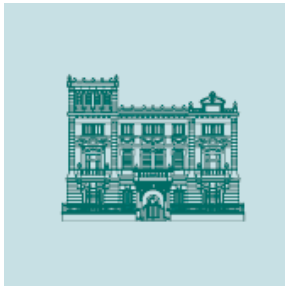
The Future of (Digital) Money

Mauro F. Guillén



Wharton
University of Pennsylvania

Indifferent

León: The Gold that funded Rome

(5 tons = $674 million)









León: The Birth of Parliamentarism

(Alfonso IX at the Cortes of 1188)

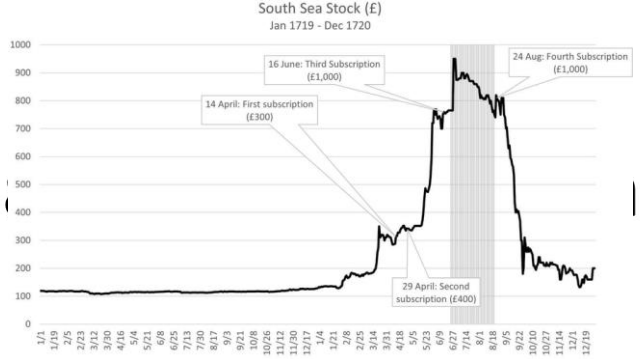


León
Cuna del Parlamentarismo

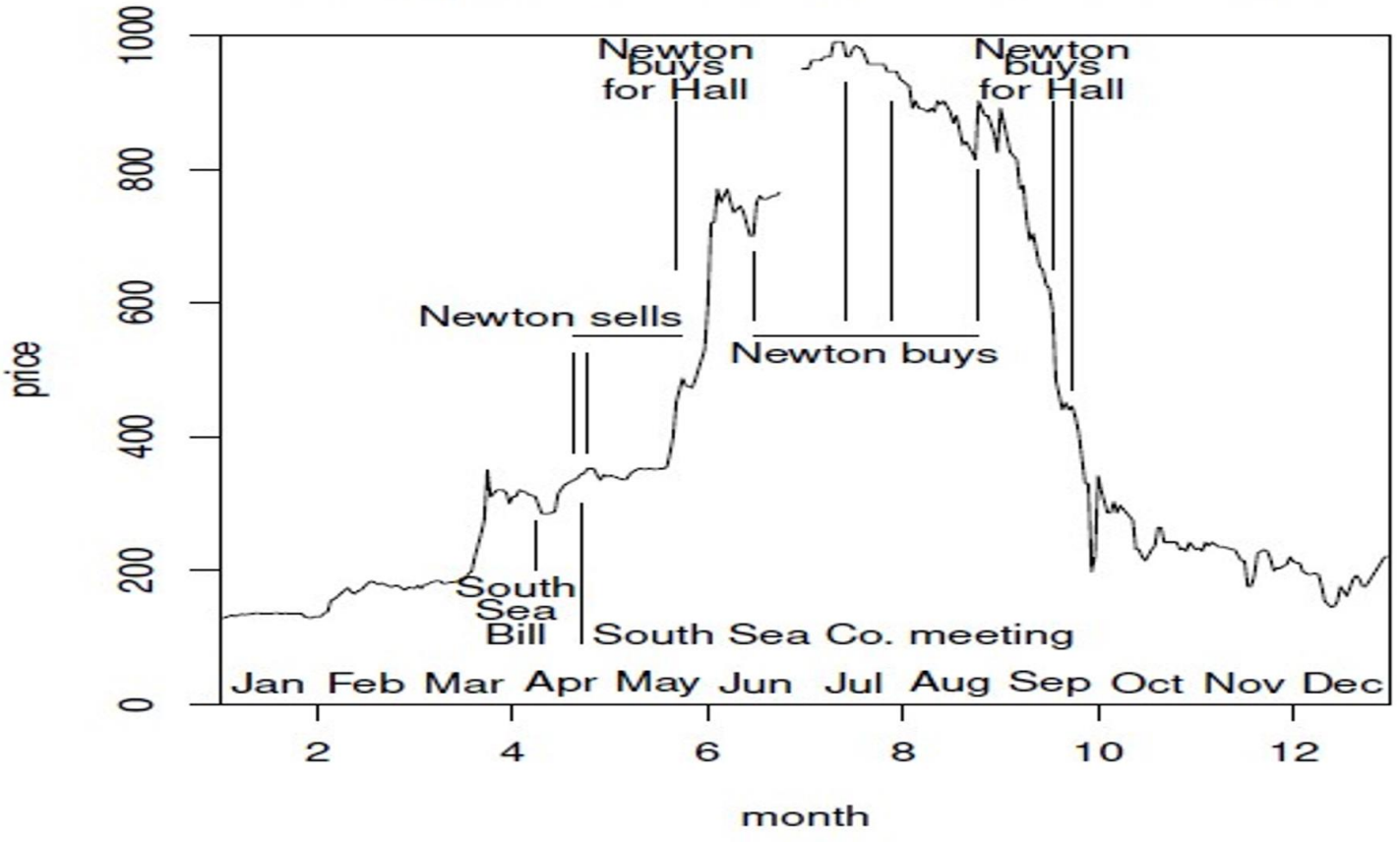


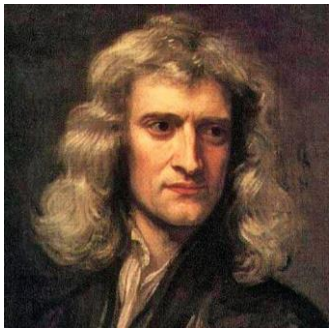
- In attendance: Clergy, nobility, and representatives from the city.
- The *Decreta* (decrees) included:
  - Prohibition against infringing upon the property of others.
  - Requirement that disputes be resolved before the courts.
  - The king's promise not to go to war without consulting all those whose counsel he is obliged to seek.

Newton Bubble



South Sea stock prices in 1720, and Newton's investments





(A. Odlyzko, "Isaac Newton and the Perils of the Financial South Sea," January 7, 2020, available at http://www.dtc.umn.edu/Odlyzko)

In the near future, will digital currencies dominate the financial landscape?

A. No.

B. Maybe.

C. Yes.

Most Likely to Survive?

A. Banks.

B. Banking.

C. Bankers.

The Brightest Undergraduate...

"Professor, you're too old to fully understand the potential of cryptocurrencies."

Motivational Quote

"Permit me to issue and control the money of a nation, and I care not who makes its laws."

—Mayer Anselm Rothschild



Mauro F. Guillén, *2030 AD: How Today's Biggest Trends Will Collide and Reshape the Future of Everything* (Nueva York: St. Martin´s, 2020).

Money is based on "people's **beliefs** and other people's **beliefs**."

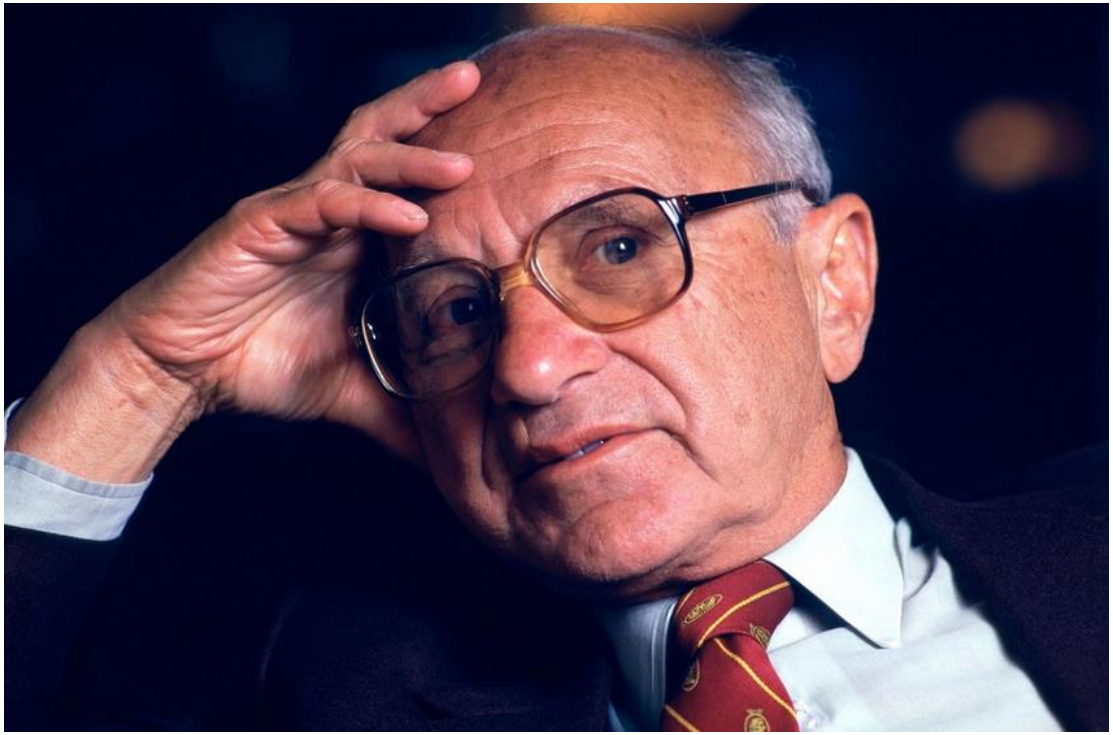


"If everyone thinks everyone else will accept money, then **everyone will accept money**."

—Max Weber

Milton Friedman

- "Inflation is always and everywhere a monetary phenomenon."
- Dream of "replacing the Fed with a computer."



Milton Friedman, *Inflation: Causes and Consequences* (New York: Asia Publishing House, 1963), p. 39.
Milton Friedman and Anna Schwartz, *A Monetary History of the United States, 1867-1960* (Cambridge, MA: NBER Publicaitions, 1963).
Earl J. Hamilton, *American Treasure and the Price Revolution in Spain, 1501-1650* (Oxford, England: Oxford University Press, 1934).

Origins of a name and a symbol…



Thaler



Real de a ocho
(Spanish Dollar)







MAURO F. GUILLEN
3455 S. Broad Street
Philadelphia, PA 19234

1027

November 25, 2013
DATE

PAY TO THE ORDER OF Cash $ 1.00

One dollar 00/100 DOLLARS

FOR

⑆22222222⑆ 000 111 555⑈ 1027





SALVADOR DALÍ
214 Cadaqués St.
New York, NY 10001

DATE May 21, 1968

PAY TO THE ORDER OF Le Cirque $ 351.27

Three hundred and fifty-one dollars 27/100 DOLLARS

Security Features Details on Back.



