepted in some markets	variable acceptance, fees, confirmation, tax and compliance
unit of account	native BTC denomination exists	most wages, prices, taxes, and debts remain in fiat units
store of value	constrained supply; long-run appreciation in parts of sample	large drawdowns and uncertain purchasing power

The assessment is empirical and use-specific. Volatility alone does not determine the definition, but it materially affects payment and value-storage performance.

A long-run price rise can coexist with an 81% loss from a previous peak



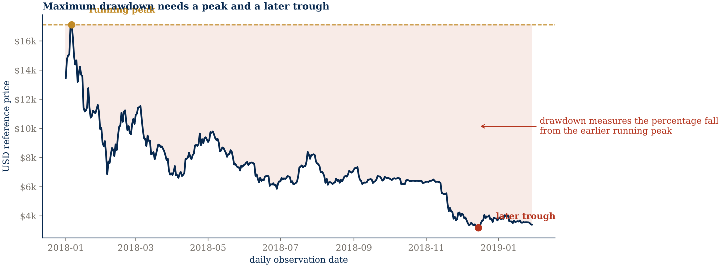
Coin Metrics Community API, BTC PriceUSD, daily 00:00 UTC reference rate, 1 Jan 2018–31 Jul 2026.

PriceUSD = Coin Metrics daily USD reference rate. The lower panel measures loss relative to the running peak, not loss relative to the sample start.

Python P2–P3 · Reproduce

Maximum drawdown measures the loss from a previous peak

$$\mathrm{DD}_t = \frac{P_t}{\max_{s\le t} P_s} - 1, \qquad \mathrm{MDD} = \min_t \mathrm{DD}_t.$$



P_t = price at date t; $\max_{s\le t} P_s$ = highest observed price up to t; MDD = maximum drawdown, reported as the most negative drawdown.

Appendix A6 · Algorithm Python P3 · Calculate

Checkpoint: Bitcoin is a transferable asset without par redemption

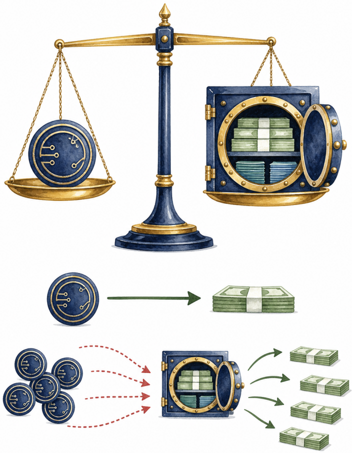
1. The protocol coordinates issuance and transaction history.
2. The holder controls an asset, not a fixed claim on an issuer.
3. Market demand determines the price in pounds or dollars.
4. Constrained supply is not the same as stable purchasing power.
5. Monetary performance must be assessed by use, evidence, and horizon.

> A stablecoin adds the element Bitcoin deliberately lacks: a private promise to redeem at a reference value.

Test the redemption promise

What keeps one private token near one pound or one dollar?

A peg is sustained through reserves, access, liquidity, and arbitrage. The ledger records tokens; the balance sheet determines whether they can return to par.



A fiat-backed stablecoin is a private claim designed to track a reference asset

> A fiat-backed stablecoin is a transferable digital token whose issuer promises redemption at a stated value and holds reserve assets to support that promise.

- The token is normally denominated in an existing unit of account, such as GBP or USD.
- The issuer creates tokens when eligible users deliver funds and cancels them on redemption.
- Stability depends on both the value of reserves and the ability to turn them into cash when requested.

Peg = target exchange value; reserve assets = assets held against outstanding tokens; redemption = conversion of tokens into the promised reference asset.

Issuance and redemption expand and contract both sides of the issuer's balance sheet

Event	Issuer assets	Issuer liabilities
issue GBP100	cash or reserve assets +£100	stablecoins outstanding +£100
redeem GBP40	cash or reserve assets −£40	stablecoins outstanding −£40

> The token supply is elastic only to the extent that issuance and redemption remain operational and economically attractive.

Outstanding tokens are the issuer's redemption liabilities under the declared design and legal terms.

Reserve coverage compares asset value with tokens outstanding

$$\text{reserve coverage ratio} = \frac{\text{market value of reserve assets}}{\text{tokens outstanding}}.$$

- A ratio of one means assets equal token liabilities at the measured values.
- A ratio above one creates a capital buffer; below one indicates an asset shortfall.
- The ratio is a solvency measure, not a guarantee of immediate cash availability.

Solvency = assets are sufficient to meet liabilities in value; capital buffer = assets in excess of token liabilities. Valuation and legal segregation also matter.

Full reserve coverage does not imply full immediate liquidity

$$\text{immediate redemption coverage} = \frac{\text{cash} + \text{assets saleable now after haircuts}}{\text{redemption requests now}}.$$

- Short-dated safe assets can still require time or a price concession to sell.
- Operational blocks, custody problems, and market closure can make assets temporarily unavailable.
- A liquidity shortfall can trigger delayed redemption even when eventual asset recovery is sufficient.

Haircut = reduction from stated or face value when an asset is sold or pledged; liquidity risk = inability to meet cash demands when due without material loss.

Arbitrage links the secondary-market price to one-for-one redemption

- Direct redemption must be accessible, credible, timely, and cheaper than the price gap.
- If access is restricted, intermediaries transmit arbitrage only imperfectly.
- A discount can therefore measure concern about value, timing, access, or operations.

Arbitrage = trading that exploits a price difference for equivalent payoffs after costs and constraints.

Peg deviation measures the price gap from the promised reference value

$$d_t = 10{,}000\left(\frac{P_t}{P^*} - 1\right) \quad \text{basis points,} \qquad P^* = 1.$$

- $d_t = -100$ means the token trades one per cent below the peg.
- $d_t = 25$ means the token trades 0.25 per cent above the peg.
- Daily reference prices can hide larger intraday deviations.

P_t = observed token price in the reference currency; P^* = target peg; one basis point = 0.01 percentage point.

