COMPUTATIONAL FINANCE & FINTECH

Finance in the 21st Century

Blockchain, Bitcoin, CBDCs and machine-speed markets

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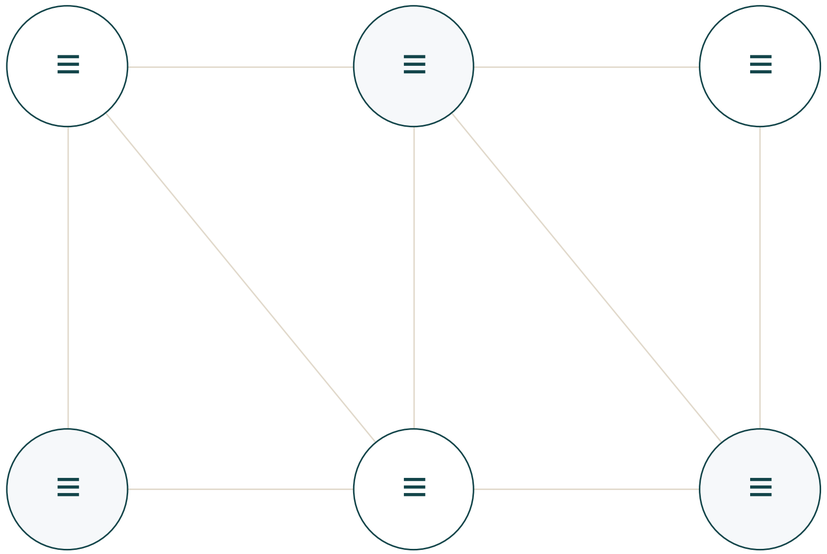
Blockchain, cryptocurrency and Bitcoin

Who maintains the ledger when there is no central operator?

Ledger • asset • supply • mining



PEER NODES

Each node checks the same protocol rules; no hub is required.

Blockchain

Blockchain is a decentralized, digital ledger system that records and securely stores information across multiple computers, ensuring transparency and immutability. Each block of data is cryptographically linked to the previous one, forming a chain of records. Its design prevents the alteration of existing data, making it a secure and reliable system for recording transactions, such as those in cryptocurrencies like Bitcoin.

Some Examples

1. **Healthcare:** Patient records can be stored on a blockchain, providing a complete, accurate, and tamper-proof medical history. It can also be used to track the spread of diseases or manage pharmaceutical supply chains.

2. **Voting Systems:** Blockchain technology can be used to create tamper-proof voting systems, enhancing transparency and reducing fraud in electoral processes.

3. **Identity Verification:** Blockchain can provide a secure and decentralized way of managing digital identities, enhancing privacy, and reducing the risk of identity theft.

4. **Real Estate:** Blockchain can streamline the real estate market by simplifying the process of buying, selling, or renting properties. It can facilitate smart contracts, reduce fraud, and enable a more transparent and efficient process.

5. **Finance:** Blockchain technology can facilitate faster, more secure payments, and money transfers. It can also enable decentralized finance (DeFi) applications, including lending platforms and prediction markets.

Cryptocurrency

Cryptocurrency is a digital or virtual form of currency that uses cryptography for security, making it difficult to counterfeit. It operates on decentralized systems called blockchains, enabling peer-to-peer transactions independent of centralized authorities like banks or governments.

Bitcoin

Bitcoin is the first decentralized cryptocurrency, created in 2009 by an unknown person using the name Satoshi Nakamoto. It operates on a peer-to-peer network where users can send and receive bitcoins (often denoted as BTC), without the need for intermediaries, leveraging blockchain technology to ensure transaction integrity and security.

Understanding Blockchain

Technology that guarantees security and transparency

Blockchain is a technology that ensures robust security and unparalleled transparency. A transformative technology that has the power to revolutionize multiple sectors beyond finance, from healthcare to supply chain management.

A chain of blocks, each containing transaction data

Not just the transaction's details, but more such as sender and receiver, but also incorporates timestamps and unique identifiers. This granular level of detail enhances the system's transparency, allowing each transaction's path to be traceable, auditable, and unquestionably clear.

Each block is linked to the previous one via cryptographic hash"

Link via a cryptographic hash - a string of numbers and letters produced by a complex mathematical algorithm. This hash serves as a kind of digital fingerprint, unique to each block. This feature is what secures the blockchain from tampering, making it immutable and exceptionally secure.