MEMO

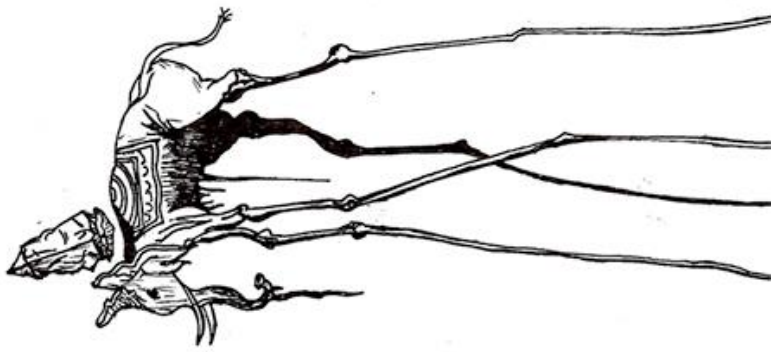
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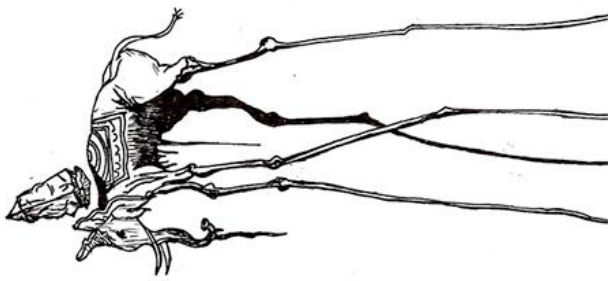
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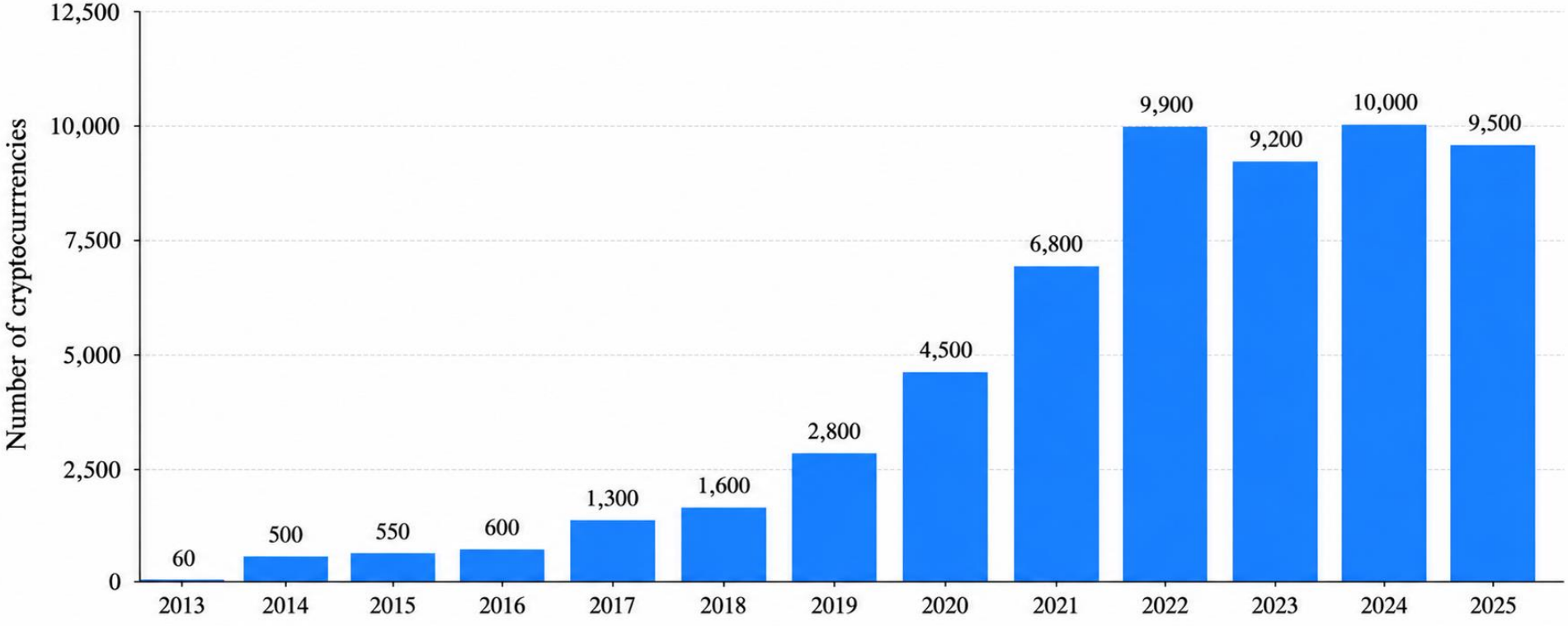
Money is based on "people's **beliefs** and other people's **beliefs**."



"If everyone thinks everyone else will accept money, then **everyone will accept money**."

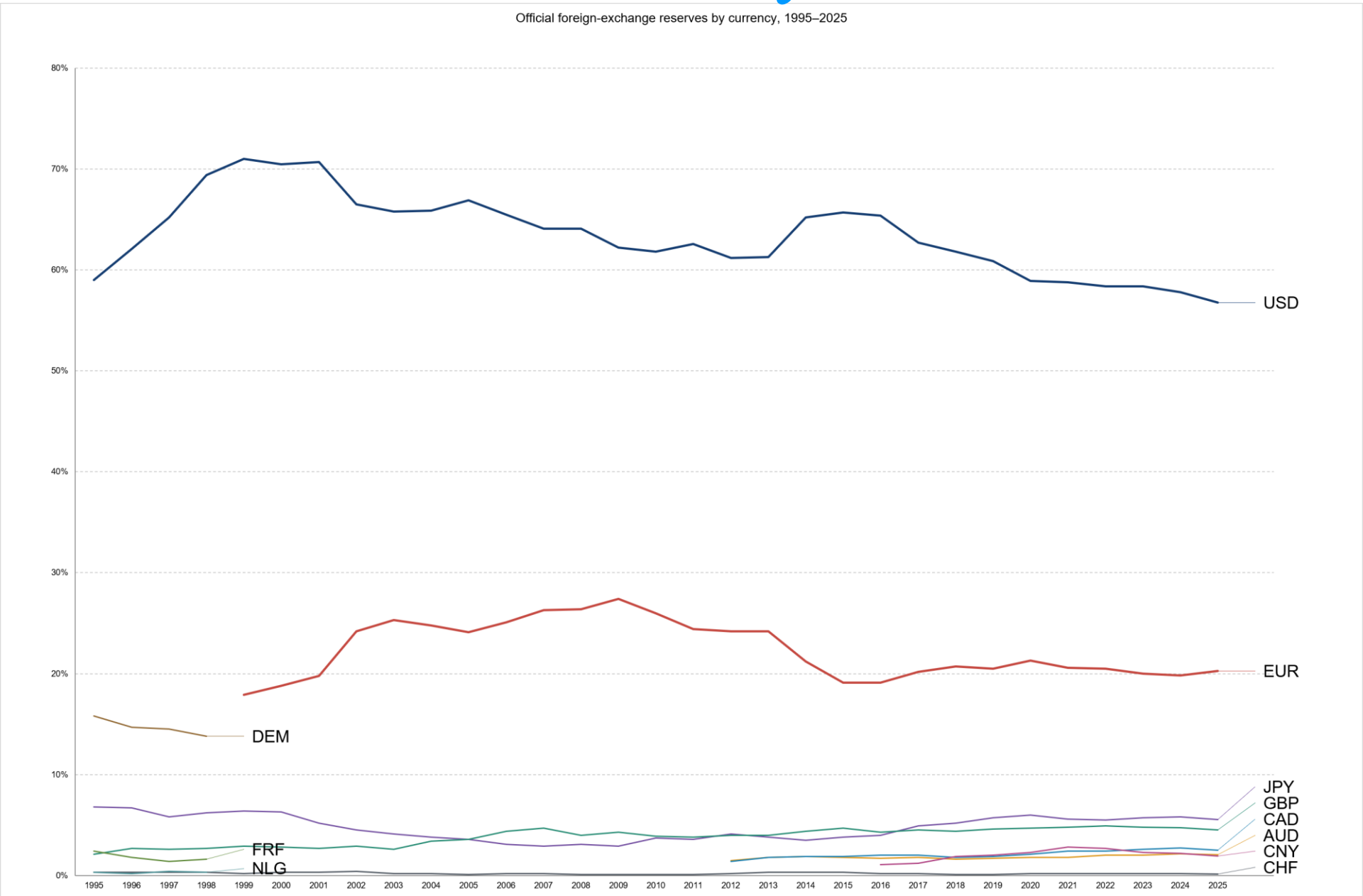
—Max Weber

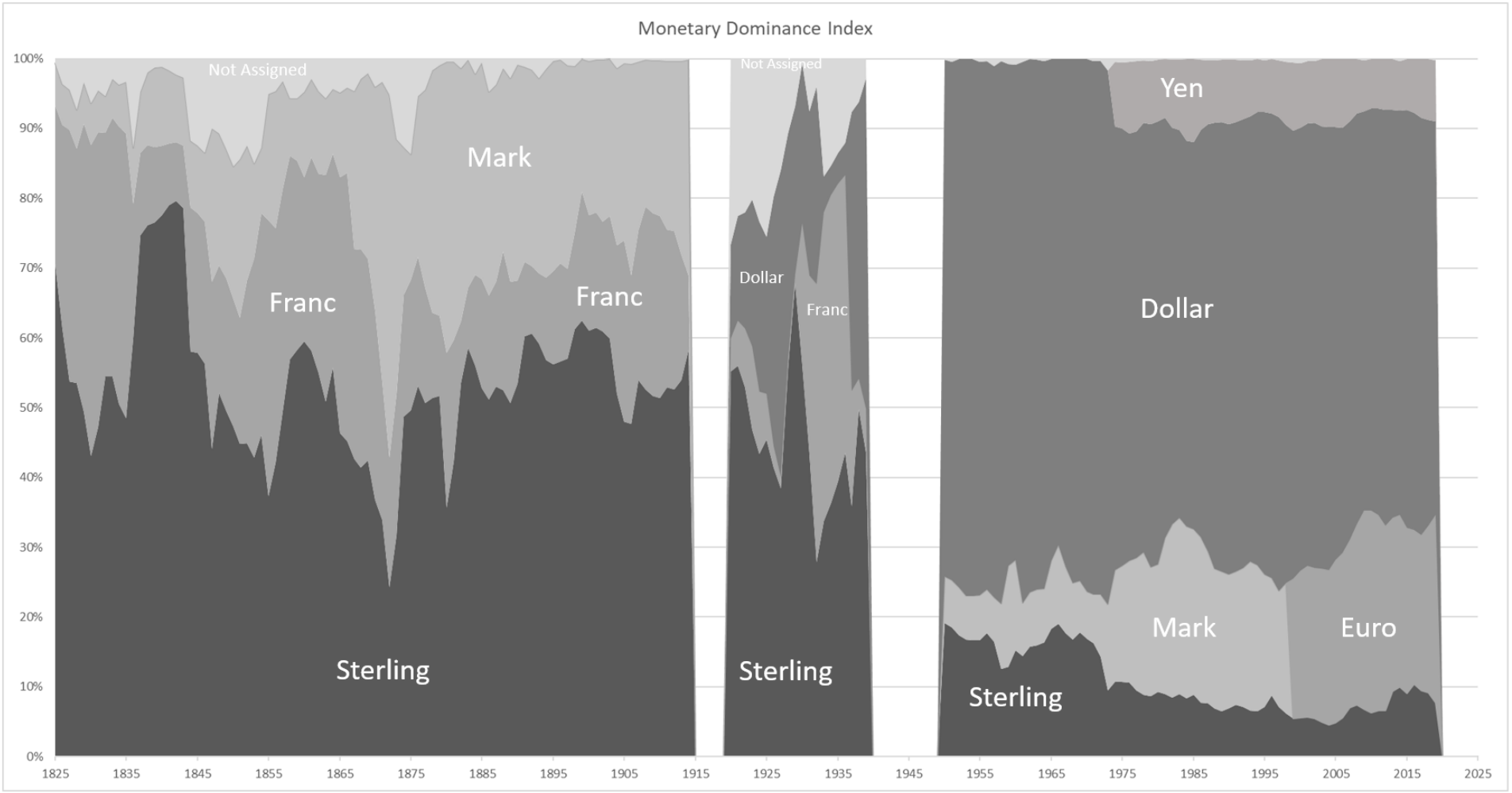
Number of cryptocurrencies worldwide, 2013–2025



Source: Statista (November 2025).