Python P4 · Peg deviation

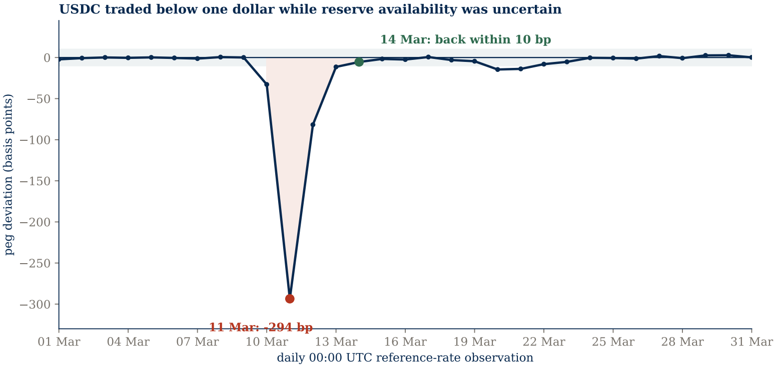
The March 2023 USDC episode tested reserve access rather than token code

- Circle disclosed that USD3.3 billion of USDC reserves remained at Silicon Valley Bank.
- That amount was about eight per cent of reserves according to the issuer's statement.
- Uncertainty concerned whether and when those funds would be available for redemption.
- Official support for bank depositors changed expected recovery and the token moved back toward par.

Circle, 12 Mar 2023; Federal Reserve, Treasury, and FDIC joint statement, 12 Mar 2023.

USDC = USD Coin, a dollar-denominated fiat-backed stablecoin. Silicon Valley Bank is abbreviated SVB.

USDC fell about 294 basis points below par in the daily reference series



Coin Metrics Community API, USDC PriceUSD, 1–31 Mar 2023; Circle event annotation.

The minimum daily reference price occurred on 11 Mar 2023. The series returned within 10 basis points of par on 14 Mar; intraday market prices differed.

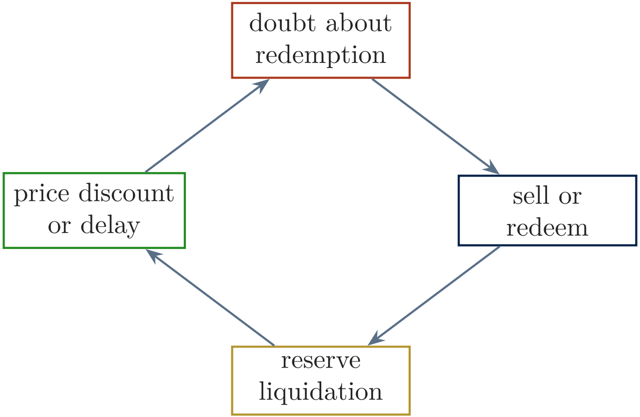
Python P4 · Reproduce

The event sequence shows how information changes redemption value

reserve-access uncertainty → expected delay or loss rises → secondary price falls below par → recovery news restores confidence

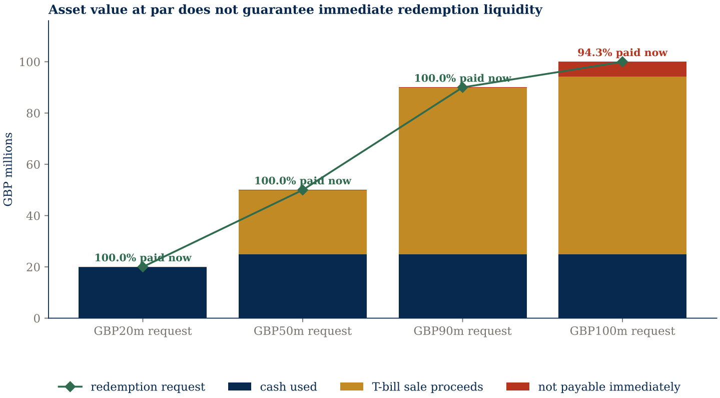
> A token price can respond before final reserve losses are known because it capitalises expected loss, delay, and access costs.

A stablecoin run is a feedback loop between fear, sales, and reserve liquidation



A run need not begin with insolvency. Expectations of delayed access can create withdrawals that force costly liquidation and weaken coverage.

Immediate resources depend on cash, saleable assets, and haircuts



Synthetic GBP100 million balance sheet; not a representation of Circle or any issuer.

The scenario assumes GBP25m cash, GBP70m Treasury bills saleable at a one per cent haircut, and GBP5m temporarily unavailable. Treasury bill = short-dated government debt.

Appendix A8 · Worked case | Python P5 · Stress test

A GBP100m redemption request exposes a GBP5.7m immediate shortfall

$$\begin{aligned}
\text{cash available} &= \pounds 25.0\text{m}, \\
\text{bill-sale proceeds} &= \pounds 70.0\text{m} \times (1 - 0.01) = \pounds 69.3\text{m}, \\
\text{paid immediately} &= \pounds 94.3\text{m}, \\
\text{immediate shortfall} &= \pounds 100.0\text{m} - \pounds 94.3\text{m} = \pounds 5.7\text{m}.
\end{aligned}$$

- GBP5.0m is unavailable now; GBP0.7m is lost through the sale haircut.
- Later recovery of the unavailable asset can close the timing gap, but not the realised sale loss.

A shortfall measured "now" combines timing and valuation effects; it is not automatically the final creditor loss.

Appendix A8 · Formula Python P5 · Calculate

Liquidity and solvency answer different redemption questions

Test	Question	Failure signal
liquidity	can requests be paid when due?	delay, gated redemption, fire sale
solvency	are total assets ultimately worth at least liabilities?	persistent asset shortfall
operations	can the issuer access assets and process claims?	outage, custody or banking blockage

> Good stablecoin analysis reports all three tests; “fully backed” addresses only part of the problem.