Official Currency Reserves





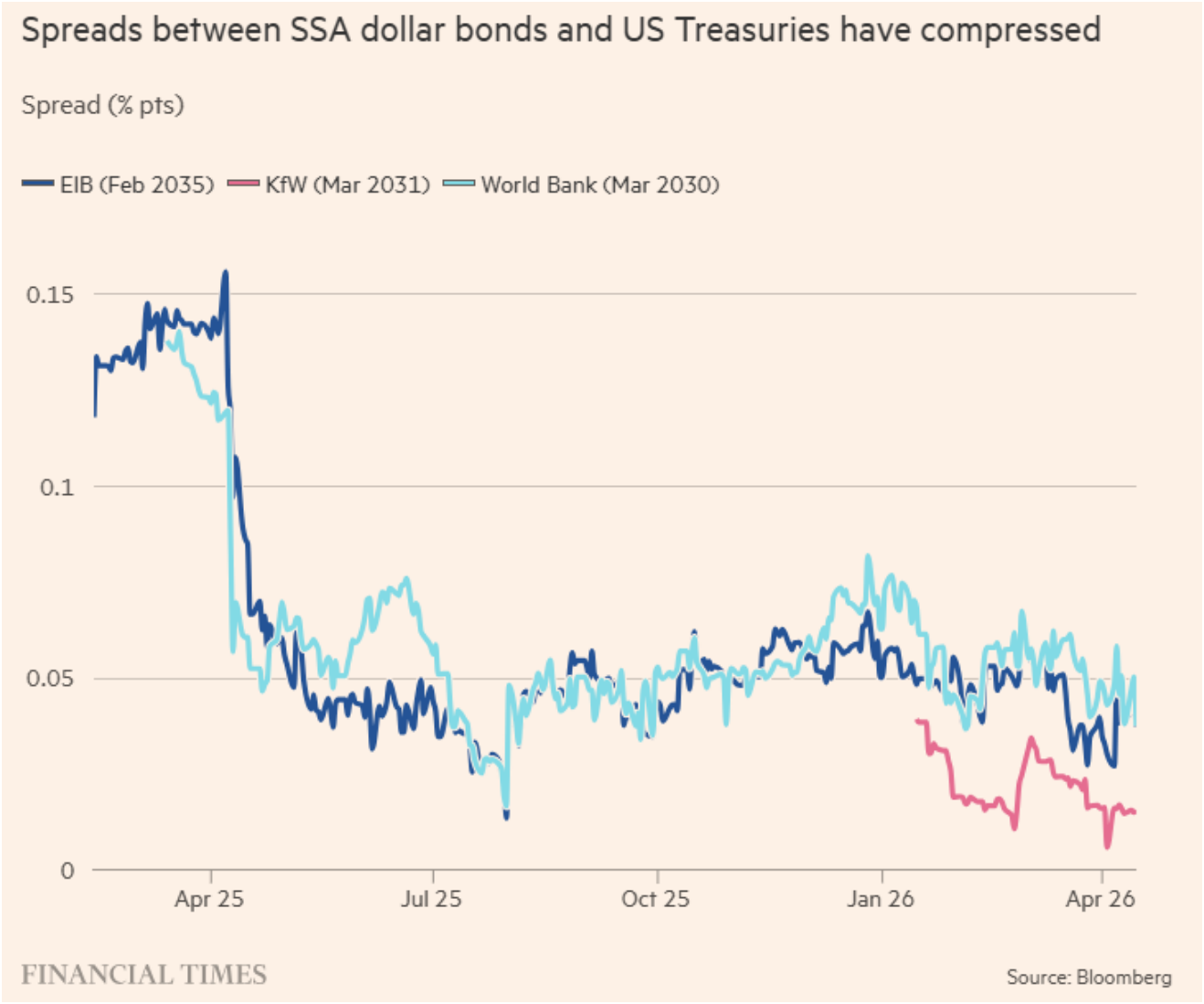
Note: The index is calculated measuring foreign-exchange co-movements.

Source: Vicquéry (2022).

FINANCIAL TIMES

US's status as lowest-cost dollar borrower challenged as investors shun Trump risk

Concerns over erratic White House policymaking have driven investors to 'very stable' development bank issuers



https://www.ft.com/content/ad217964-bcc9-468a-868f-810e118a4fbc?shareType=nongift


FEDERAL RESERVE NOTE
THE UNITED STATES OF AMERICA
THIS NOTE IS LEGAL TENDER
FOR ALL DEBTS, PUBLIC AND PRIVATE
B 03542754 F
WASHINGTON, D.C.
B 03542754 F
SERIES 2009
WASHINGTON
ONE DOLLAR
Treasurer of the United States.
Secretary of the Treasury.


中国人民银行
1
壹圆
BX5 1290698
毛泽东1893-1976

Digital Currencies

Private Cryptocurrencies:

- Peer to peer.
- Decentralized.
- Ruled by algorithm.
- Types: utility, stablecoins (Tether), etc.
- Bitcoin is “a combination of a bubble, a Ponzi scheme and an environmental disaster.” (President of BIS).

Central Bank Digital Currencies:

- Issued by CB.
- Centralized.
- Controlled by CB.
- Types: wholesale, retail, interest or non-interest.
- Bahamas, Nigeria, and Eastern Caribbean Union.
- >100 countries doing research or pilots.

VANITY FAIR

Crypto's True Believers Demand to Be Taken Seriously

They partied like rock stars, searched for aliens, practiced survivalism, and sometimes showed up without shoes. Then crypto winter came—and they lost billions. Clara Molot talks to the zealots who are holding the line.

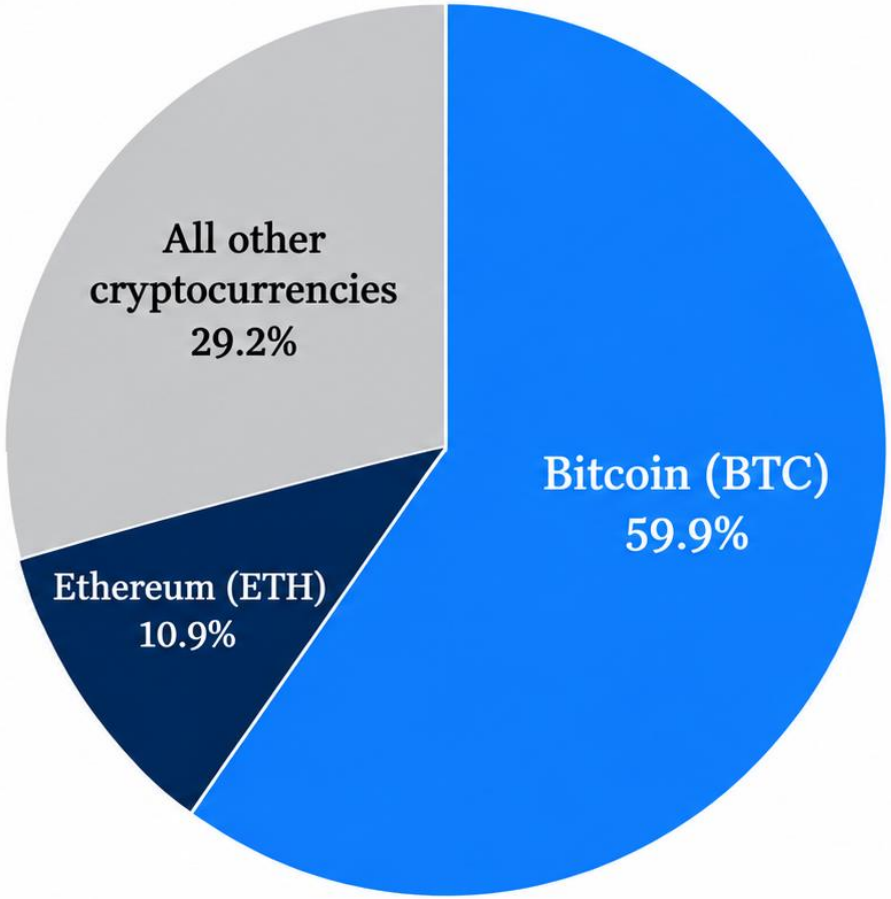
BY CLARA MOLOT
PHOTOGRAPHER JEREMY LIEBMAN

MARCH 17, 2026



https://www.vanityfair.com/news/story/cryptos-true-believers

Cryptocurrency market capitalization dominance — October 2026

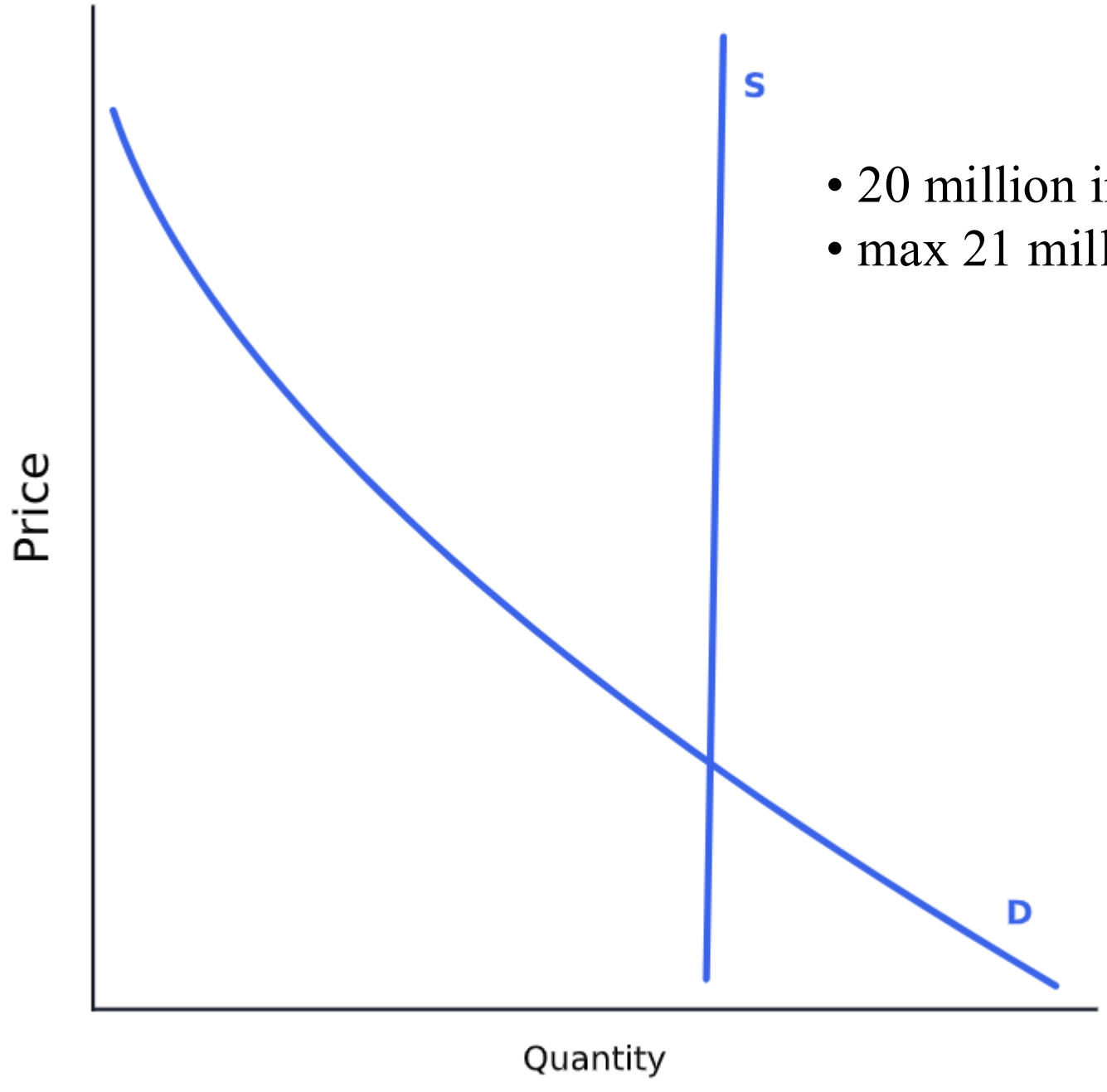


Source: CoinMarketCap, October 2026. Shares of total cryptocurrency market capitalization.

Leading Cryptocurrencies

- Bitcoin
  - 2008.
  - **Proof of work**: everyone in the network rushes to verify every transaction, which results in waste.
- Ethereum:
  - 2014.
  - **Proof of stake**: transactions verified by a lottery of users who have deposited collateral (stake).
  - Smart contracts.

Bitcoin

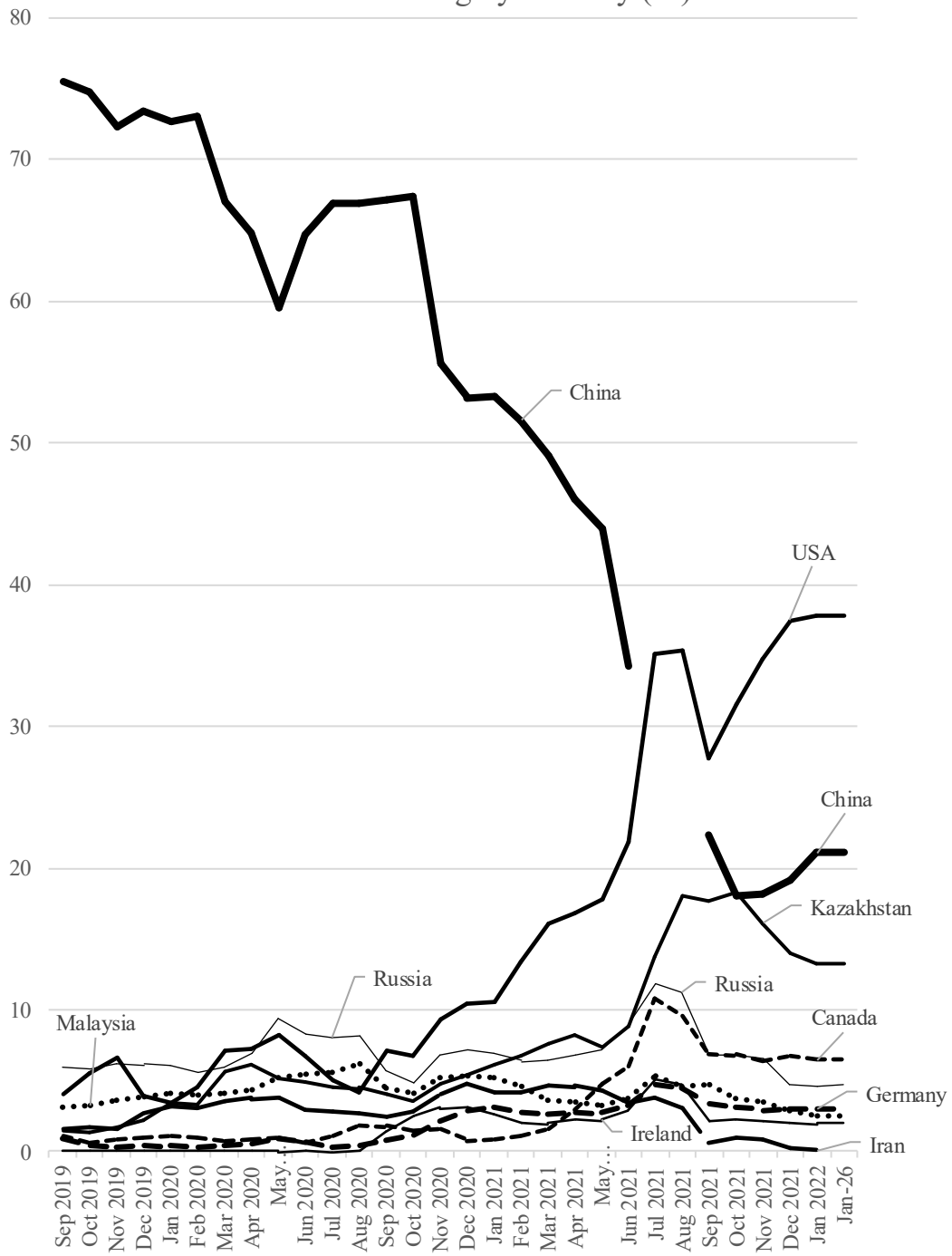


- 20 million in circulation
- max 21 million by ~2140

Bitcoin Mining Map



https://ccaf.io/cbnsi/cbeci/mining_map


Bitcoin Mining by Country (%)
80
70
60
50
40
30
20
10
0
China
USA
China
Kazakhstan
Russia
Russia
Malaysia
Canada
Germany
Ireland
Iran
Sep 2019
Oct 2019
Nov 2019
Dec 2019
Jan 2020
Feb 2020
Mar 2020
Apr 2020
May...
Jun 2020
Jul 2020
Aug 2020
Sep 2020
Oct 2020
Nov 2020
Dec 2020
Jan 2021
Feb 2021
Mar 2021
Apr 2021
May...
Jun 2021
Jul 2021
Aug 2021
Sep 2021
Oct 2021
Nov 2021
Dec 2021
Jan 2022
Jan-26

Historical Bitcoin greenhouse gas emissions

Select a time window by clicking and dragging to define the start and end dates on the timeline below



https://ccaf.io/cbnsi/cbeci

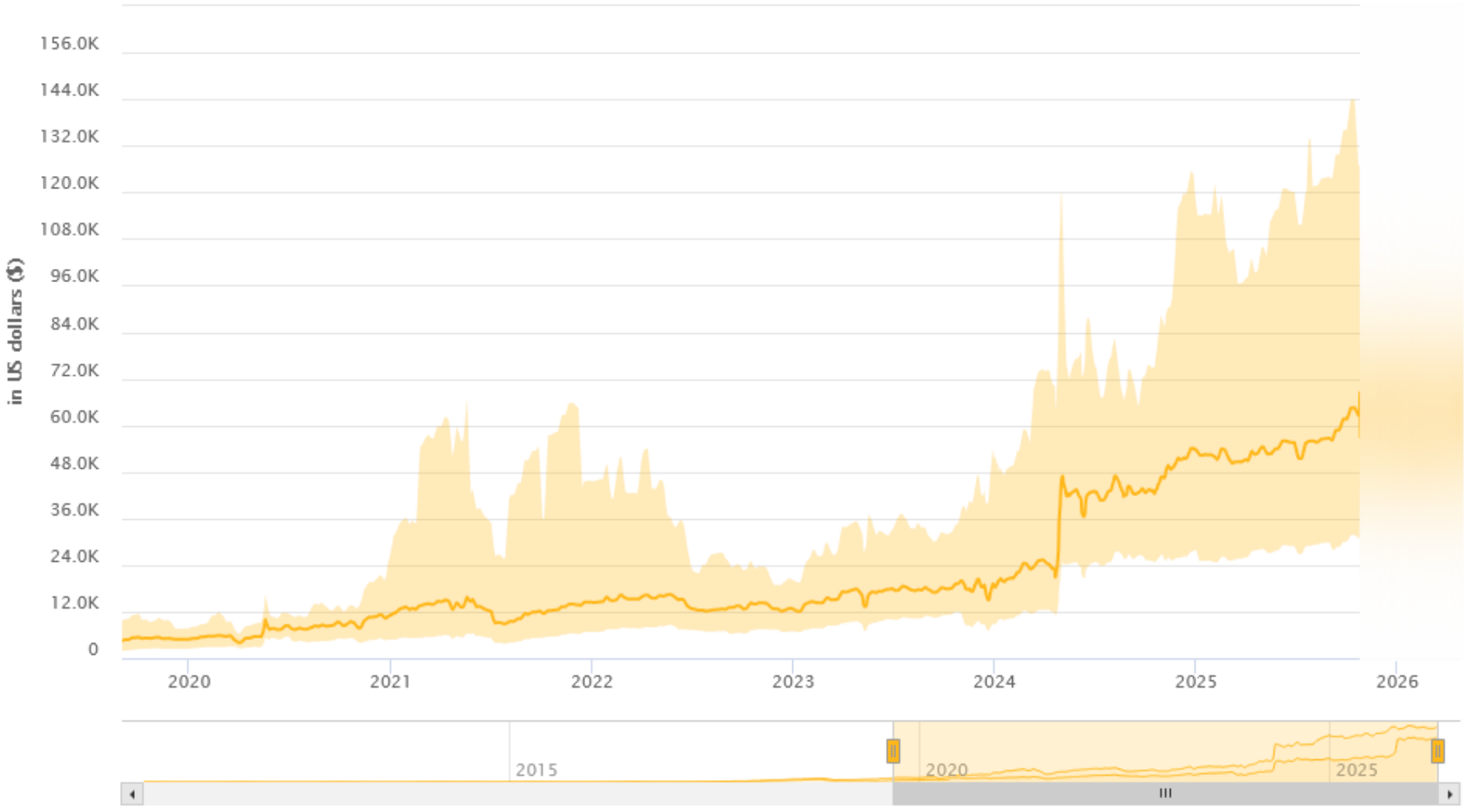
Historical Cost to Mine One BTC

Select a time window by clicking and dragging to define the start and end dates on the timeline below

Daily | Yearly

7d | 1m | 3m | 6m | YTD | 1y | All | Custom

2019-08-31 - 2026-04-24



https://ccaf.io/cbnsi/cbeci

Bitcoin

- **Negative carry** due to opportunity cost, and in the absence of rewards.
- **Zero use value**: unlike gold.
- **Free to store**: unlike commodities.
- But there are **transaction fees**.
- **Divisible**: like gold, unlike diamonds.
- **Rigid supply** ⇒ Price driven by demand.

Path Dependency (non-ergodicity)

- Any investment's returns: $P_{t+1} = P_t(1 + r_t).$
- Your wealth after T periods:

$$W_T = W_0 \prod_{t=1}^{T} (1 + r_t).$$

- Note it's **multiplicative**: if price +50%, and then −50%, the loss is 25%.
- Or: a −70% requires a +233% to break even.

- Therefore:

$$\lim_{T \to \infty} \frac{1}{T} \log \frac{W_T}{W_0} = E[\log(1 + r)]$$

Implications

- Bitcoin is **non-ergodic**, even if its algorithmic rules are perfectly known.
- The future distribution of **demand** is partly generated by the system's own history.
- **High volatility** ⇒ Geometric change is much larger than arithmetic change.
- This does **not** mean Bitcoin is unpredictable.
- **Wrong** question: "What is the expected return?"
- Correct Question: "What happens to my wealth when I actually **experience the process through time**?"

Two Problematic Aspects

- Miners' revenue $R = P\,(Q + F)$:

  P: price of bitcoin.

  Q: number of new bitcoins for each block.

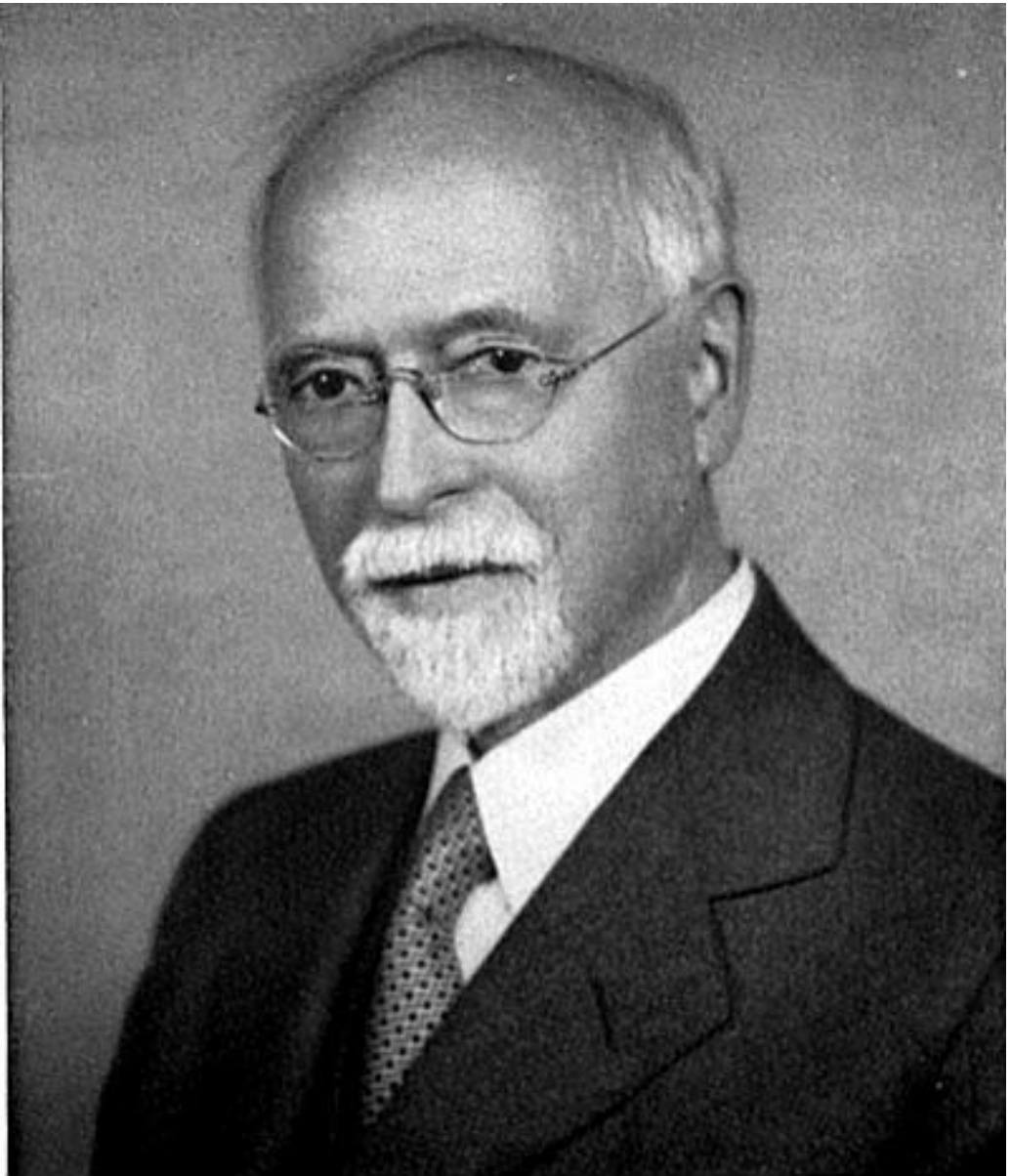
  F: transaction fees.