The June 2026 UK proposal addresses backing, liquidity, and concentration

- Proposed backing for a systemic sterling stablecoin: 70% short-term UK government debt and 30% unremunerated Bank of England deposits.
- Proposed central-bank liquidity facility: eligible high-quality collateral could support redemptions under stress.
- Temporary issuance guardrail: GBP40 billion for each systemic stablecoin while the regime develops.
- The June document contains policy positions and a draft Code; final rules were intended later in 2026.

Bank of England, *Proposed regulatory regime for systemic sterling stablecoins*, 22 Jun 2026.

Systemic = capable of becoming important to UK payments or financial stability. Unremunerated deposits earn no interest. Proposed government debt maturity: six months or less.

Checkpoint: a peg is a balance-sheet and market mechanism

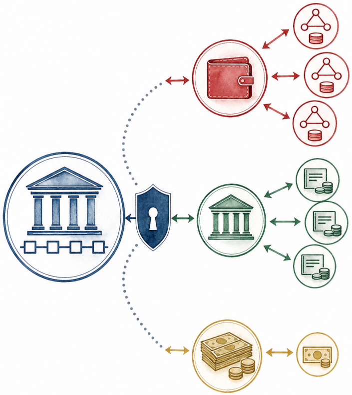
1. Identify who has the legal right to redeem and under what conditions.
2. Value reserves and distinguish total coverage from immediate liquidity.
3. Calculate the price deviation from the peg.
4. Ask whether arbitrage can transmit direct redemption into market prices.
5. Stress timing, haircuts, concentration, custody, and operations.

> The next design changes the issuer: a CBDC would be public money rather than a private redemption claim.

Compare public and private money

What would a retail CBDC change for users, banks, and the central bank?

Hold the interface constant and change the issuer. The central question is not whether the balance is digital, but whether it is a direct public liability and how access is organised.



Retail and wholesale CBDCs differ mainly in eligible users and purpose

Form	Typical holder	Main purpose
retail CBDC	households and firms	everyday digital public money
wholesale CBDC	banks and financial institutions	settlement of financial transactions
central-bank reserves	eligible institutions	existing wholesale settlement money

> CBDC is a digital liability of the central bank. The policy design determines access, privacy, remuneration, limits, and intermediaries.

Retail = available for household or business use; wholesale = restricted to financial institutions or market infrastructures.

A possible digital pound would be a new access form for existing public money

- It would be denominated in pounds and issued by the Bank of England.
- GBP10 of digital pounds would be intended to have the same nominal value as GBP10 cash.
- It would complement cash rather than replace cash under the current design proposition.
- Private firms would provide wallets and customer-facing services in a proposed two-tier model.

Bank of England and HM Treasury, digital pound design materials and 4 Mar 2026 progress update.

Design proposition = a basis for technical and policy exploration, not a decision to issue. Wallet providers are called payment interface providers in UK design materials.

The proposed platform model separates public settlement from private interfaces

- The central bank would provide the core asset and platform.
- Regulated private providers could compete over user experience and additional services.
- Allocation of data and compliance duties becomes part of monetary design.

Core ledger = authoritative record of digital-pound holdings and transfers under the explored architecture.

Issuer and redemption distinguish four superficially similar balances

Object	Issuer	Holder's asset	Conversion anchor
bank deposit	commercial bank	bank liability	convert at par into public money
tokenised deposit	commercial bank	bank liability on token infrastructure	same bank-credit anchor, different record
fiat-backed stablecoin	private non-bank or group	issuer redemption claim	reserve-backed redemption under terms
retail CBDC	central bank	central-bank liability	public money itself

Tokenised deposit = commercial-bank deposit represented on programmable or distributed-ledger infrastructure; it remains a bank liability.

Tokenisation changes the record; it does not automatically change the issuer

> Programmability is an infrastructure feature. Credit risk follows the liability and legal claim, not the visual form of the token.

The case for a retail CBDC begins with public access and system resilience

- Preserve access to central-bank money as cash use changes.
- Maintain a public anchor for confidence and par conversion in a more digital economy.
- Support competition and innovation through common public infrastructure.
- Provide an alternative payment channel with designed resilience and inclusion.
- Enable public policy choices over access, privacy, and interoperability.

Interoperability = capacity of systems or providers to exchange information and value under shared rules.
Each motivation depends on detailed design and alternatives.

The principal risks concern privacy, bank funding, operations, and public-sector scope

- **Privacy:** transaction data may be more visible or linkable than users expect.
- **Bank funding:** deposits could move toward CBDC, especially in stress.
- **Operational concentration:** failure of core infrastructure could affect many users.
- **Cybersecurity:** a public platform becomes critical national infrastructure.
- **Boundary of the state:** design may expand central-bank involvement in retail finance.

These are design trade-offs, not predictions that every CBDC will produce the same outcome.

Moving GBP100 from a deposit into CBDC changes bank funding and reserves

$$\begin{aligned} \text{household:} &\quad \text{deposit } -\pounds 100, \quad \text{CBDC } +\pounds 100, \\ \text{commercial bank:} &\quad \text{deposit liability } -\pounds 100, \quad \text{reserves } -\pounds 100, \\ \text{central bank:} &\quad \text{reserves } -\pounds 100, \quad \text{CBDC liability } +\pounds 100. \end{aligned}$$

- The household changes the issuer of its monetary asset.
- The bank loses deposit funding and settlement reserves.
- System-wide effects depend on scale, speed, limits, and bank adjustment.