- Q is programmed to halve every ~4 years. It will equal zero in ~2140. At that point, miners become mere transaction validators.
- Currently, $Q = 3.125$ bitcoin per block.
- **Feedback loop**: $Q\downarrow \Rightarrow R\downarrow \Rightarrow$ number & hash power of miners$\downarrow \Rightarrow$ confidence in bitcoin$\downarrow \Rightarrow$ $P\downarrow \Rightarrow R\downarrow$, and so on.
- **Free-rider problem**: security is free for those who simply hold bitcoin, without transacting.

Bitcoin Can Test Your Nerves

- Investor A: 100 → 200 → 400 → 800.
- Investor B: 100 → 30 → 15 → 800.
- B has experienced an 85% drawdown along the way.
- If B is leveraged, needs liquidity, faces margin calls, or is psychologically weak, it is likely they would sell the investment at some point before it reaches a value of 800.

Fisher's Quantitative Theory of Money



$MV \equiv PT$

M: total money supply.

V: Velocity of circulation.

P: Total price level.

T: Volume of transactions.

Formulated in 1911.

Application to Bitcoin

- $MV \equiv PT$.
- Hence, the **dollar value** of all bitcoins is: $P_B M_B = T / V$, which means that:
- $P_B = T / M_B V$.
- Thus, the dollar price of bitcoin is **inversely** proportional to V.
- $\Rightarrow$ bitcoin becoming widely used does **not** mean that bitcoin's price increases.

Expectations

- For bitcoin, V depends on people's **expectations** as to P_B.
- Note that if people hold bitcoin as a store of value $\Rightarrow V\downarrow \Rightarrow P_B\uparrow$.
- If people expect $P_B\uparrow$ in the future, they have an incentive to hold rather than spend $\Rightarrow V\downarrow \Rightarrow P_B\uparrow$, i.e. a self-fulfilling prophecy.
- Or, the reverse: if they expect $P\downarrow$, they will spend/sell $\Rightarrow V\uparrow \Rightarrow P_B\downarrow$.

So, is Bitcoin an Inflation Hedge?

- If demand goes up, the value of BTC rises, which is **deflationary** (~inflation hedge).
- If demand goes down, the value of BTC drops, which is **inflationary**.
- This happens because there is no authority or lines of code that **adjust the supply** of bitcoin depending on what happens to the demand.

VANITY FAIR

Crypto's True Believers Demand to Be Taken Seriously

They partied like rock stars, searched for aliens, practiced survivalism, and sometimes showed up without shoes. Then crypto winter came—and they lost billions. Clara Molot talks to the zealots who are holding the line.

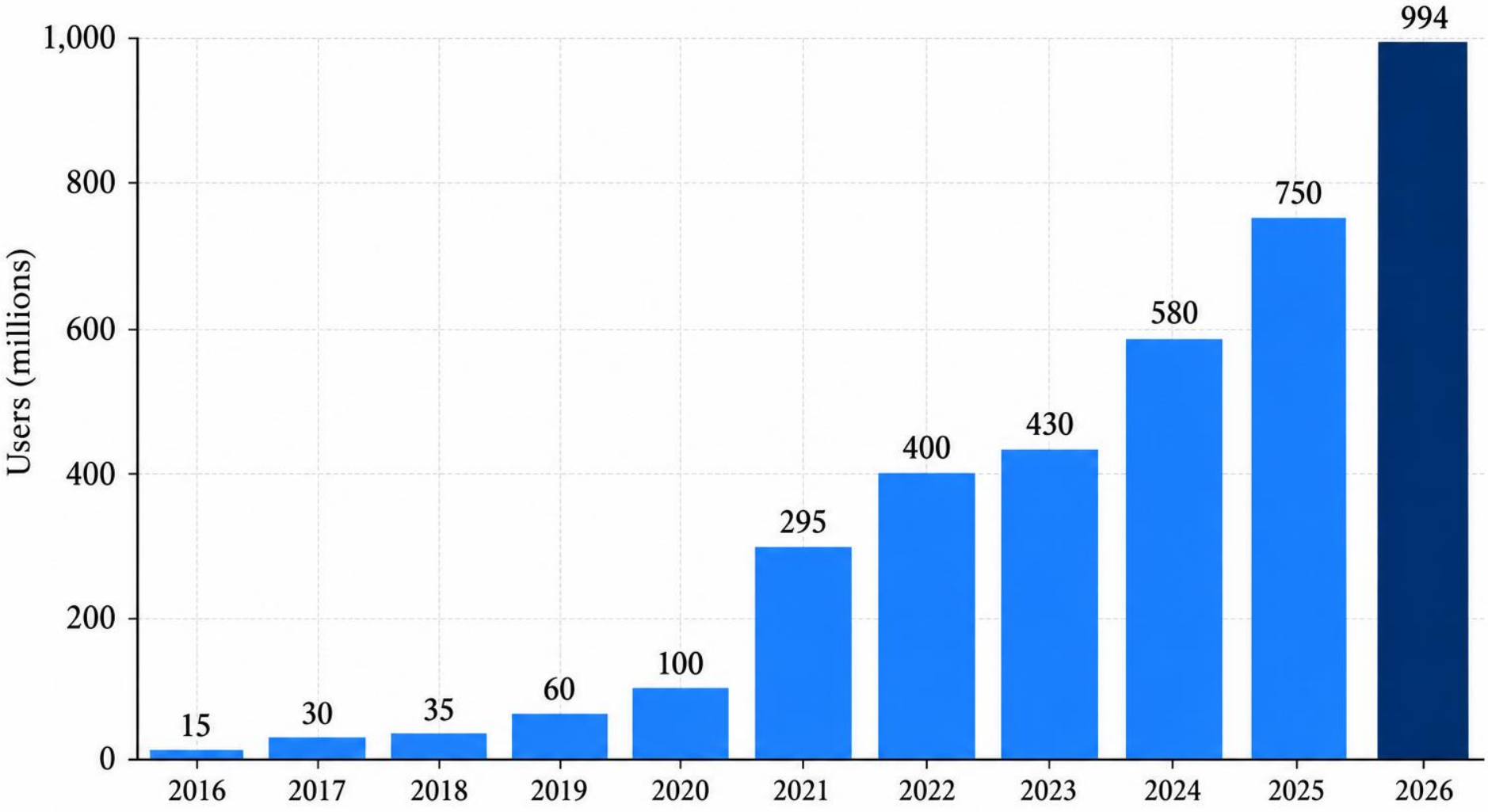
BY CLARA MOLOT
PHOTOGRAPHER JEREMY LIEBMAN

MARCH 17, 2026



https://www.vanityfair.com/news/story/cryptos-true-believers

Cryptocurrency users worldwide, 2016–2026



Illustrative combined series; estimates from different methodologies. 2026 projected.
Sources: Statista, Cambridge CJBS, Crypto.com, European Commission JRC.

Stablecoins

- The cryptocurrency is supposedly pegged to a **reference asset**, e.g. fiat currency or commodity.
- But it requires the issuer to maintain reserves, which is not always done.
- **Tether** is the best known.
- Recent changes in regulation allow for stablecoins to offer "rewards," which are tantamount to yields, a loophole that banks want closed.

https://www.economist.com/finance-and-economics/2025/12/15/cryptos-real-threat-to-banks

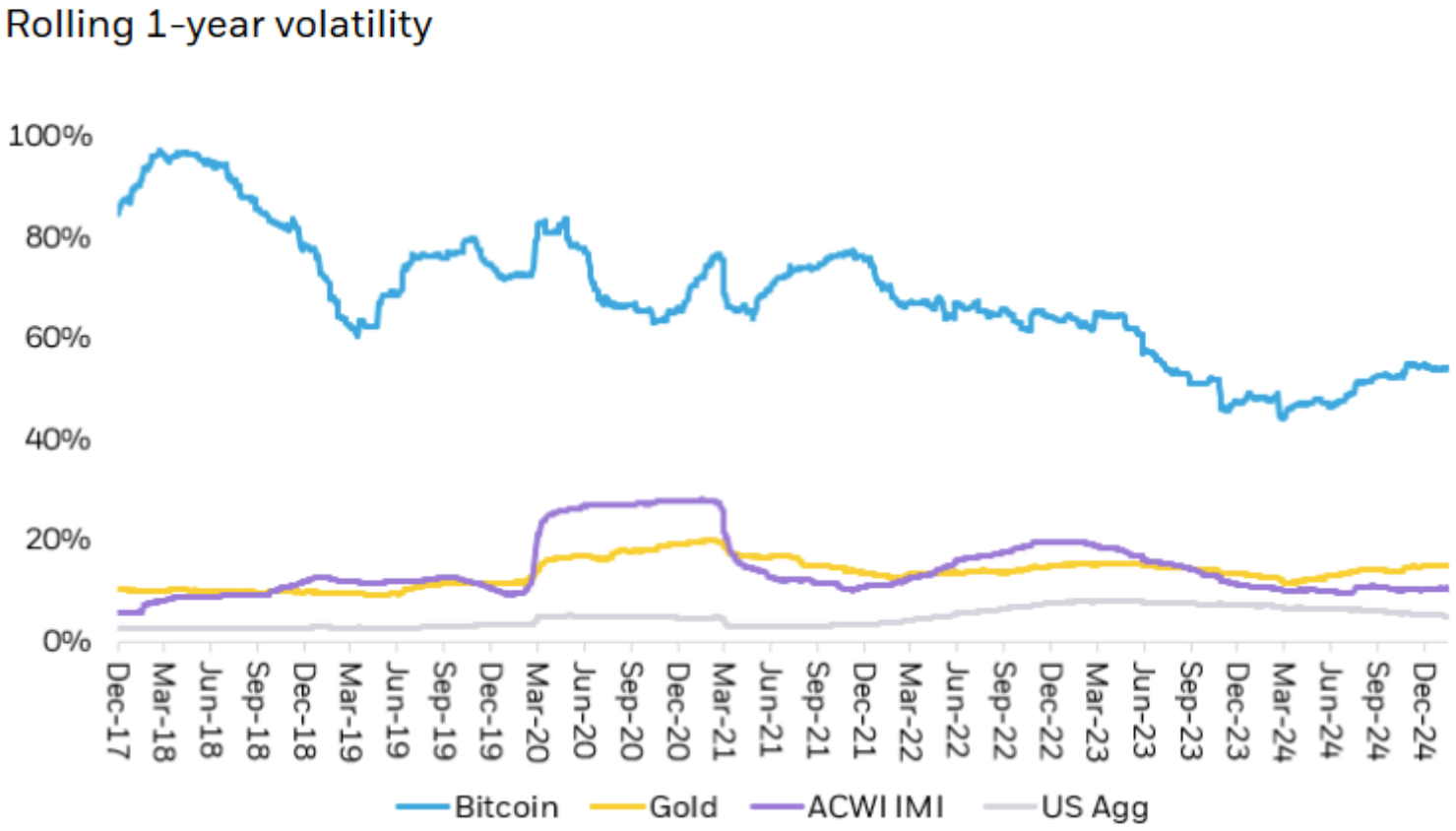
Largest Stablecoins

- **Tether**: Backed 1:1 by USD or equivalent assets held by Tether.
- **USDC**: Backed by USD, treasuries.
- **Ethena USDe**: Backed by a diversified basket of cryptoassets (Bitcoin, Ethereum, etc.), and an equal short position in the perpetual futures market which means that the net value stays at roughly 1 USD.

Bitcoin as an asset class

- Legitimacy & Diversification.
- Regulation: In January 2024 the SEC approved the first bitcoin ETFs, which track the value of bitcoin but trade in traditional exchanges.
- Volatility.
- Correlation with other assets.
- Largest Bitcoin ETFs managed by BlackRock and Fidelity.