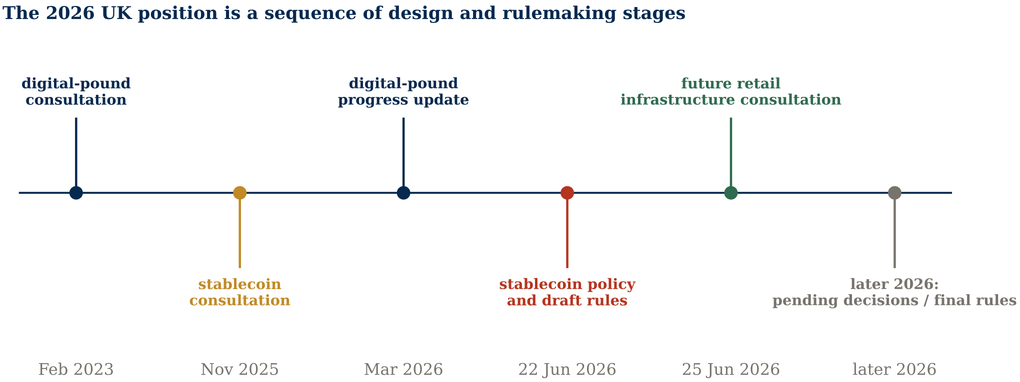
Funding = liabilities used to finance bank assets. The entries abstract from fees, timing, and any offsetting central-bank liquidity operation.

Design choices can reduce risks but also limit usefulness

Design choice	Intended effect	Trade-off
holding limits	restrain large deposit migration	less useful for larger payments or balances
no interest	reduce competition with deposits	weaker monetary-policy pass-through tool
tiered privacy and access	limit unnecessary data exposure	more complex compliance and architecture
private interfaces	preserve competition and service choice	reliance on intermediaries remains
offline functionality	resilience and inclusion	fraud and double-spend controls become harder

No design removes every trade-off. The relevant comparison is CBDC versus realistic alternatives, including upgraded bank-payment infrastructure.

The UK remained in design and decision mode in August 2026



Bank of England and HM Treasury; status frozen at 15 Aug 2026.

> The March 2026 update stated that no decision had been made; the design phase would conclude in 2026 and a decision would follow later in the year.

Python P1 · Frozen status

Checkpoint: compare liabilities before comparing interfaces

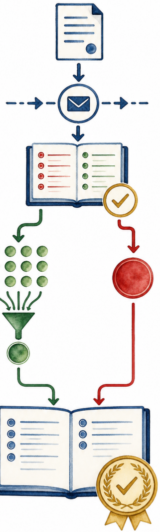
1. Who issues the balance and bears the liability?
2. Is conversion into public money required, or is the asset already public money?
3. Which providers manage access, data, compliance, and customer service?
4. How would large conversions change bank funding and settlement liquidity?
5. Which alternative infrastructure could meet the same policy objective?

> Even the safest liability still needs a payment process: instruction, clearing, settlement, and finality.

Trace the payment to finality

What happens between “pay” and an irrevocable interbank transfer?

Separate the customer message from the obligations it creates. Then compare net retail settlement with real-time gross settlement using current UK payment data.

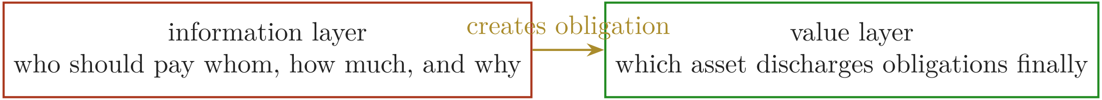


A payment moves through initiation, messaging, clearing, settlement, and finality

Finality = the point at which settlement is legally and operationally irrevocable under the system's rules. Customer notification may occur earlier.

Appendix A11 · Terms

The payment message and the settlement asset are not the same object



- A card network can carry instructions while commercial-bank deposits fund the customer payment.
- Interbank settlement may then occur in central-bank reserves.
- Faster messaging does not by itself change the issuer of money or settlement finality.

Clearing calculates obligations; settlement discharges them

$$\text{net obligation of bank } i = \text{payments sent by } i - \text{payments received by } i.$$

- Clearing validates, matches, routes, and calculates who owes what.
- Settlement transfers the agreed settlement asset between participants.
- A system can clear transactions continuously but settle net obligations at defined cycles.

A positive net obligation in this sign convention means the bank must pay reserves; a negative value means it receives reserves.

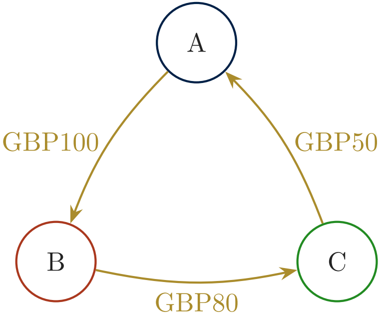
Appendix A12 · Netting

Gross settlement pays each instruction; net settlement pays the offsetting balance

Method	Settlement amount	Main implication
gross	each payment settled separately	high liquidity need; immediate finality possible
bilateral net	offset between each pair	lower liquidity; pair-specific exposure until settlement
multilateral net	offset across all participants	largest liquidity saving; dependence on system-wide completion

RTGS = real-time gross settlement: each payment settles individually in central-bank money with finality in real time.

Three payments with GBP230 gross value require only GBP50 from the net debtor



net positions:

A pays GBP50

B receives GBP20

C receives GBP30

$$\text{gross value} = 100 + 80 + 50 = \pounds 230, \qquad \sum_i \text{net position}_i = 0.$$

A supplies GBP50 of settlement liquidity; B and C receive the two net credits.

Appendix A12 · Entries Python P6 · Calculate

Netting economises on liquidity but leaves obligations unsettled for longer

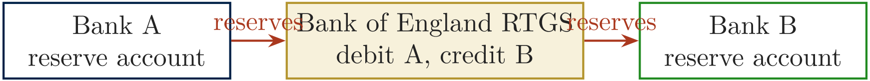
$$\text{liquidity saving} = 1 - \frac{\text{funds required after netting}}{\text{gross payment value}} = 1 - \frac{50}{230} = 78.3\%.$$

- Less settlement liquidity is required for the same customer-payment value.
- Participants remain exposed until the net cycle settles.
- Default arrangements, loss allocation, collateral, and queue rules become important.

The example measures a simple funding saving, not the complete liquidity profile of an operating payment system.

Python P6 · Liquidity saving

Central-bank reserves provide the final settlement asset between banks



> Settlement in a liability of the common central bank removes the need for Bank B to accept Bank A's private promise as the final asset.