Figure 4: Bitcoin's volatility is still high, but coming down

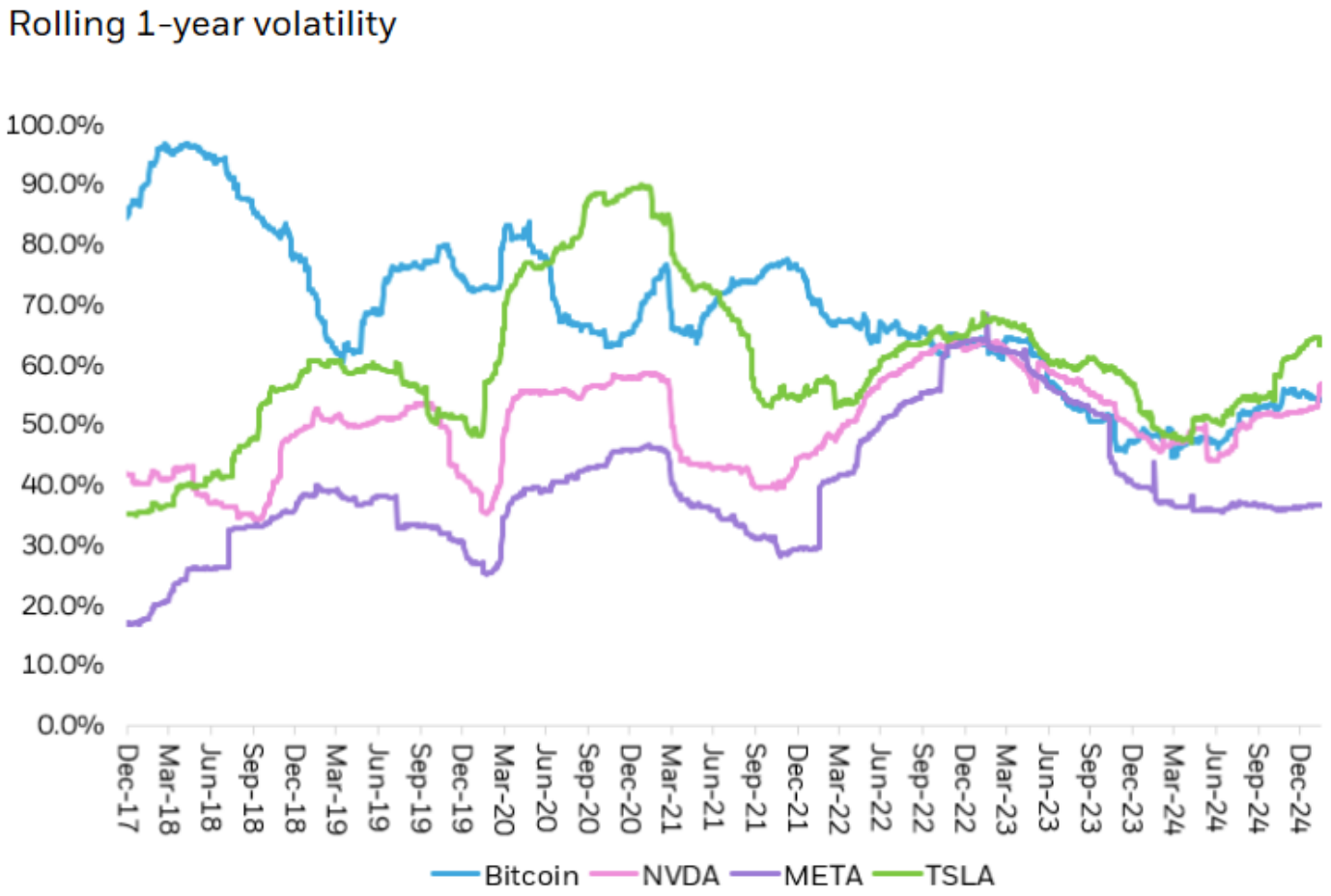


Source: Bloomberg. Bitcoin represented by Bloomberg Bitcoin Spot Price, Gold represented by Bloomberg Gold Spot Price, ACWI IMI represented by the MSCI ACWI IMI Net Total Return USD Index, US Agg represented by Bloomberg US Agg Total Return Value Unhedged USD Index. Volatility Annualized using daily returns. **For illustrative purposes only. Not meant to guarantee any future result or experience.**

Chart description: Line chart depicting the rolling 1-year volatility of Bitcoin alongside gold, global equities, and U.S. bonds, illustrating Bitcoin's historically high but decreasing volatility relative to other major asset classes from December 2017 to December 2024.

https://www.ishares.com/us/insights/bitcoin-volatility-trends

Figure 3: Bitcoin's volatility vs. certain mega cap tech stocks



Source: Bloomberg. Bitcoin represented by Bloomberg Bitcoin Spot Price volatility Annualized using daily returns. **For illustrative purposes only. Not meant to guarantee any future result or experience. Any companies mentioned do not necessarily represent current or future holdings of any BlackRock products.** For actual Fund holdings, please visit **www.ishares.com**.

Chart description: Line chart showing the rolling 1-year volatility of Bitcoin juxtaposed with select mega cap companies: NVDA (NVIDIA Corporation), META (Meta Platforms Inc.), and TSLA (Tesla Inc.), showing a convergence in volatility levels over time from December 2017 to December 2024.

https://www.ishares.com/us/insights/bitcoin-volatility-trends

Correlations of Price Movements Between Major Asset Classes

(Pearson Correlation Coefficients of Daily Returns)

Asset Classes	Bitcoin	US Equity (S&P 500)	Developed Markets Equity (EAFE)	Emerging Markets Equity (EM)	Global High Yield (USD)	Int'l Corporate IG (USD)	Int'l Treasury	US Corporate IG	US Treasuries	Gold	Oil
Bitcoin											
US Equity (S&P 500)	0.33										
Developed Markets Equity (EAFE)	0.28	**0.87**									
Emerging Markets Equity (EM)	0.23	0.72	0.74								
Global High Yield (USD)	0.15	0.57	0.53	0.61							
Int'l Corporate IG (USD)	0.09	0.53	0.50	0.47	0.79						
Int'l Treasury	-0.05	0.22	0.25	0.25	0.21	0.36					
US Corporate IG	0.07	0.64	0.60	0.55	0.84	0.86	0.39				
US Treasuries	-0.10	-0.18	-0.15	-0.12	-0.21	-0.24	0.71				
Gold	0.25	0.21	0.20	0.23	0.15	0.12	-0.10	0.11			
Oil	0.12	0.43	0.40	0.48	0.54	0.36	0.16	0.38	-0.08	0.25	

Notes: Correlations based on daily total returns over the period Jan 1, 2018 – Apr 30, 2024.

Sources: CoinMetrics (Bitcoin), S&P Dow Jones Indices, MSCI, ICE BofA, JP Morgan, Bloomberg.



Volatility

- Note volatility is not good for a means of payment.
- But volatility may be an attractive feature for an asset class in the context of portfolio investing.
- Therefore, it's important to look at correlations with other asset classes.

Exhibit 72: Bitcoin vs. Leveraged S&P 500 Returns

S&P 500 returns, leveraged to match bitcoin's volatility, would have exceeded those of bitcoin.

Jun 2021–Dec 2025	S&P 500	Bitcoin	Levered S&P 500
Annualized Compounded Return	12.2%	18.2%	21.3%
Volatility	16.9%	53.3%	53.3%
Sharpe Ratio	0.57	0.54	0.57

Data through December 31, 2025.
Note: Return for levered S&P 500 is rebalanced daily to maintain the same volatility level. Data since the publication of our piece, *Digital Assets: Beauty Is Not in the Eye of the Beholder*.
Source: Investment Strategy Group, Bloomberg.

Goldman Sachs, *Outlook 2026*, p. 52. https://pwm.gs.com/nam/en-us/insights/markets-and-investing/market-insights/outlook?gsid=10439

THE WALL STREET JOURNAL.

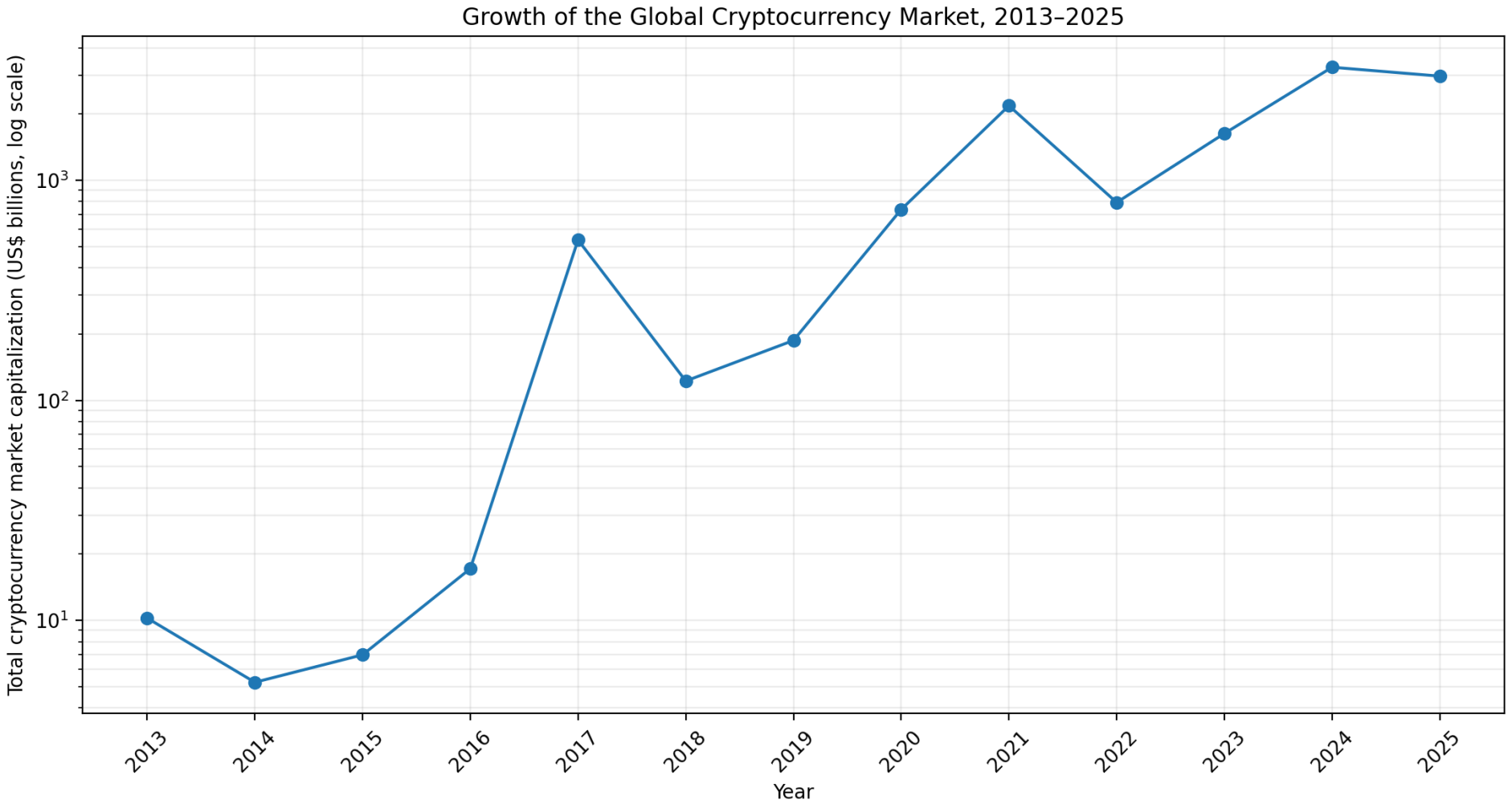
Kraken Becomes First Crypto Firm to Win Access to Fed's Core Payments System

'Master account' approval gives firm access to the same payment rail as thousands of banks and credit unions

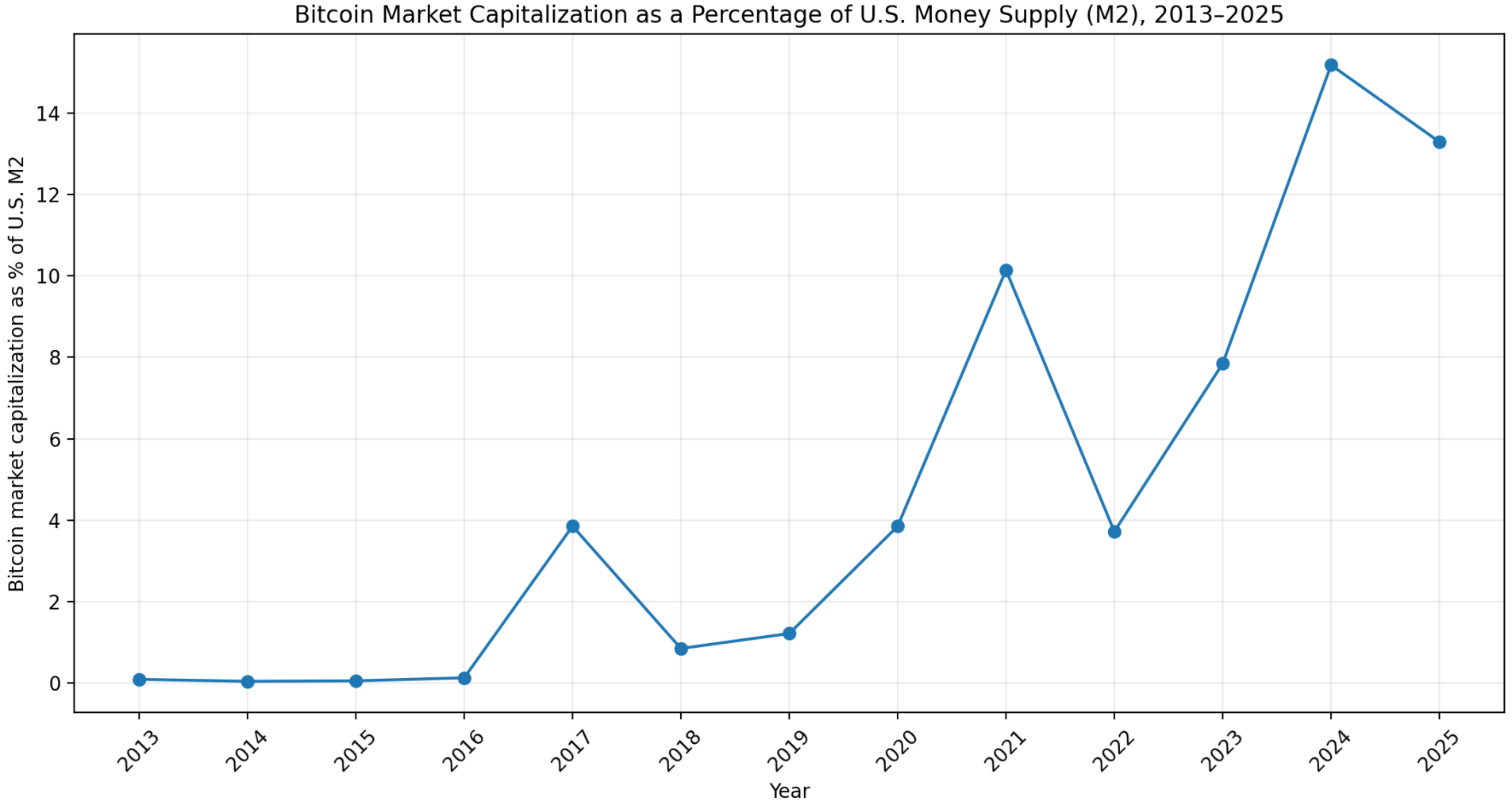
- Integrates Crypto into the mainstream financial system (March 2026)
- Fedwire handles $4 trillion daily.
- Kraken was founded in 2011. Its current valuation is $20 billion. Plans an IPO.
- The Office of the Comptroller of the Currency signed off on plans for 5 cryptocompanies, including Circle and Ripple, to establish national "trust banks" (December 2025).
- Banks criticized both decisions.

Kraken Becomes First Crypto Firm to Win Access to Fed's Core Payments System - WSJ

Total Value of all Cryptocurrencies

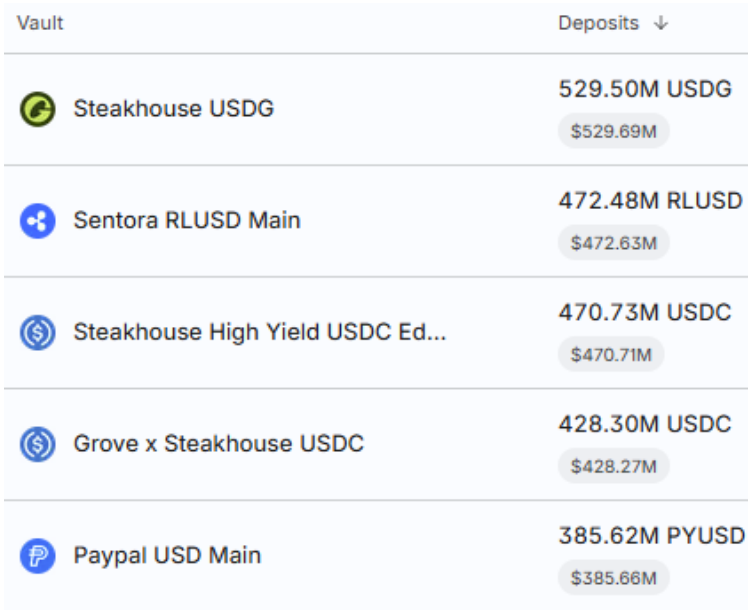


Bitcoin Market Cap as % of USD M2



Crypto Vaults

- A new way of lending digital tokens.
- Returns go to owners of stablecoins (up to 10%).
- A “curator” acts as the fund manager.
- Some $bn 20 in deposits.
- Transacted on the blockchain with smart contracts.
- SEC looking into whether compliance is needed.



CBDCs
Central Bank Digital Currencies

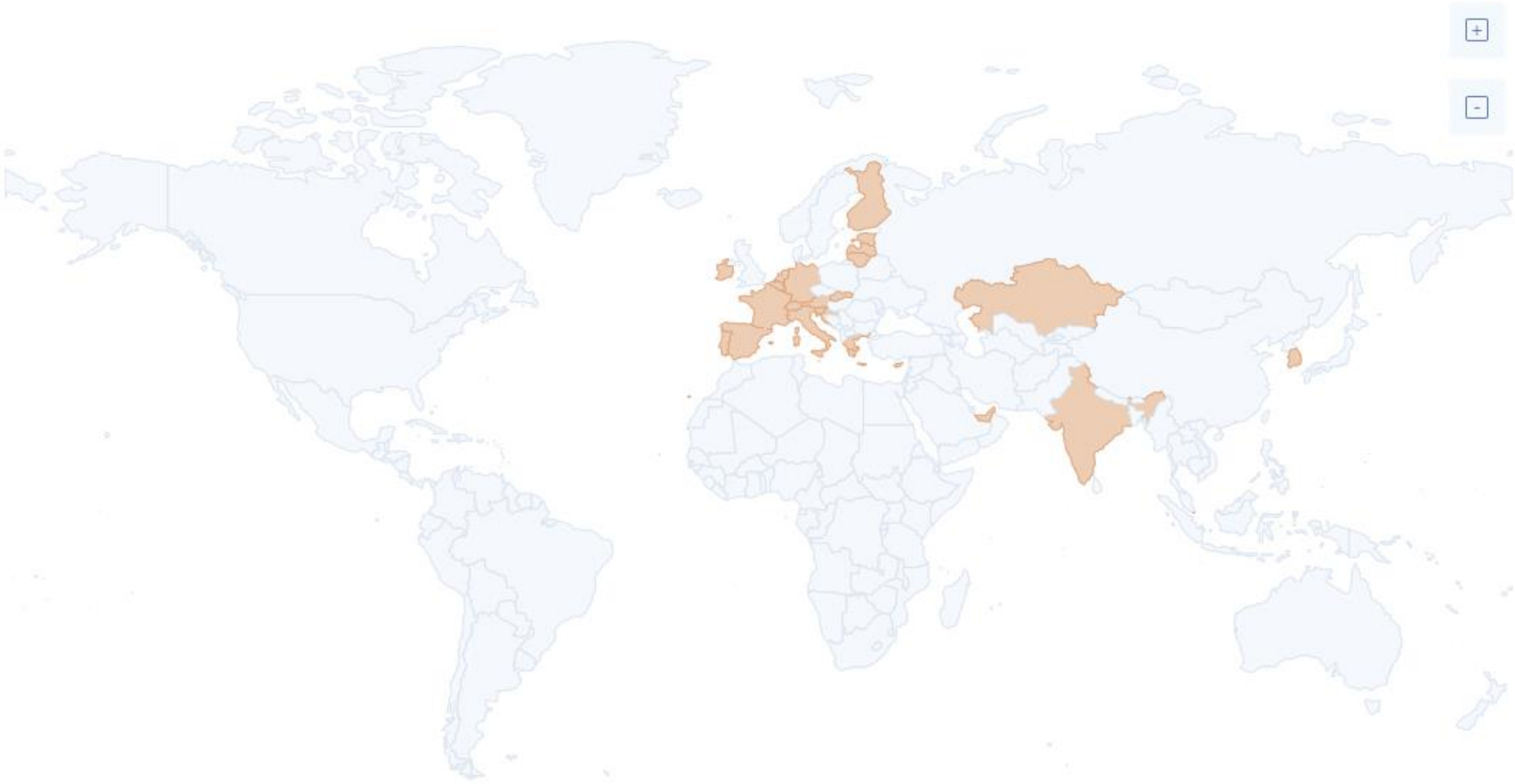
Existing types of money

- (Physical) Central bank money.
- (Digital) Commercial bank money: FDIC insured.
- (Digital) Nonbank money: app (e.g. ApplePay, AliPay, PayPal, Venmo), cryptocurrencies, stablecoins…
- Central Bank Digital Currency (CBDC):
  - A liability of the CB.
  - It's risk-free no matter where it resides, e.g. app, commercial bank account, etc.

CBDCs: The Background

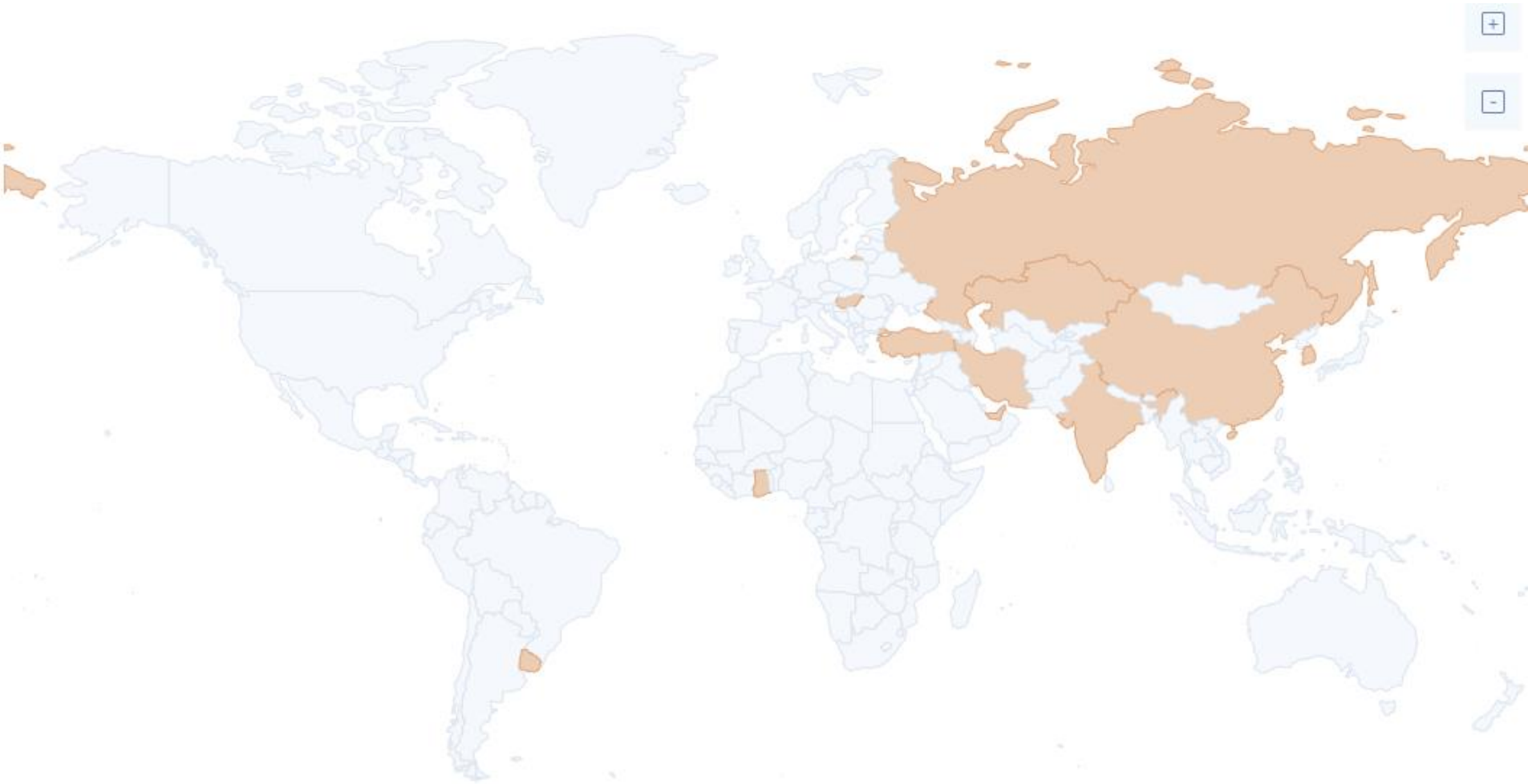
- Decline in the use of cash: CBs are losing relevance.
- Governments eager to position themselves for the digital revolution.
- Global financial leadership & sovereignty.
- Continued interest in cryptocurrencies.
- Ameliorate financial exclusion.