RTGS also names the Bank of England infrastructure that holds settlement accounts and processes sterling settlement.

Faster Payments prioritises rapid retail account-to-account transfers

- Customers can send near-real-time bank payments, normally available continuously.
- The recipient may see funds within seconds while interbank obligations follow the system's settlement arrangements.
- Use cases include person-to-person transfers, bills, business payments, and standing orders.
- In Q4 2025, FPS processed 1.455 billion payments worth GBP1.270 trillion.

Pay.UK, *UK Payment Statistics Q4 2025*.

FPS = Faster Payment System. Account-to-account means value moves directly between bank accounts without a card transaction.

CHAPS prioritises individual finality for high-value and time-critical payments

- Direct participants submit sterling payments for individual settlement in RTGS.
- Payments are gross: each accepted instruction settles separately in central-bank money.
- Typical uses include financial-market activity, corporate treasury, property, and other urgent payments.
- In 2025, CHAPS processed 53.3 million payments worth GBP93.9 trillion.

Bank of England, payment and settlement statistics, updated 5 May 2026.

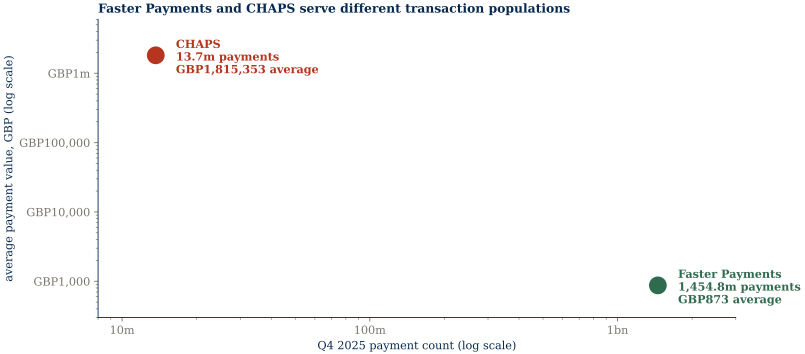
CHAPS = Clearing House Automated Payment System. High value describes typical use, not a universal minimum transaction size.

Faster Payments and CHAPS solve different settlement problems

Dimension	Faster Payments	CHAPS
main use	high-volume retail and business transfers	high-value or time-critical payments
customer speed	normally seconds	same-day subject to operating rules
settlement logic	obligations settled under FPS arrangements	individual RTGS settlement
value profile	many lower-value transactions	fewer, much larger transactions

Customer speed, clearing frequency, and final interbank settlement are separate dimensions; "instant payment" should specify which one is meant.

In Q4 2025, FPS had 106 times the volume but only one-twentieth of CHAPS value



Pay.UK, *UK Payment Statistics Q4 2025*; calculations use exact quarterly totals.

Volume = number of payments; value = total pounds transferred. The chart uses logarithmic axes; read the labels before comparing distances.

Python P7 · Scale ratios

Average transaction value reveals the different economic roles

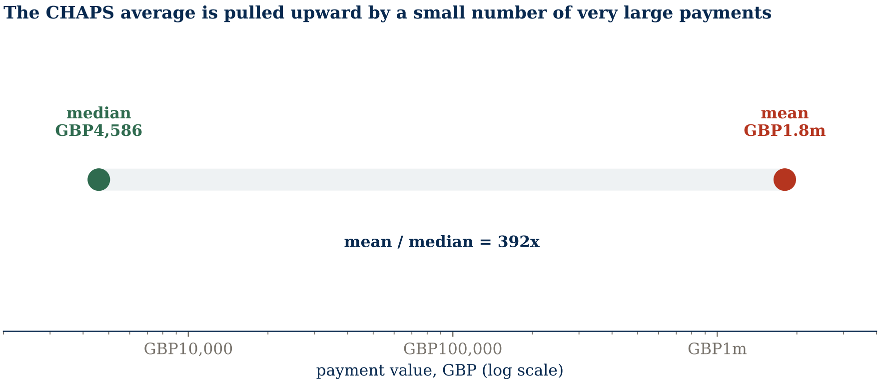
$$\overline{x}_{\text{FPS}} = \frac{£1.269677\text{tn}}{1.454782\text{bn}} = £872.76,$$
$$\overline{x}_{\text{CHAPS}} = \frac{£24.824954\text{tn}}{13.675\text{m}} = £1.815\text{m}.$$

- The CHAPS average was about 2,080 times the FPS average in Q4 2025.
- The average summarises scale; it does not describe the typical observation when values are highly skewed.

tn = trillion; bn = billion; m = million. The calculation divides exact quarterly value by exact quarterly volume.

Python P7 · Average value

CHAPS had a GBP1.8m mean but only a GBP4,586 median payment in 2025



Bank of England, annual CHAPS statistics for 2025; mean reported to one decimal million.

Median = middle payment after ordering values; the mean-to-median ratio is about 393, showing a strongly right-skewed distribution.

Python P7 · Distribution insight

The June 2026 consultation asks whether retail infrastructure should support a common point-of-sale option

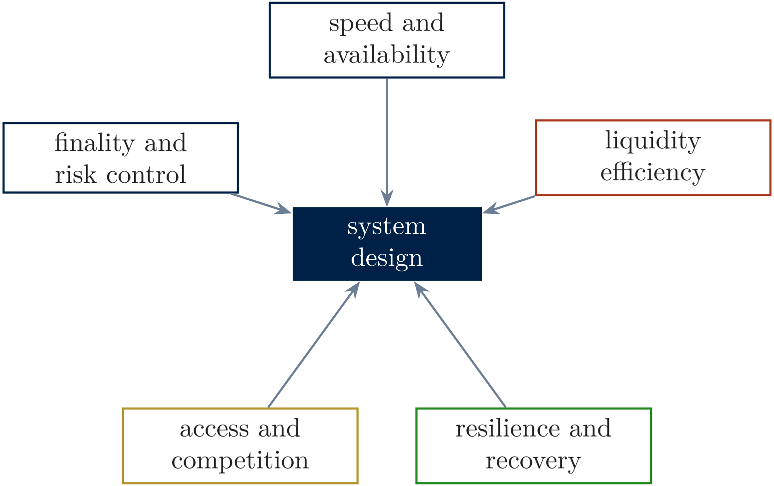
- The Bank of England proposed a next generation of UK retail payments infrastructure for consultation.
- One design question is a common account-to-account option at the point of sale.
- The objectives include resilience, competition, innovation, and effective public oversight.
- The consultation closes on 11 September 2026; it is not a completed replacement system.

Bank of England, *The next generation of retail payments infrastructure*, 25 Jun 2026.

Point of sale = the place or digital checkout where a purchase is initiated. Consultation = a proposal inviting evidence before final policy.

Python P1 · Policy status

Payment-system design is a constrained optimisation problem



The appropriate design depends on transaction size, urgency, failure cost, participant structure, and available settlement liquidity.

One framework connects money, Bitcoin, stablecoins, CBDC, and payment rails

Object	Who issues?	What anchors value?	Where does transfer become final?
bank deposit	commercial bank	par conversion and institutions	bank ledger plus inter-bank settlement
Bitcoin	protocol issuance	market demand and constrained supply	network confirmation under protocol
stablecoin	private issuer	reserves and redemption	token ledger plus redemption/settlement rails
retail CBDC	central bank	public liability	central-bank platform under design
payment system	no monetary issuer as a rail	not itself a form of money	declared settlement asset and rules

Final checklist: classify the balance, then trace the transfer

1. State the monetary function and unit of account.
2. Identify the issuer, holder's claim, and legal redemption right.
3. Test asset value, liquidity, market access, and operational access.
4. Separate the payment instrument and message from the money transferred.
5. Calculate clearing obligations and identify the final settlement asset.
6. Distinguish current arrangements, formal proposals, and unresolved policy choices.

> A digital balance is not understood until its balance sheet and its path to final settlement are both visible.

References and data sources

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Data definitions, event dates, assumptions, and reproducible calculations are documented in the linked appendices and Python notebook.

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Technical appendix map

A1 Notation and units
A2 Money distinctions
A3 Deposit entries
A4 Cross-bank settlement
A5 Bitcoin supply
A6 Drawdown audit
A7 Stablecoin entries
A8 Redemption stress
A9 CBDC architecture
A10 CBDC conversion
A11 Payment stages
A12 Netting entries
A13 Claim comparison
A14 Data provenance

The appendix holds accounting details, derivations, qualifications, and audit trails supporting the main sequence.

Python practical map

A1. Notation and unit conventions

Symbol	Meaning	Unit or range
P_t	market price on date t	reference currency per token or BTC
P^*	stablecoin target price	normally 1 reference-currency unit
d_t	peg deviation	basis points
DD_t	drawdown from running peak	decimal or percent, non-positive
R, L	reserve asset value; token liabilities	currency units
n_i	bank i net settlement position	currency units, sign declared

Conversion: $1\% = 100$ bp, £1tn=£1,000bn=£1,000,000m.

← **Return to four objects**

Appendix map

A2. Money, wealth, income, instruments, and rails are not synonyms

Concept	Test	Example
money	generally accepted payment or debt repayment	bank deposit
wealth	net stock of valuable assets	shares plus deposits less debt
income	resources received per period	monthly salary
instrument	device or mandate initiating payment	card or direct debit
rail	rules and infrastructure carrying transfers	FPS or CHAPS

An object may occupy more than one category, but the categories answer different economic questions.

← **Return to stock and flow**

Appendix map

A3. Deposit creation preserves the bank accounting identity

$$\underbrace{\Delta\text{assets}}_{+\pounds 10{,}000\ \text{loan}} = \underbrace{\Delta\text{liabilities}}_{+\pounds 10{,}000\ \text{deposit}} + \underbrace{\Delta\text{equity}}_{0}.$$

- Loan approval creates a contractual asset for the bank and debt for the borrower.
- Deposit crediting creates money available for the borrower to spend.
- Repayment reverses principal on both sides; interest affects income and equity.
- Capital, liquidity, funding, risk, and regulation constrain lending even though no prior deposit is mechanically moved to the borrower.

The example records origination only. Credit losses, fees, interest accrual, and regulatory requirements are omitted.

← **Return to deposit creation**

Appendix map

A4. Cross-bank payment entries reconcile customer deposits and reserves

Balance sheet	Payer deposit	Payee deposit	Reserves
household payer	$-£100$	–	–
household payee	–	$+£100$	–
Bank A	liability $-£100$	–	asset $-£100$
Bank B	–	liability $+£100$	asset $+£100$
central bank	–	–	A $-£100$, B $+£100$

The central bank's total reserve liability is unchanged; ownership of GBP100 of reserves moves from Bank A to Bank B.

← **Return to cross-bank payment**

Appendix map

A5. The Bitcoin cap follows from a geometric issuance schedule

$$\text{BTC in era } h \approx 210{,}000 \times 50 \times 2^{-h},$$

$$\text{eventual total} \approx 210{,}000 \times 50 \sum_{h=0}^{\infty} 2^{-h},$$

$$= 10.5\text{m} \times \frac{1}{1 - 1/2} = 21\text{m BTC}.$$

- The exact realised total reflects discrete-unit rounding and protocol rules.
- Fees can compensate block producers as the subsidy declines.
- A constrained long-run quantity does not imply a stable short-run price.

Geometric series: $1 + 1/2 + 1/4 + \cdots = 2$. m = million.

← **Return to issuance schedule**

Appendix map

A6. Drawdown requires a running peak, not the final sample maximum

$$\begin{aligned} H_t &= \max(P_1, \ldots, P_t), \\ \mathrm{DD}_t &= P_t/H_t - 1, \\ \mathrm{MDD} &= \min_t \mathrm{DD}_t. \end{aligned}$$

- At a new high, $P_t = H_t$ and drawdown equals zero.
- A fall from 100 to 70 gives $70/100 - 1 = -30\%$.
- A rise from 70 to 91 is a 30% return but still a -9% drawdown from 100.
- The 2018–Jul 2026 BTC sample MDD is -81.38%.