Wholesale CBDC pilots

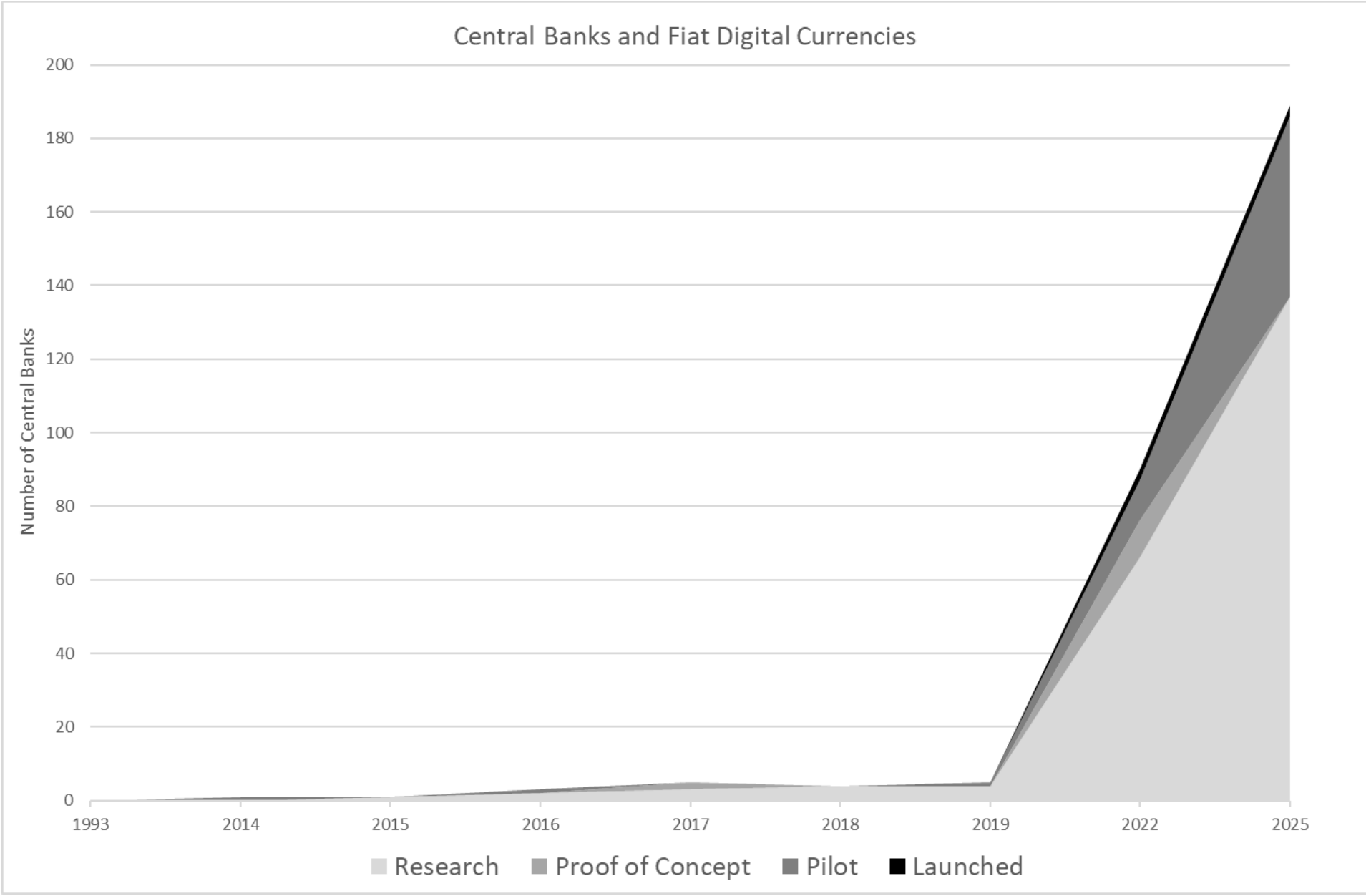


https://cbdctracker.org/

Retail CBDC pilots



https://cbdctracker.org/


Central Banks and Fiat Digital Currencies
Number of Central Banks
200
180
160
140
120
100
80
60
40
20
0
1993
2014
2015
2016
2017
2018
2019
2022
2025
Research
Proof of Concept
Pilot
Launched

Retail Plans

- Fed and ECB waiting to see if there is support from the executive and legislative branches.

What's their Position?

- Banks.
- Community banks.
- Insurance companies.
- Large, established companies.
- Startups.

Considerations

- Privacy.
- Cybersecurity.
- Risks.
- Impact on intermediaries.
- Effectiveness of monetary policy.
- Fostering entrepreneurship.
- Transparency & identity verification: Criminal activity.
- Financial inclusion

Tech Options

- The CB would operate a central ledger.
- BoE: a public/private platform model.
  - Interface providers: Users to access the ledger indirectly with a pass-through wallet on smartphones or smartcards.
- ECB: perhaps direct access.
- Major infrastructure investments needed.
- A centralized design such as the ones in existence, connecting the CB with banks.
- The system would be as private as a bank account is nowadays.

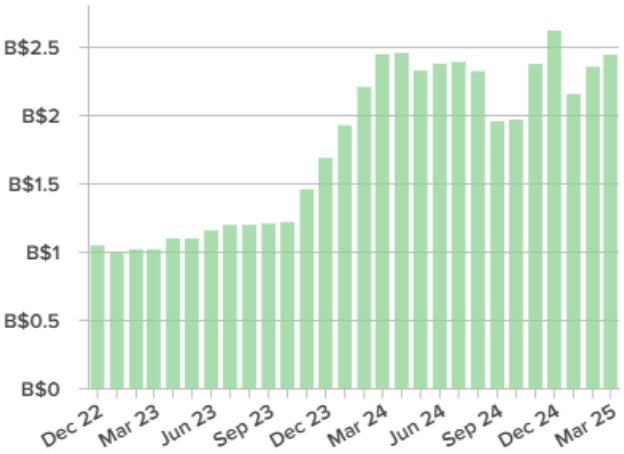
Active CBDCs

- DCash (ECU, March 2019):
  - Limited pilot.
- Sand dollar (Bahamas, Oct 2020):
  - Individual cap.
- eNaira (Nigeria, Oct 2021):
  - About $44 million in circulation.
- Pilot Digital Renminbi (April 2021):
  - Retail pilot restricted to less than:
    - 2% of M0, and 1% of M1.
    - Transaction volume = $986 bn.
- Pilot eRupee(2023):
    - $122 mn in circulation.

CBDCs in circulation

Total SandDollar in circulation

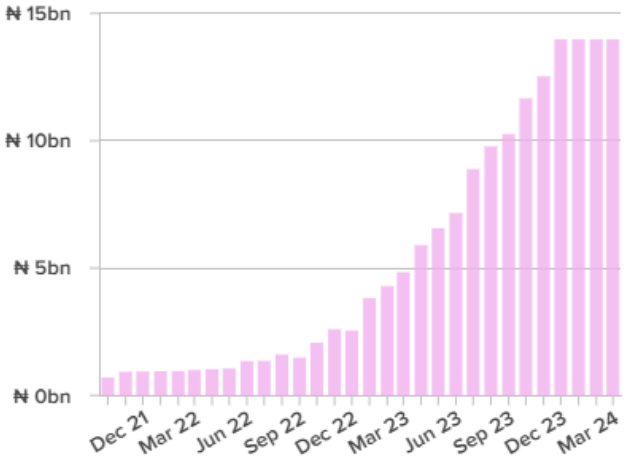
From 2022-2024 (in millions)



Source: Central Bank of Bahamas

Total eNaira in circulation

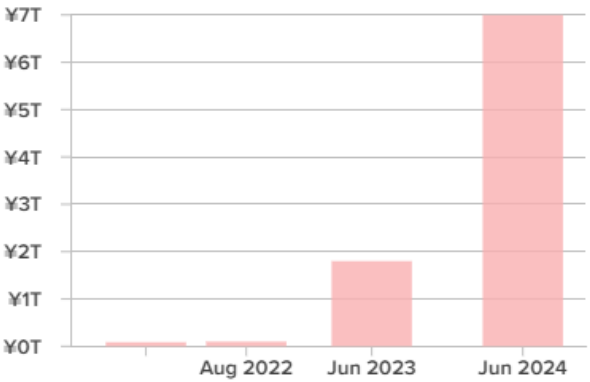
From 2021-2024 (in billions)



Source: Central Bank of Nigeria

e-CNY transaction volume quadruples from 2023

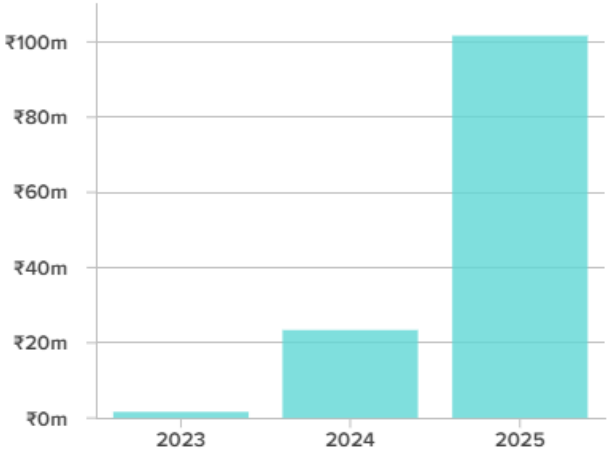
Cumulative transaction volumes for select months (2021-2024)



Source: People's Bank of China • PBoC did not release official data in 2022

Total e-rupee in circulation

From 2023-March 2025 (in millions)



Source: Reserve Bank of India

https://www.atlanticcouncil.org/cbdctracker/

How Long until an eDollar is launched?

- 1 year?
- 2 years?
- 3 years?
- 5 years?
- 10 years?
- 15 years?
- 20 years?

Most Likely to Survive?

A. Banks.

B. Banking.

C. Bankers.

Geopolitics

- China: Circumvent the dollar.
- USA: Contain Chinese financial influence.
- Europe's bêtes noires:
  - Visa, MC, PayPal.
  - SWIFT

VANITY FAIR

Crypto's True Believers Demand to Be Taken Seriously

They partied like rock stars, searched for aliens, practiced survivalism, and sometimes showed up without shoes. Then crypto winter came—and they lost billions. Clara Molot talks to the zealots who are holding the line.

BY CLARA MOLOT
PHOTOGRAPHER JEREMY LIEBMAN

MARCH 17, 2026



https://www.vanityfair.com/news/story/cryptos-true-believers



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