Recovery from a loss is asymmetric: after an 81.38% decline, price must rise about 437% from the trough to regain the peak.

← **Return to drawdown**

Appendix map

A7. Stablecoin issuance and redemption preserve the issuer identity

$$\underbrace{\text{reserve assets}}_{R} = \underbrace{\text{token liabilities}}_{L} + \underbrace{\text{issuer equity}}_{E}.$$

Event	ΔR	ΔL	ΔE
issue at par	+100	+100	0
redeem at par	−40	−40	0
reserve loss	−5	0	−5

A loss first absorbs issuer equity if a positive buffer exists; token holders face a shortfall when losses exceed available capital and other support.

← **Return to stablecoin entries**

Appendix map

A8a. Immediate redemption coverage depends on saleable resources

For request Q, cash C, saleable securities S, haircut h, and unavailable assets U:

$$\begin{aligned} A_{\text{now}} &= C + (1-h)S, \\ \text{paid now} &= \min(Q, A_{\text{now}}), \\ \text{shortfall now} &= \max(0, Q - A_{\text{now}}), \\ \text{eventual par assets before sale loss} &= C + S + U. \end{aligned}$$

- U can recover later and therefore creates a timing gap rather than an automatic final loss.
- The haircut hS is a realised valuation loss if securities are sold immediately.
- Coverage must be calculated against requests due now, not total token supply alone.

A_{now} = assets convertible into cash immediately after sale discounts.

← **Return to liquidity coverage**

Appendix map

A8b. The synthetic reserve scenario remains liquid through GBP90m

Request	Paid now	Shortfall now	Immediate coverage
GBP20m	GBP20.0m	GBP0.0m	100.0%
GBP50m	GBP50.0m	GBP0.0m	100.0%
GBP90m	GBP90.0m	GBP0.0m	100.0%
GBP100m	GBP94.3m	GBP5.7m	94.3%

> At GBP100m, the GBP5.7m immediate shortfall equals GBP5.0m unavailable now plus GBP0.7m lost through the one per cent securities haircut.

$C = 25$, $S = 70$, $h = 1\%$, and $U = 5$, all in GBP millions. The scenario is synthetic.

← **Return to redemption case**

Appendix map

A9. A two-tier CBDC allocates functions across institutions

Function	Central bank	Private interface provider
monetary liability	issue and redeem CBDC	no issuer liability for CBDC
core record	maintain authoritative platform	submit authorised instructions
customer onboarding	set framework and standards	identity and compliance checks
service design	public requirements and access rules	wallets, support, additional services
data	architecture and legal limits	customer data under assigned duties

Actual allocation remains a design choice. The table describes the explored UK platform model at a high level.

← **Return to platform model**

Appendix map

A10. Deposit-to-CBDC conversion changes the composition of central-bank liabilities

Institution	Asset entry	Liability entry
household	deposit −100; CBDC +100	none
commercial bank	reserves −100	deposit −100
central bank	no asset change in base case	reserves −100; CBDC +100

> The central bank swaps one liability, reserves, for another, CBDC. The commercial bank loses both a reserve asset and deposit funding.

If the central bank lends reserves back to the commercial bank, its assets and reserve liabilities expand; that offset is a separate policy operation.

← **Return to CBDC conversion**

Appendix map

A11. Payment-stage definitions prevent premature claims of finality

Stage	Output	Failure example
initiation	valid payer authorisation	fraud or insufficient authentication
messaging	instruction reaches relevant institutions	routing error or outage
clearing	validated gross or net obligations	unmatched data or participant default
settlement	settlement asset changes ownership	insufficient liquidity
finality	transfer cannot be revoked under rules	legal or operational ambiguity

Crediting the payee before interbank finality can create credit exposure for the payee's bank or the payment system.

← **Return to payment journey**

Appendix map

A12. Netting entries must sum to zero across participants

Use $n_i = \text{outgoing}_i - \text{incoming}_i$, so $n_i > 0$ means pay reserves:

$$n_A = 100 - 50 = 50, \qquad n_B = 80 - 100 = -20,$$
$$n_C = 50 - 80 = -30, \qquad \sum_i n_i = 50 - 20 - 30 = 0.$$

$$\text{funds supplied by net debtors} = \sum_i \max(n_i, 0) = £50.$$

- A pays GBP50; B receives GBP20 and C receives GBP30.
- Gross customer-payment value remains GBP230; only the settlement funding changes.

A non-zero sum reveals a missing payment, sign, or participant.

← **Return to netting example**

Appendix map

A13. Compare risk by following the legal claim and settlement path

Object	Direct credit exposure	Liquidity or conversion risk	Principal residual risks
bank deposit	commercial bank	access and par conversion under framework	bank, operational, fraud beyond protections
Bitcoin	no issuer	market sale required for fiat conversion	price, custody, network, regulation
stablecoin	private issuer and reserve structure	redemption access, reserve sale, peg	credit, liquidity, custody, operations
retail CBDC	central bank	no private redemption step into public money	operational, privacy, cyber, design
payment rail	depends on money moved	timing until settlement finality	participant, operational, liquidity, legal

The table is a classification framework, not a ranking. Risk depends on the named issuer, jurisdiction, rules, custody, and use case.

← **Return to course map**

Appendix map

A14. Frozen data provenance, dates, and transformations

File or series	Source	Convention
BTC PriceUSD	Coin Metrics Community API	daily 00:00 UTC reference rate, 2018–31 Jul 2026
USDC PriceUSD	Coin Metrics Community API	daily reference rate, Mar 2023; peg fixed at USD1
FPS and CHAPS Q4	Pay.UK Q4 2025 PDF	exact quarterly volume and value totals
CHAPS 2025 distribution	Bank of England statistics	annual rounded mean and reported median
UK policy status	Bank of England official pages	frozen at 15 Aug 2026; proposal and decision labels retained
redemption scenario	disclosed synthetic inputs	cash 25, bills 70, unavailable 5, haircut 1%, GBPm

Derived CSV files preserve dates and calculation inputs. The notebook reads frozen local files and does not require live downloads.

← Return to sources

Appendix map

Python practical map

P1 Inspect frozen policy status

P2 Load Bitcoin prices

P3 Calculate drawdown

P4 Measure the USDC peg

P5 Stress redemption liquidity

P6 Calculate net settlement

P7 Compare UK payment scales

P8 Validate identities

- The notebook reproduces calculations already developed in the lecture.
- Frozen local data keep policy dates, market series, and payment totals reproducible.
- Assertions check financial identities, signs, and units after each stage.

Technical appendix map

P1. Inspect the frozen UK policy status before analysis

```python
import pandas as pd

policy_path = "../data/derived/day08_uk_policy_status.csv"
policy = pd.read_csv(policy_path, parse_dates=["official_source_date"])

# Display status words so proposals are not reported as completed policy.
print(policy[["topic", "status", "official_source_date"]])
assert not policy["status"].str.contains("introduced").any()

```

Expected result: the digital pound is in a design phase; stablecoin rules are proposed; future retail infrastructure is under consultation.

← Return to 2026 landscape

Practical map

P2. Load and inspect the frozen Bitcoin price series

```python
btc_path = "../data/derived/day08_btc_daily.csv"
btc = pd.read_csv(btc_path, parse_dates=["date"])

# Check the date range and inspect prices before transforming them.
print(btc[["date", "price_usd"]].head())
print(btc[["date", "price_usd"]].tail())
print("rows:", len(btc))

assert btc["price_usd"].gt(0).all()
```

The frozen series contains daily Coin Metrics reference prices from 1 Jan 2018 through 31 Jul 2026.

← Return to Bitcoin chart

Practical map

P3. Calculate running peaks and drawdowns

```python
# cummax stores the highest price observed up to each date.
btc["running_peak"] = btc["price_usd"].cummax()
btc["drawdown"] = btc["price_usd"] / btc["running_peak"] - 1

trough_row = btc.loc[btc["drawdown"].idxmin()]
print("MDD (%):", round(100 * trough_row["drawdown"], 2))
print("trough date:", trough_row["date"].date())

assert btc["drawdown"].le(1e-12).all()
```

Expected MDD: −81.38%, with the sample trough drawdown on 15 Dec 2018. The assertion prevents drawdowns above zero.

← **Return to drawdown formula**

Practical map

P4. Express the USDC price gap in basis points

```python
usdc = pd.read_csv(
    "../data/derived/day08_usdc_march2023.csv",
    parse_dates=["date"]
)

# One basis point is 0.0001 of the USD1 peg.
usdc["peg_deviation_bp"] = 10_000 * (usdc["price_usd"] - 1)
worst = usdc.loc[usdc["peg_deviation_bp"].idxmin()]

print(worst[["date", "price_usd", "peg_deviation_bp"]])
```

Expected minimum daily deviation: about −293.5 bp on 11 Mar 2023. The task then finds the first later date within 10 bp of par.

← **Return to USDC chart**

Practical map

P5. Stress immediate redemption coverage

```python
def redemption_result(request, cash, bills, haircut):
    """Return immediate payment and shortfall, all in GBPm."""
    resources_now = cash + bills * (1 - haircut)
    paid_now = min(request, resources_now)
    shortfall_now = max(0, request - resources_now)
    return paid_now, shortfall_now

paid, shortfall = redemption_result(100, 25, 70, 0.01)
print(paid, shortfall)
assert abs(paid - 94.3) < 1e-12
```

Expected output: GBP94.3m paid immediately and GBP5.7m shortfall. Extend the function across requests and haircuts.

← **Return to redemption case**

Practical map

P6. Calculate multilateral net positions from payment records

```python
payments = pd.DataFrame({
    "sender": ["A", "B", "C"],
    "receiver": ["B", "C", "A"],
    "amount": [100, 80, 50]
})

outgoing = payments.groupby("sender")["amount"].sum()
incoming = payments.groupby("receiver")["amount"].sum()
net_due = outgoing.sub(incoming, fill_value=0).sort_index()

print(net_due)
assert abs(net_due.sum()) < 1e-12
```

Expected net due: A pays 50, B receives 20, and C receives 30. A positive number means reserves payable.

← **Return to netting example**

Practical map

P7. Compare volume, value, and average payment size

```
systems = pd.read_csv(
    "../data/derived/day08_payments_q4_2025.csv"
).set_index("system")

systems["average_gbp"] = systems["value_gbp"] / systems["volume_count"]
volume_ratio = systems.loc["Faster Payments", "volume_count"] / systems.loc["CHAPS", "volume_count"]
average_ratio = systems.loc["CHAPS", "average_gbp"] / systems.loc["Faster Payments", "average_gbp"]

print(systems[["volume_count", "value_gbp", "average_gbp"]])
print(round(volume_ratio, 2), round(average_ratio, 2))
```

Expected ratios: FPS volume is 106.38 times CHAPS volume; the CHAPS average payment is 2,080.01 times the FPS average.

← **Return to payment averages**

Practical map

P8. Assertions protect accounting, units, and signs

```python
# A stablecoin issued at par has equal asset and liability changes.
assert 100 == 100

# Net payment positions must cancel across the closed system.
assert abs(net_due.sum()) < 1e-12

# Drawdown cannot be positive relative to its own running peak.
assert btc["drawdown"].max() <= 1e-12

# GBP100m request minus GBP94.3m paid equals GBP5.7m shortfall.
assert abs((100 - paid) - shortfall) < 1e-12
print("all Day 8 checks passed")
```

The complete solution notebook also checks date ranges, missing values, peg-recovery logic, and source totals.

← **Return to final checklist**

Practical map