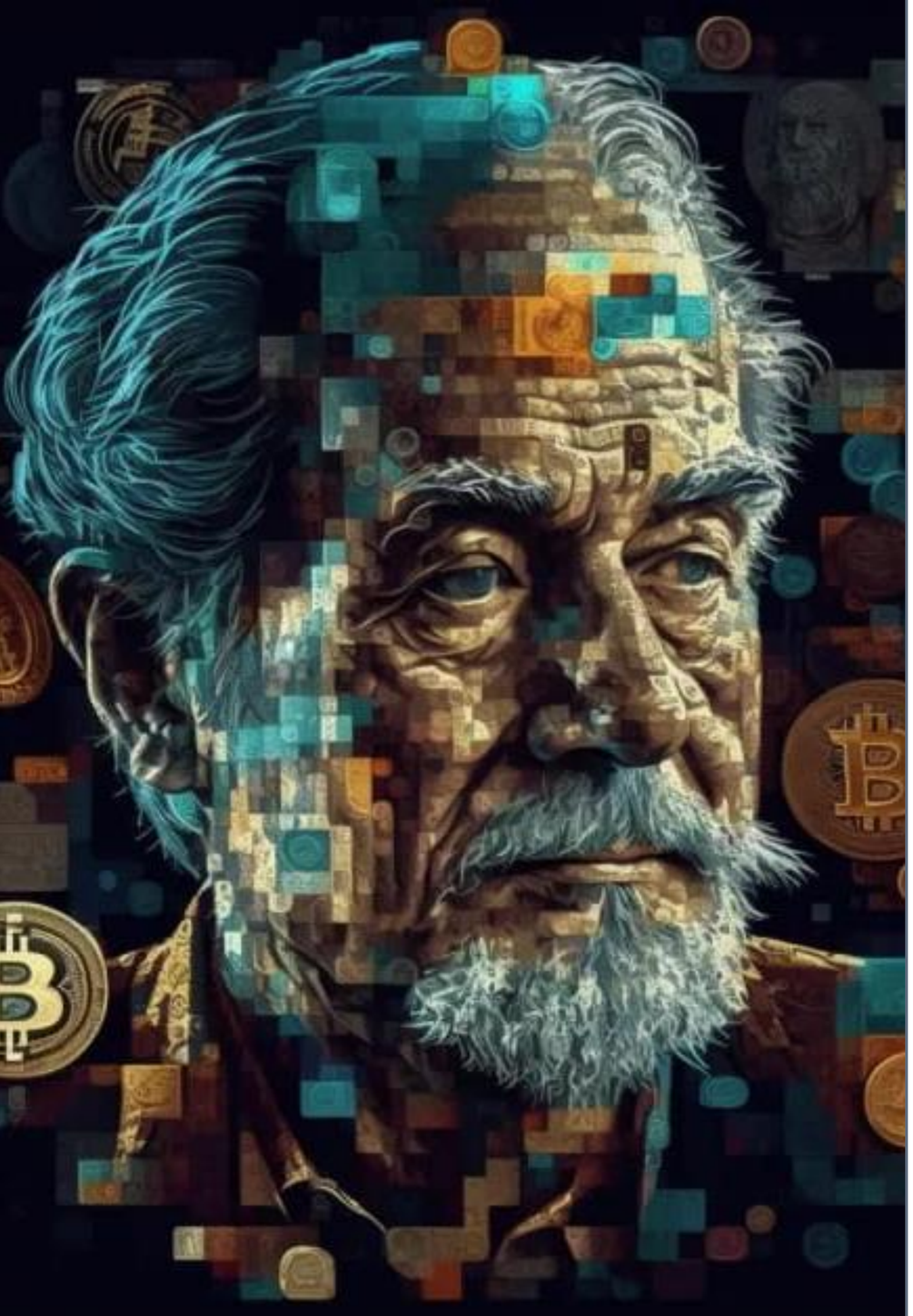
Understanding Cryptocurrency

Operates independently of a central bank

Operates independently of a central bank: Cryptocurrencies aren't issued or regulated by any centralized authority. This makes them immune to government interference and manipulation, providing a level of financial freedom and anonymity not possible with traditional currencies.

Cryptographic security

They use cryptographic security. This means that transactions and control over the creation of new units are secured using complex mathematical problems, making them extremely secure and almost impossible to hack or counterfeit.



Understanding Bitcoin

Created in 2009 by Satoshi Nakamoto

Born out of the ashes of the 2008 financial crisis. This elusive creator or creators remained anonymous, but their innovation has left an indelible mark on the world.

What was the main message?

The first block, or the 'genesis block' as it is called, contained a text message from Nakamoto: "The Times 03/Jan/2009 Chancellor on brink of second bailout for banks," pointing to Bitcoin's founding in the midst of a financial crisis.

What does the message say?

Nakamoto's reference to the events of the time in the genesis block was a clear commentary on the state of the traditional financial system. Nakamoto's proposed an alternative system where a new, more equitable form of money could offer a potential solution.

Eat Out from £5

More than 900 great restaurants, including four **Gordon Ramsay** favourites from £15

Start collecting tokens today. Pullout inside

Israel prepares to send tanks and troops into Gaza

Israel allowed foreigners to flee the Gaza Strip as it prepared for a ground offensive. At least 430 Palestinians were killed in a week of airstrikes. News, page 3

Chancellor on brink of second bailout for banks

Billions may be needed as lending squeeze tightens

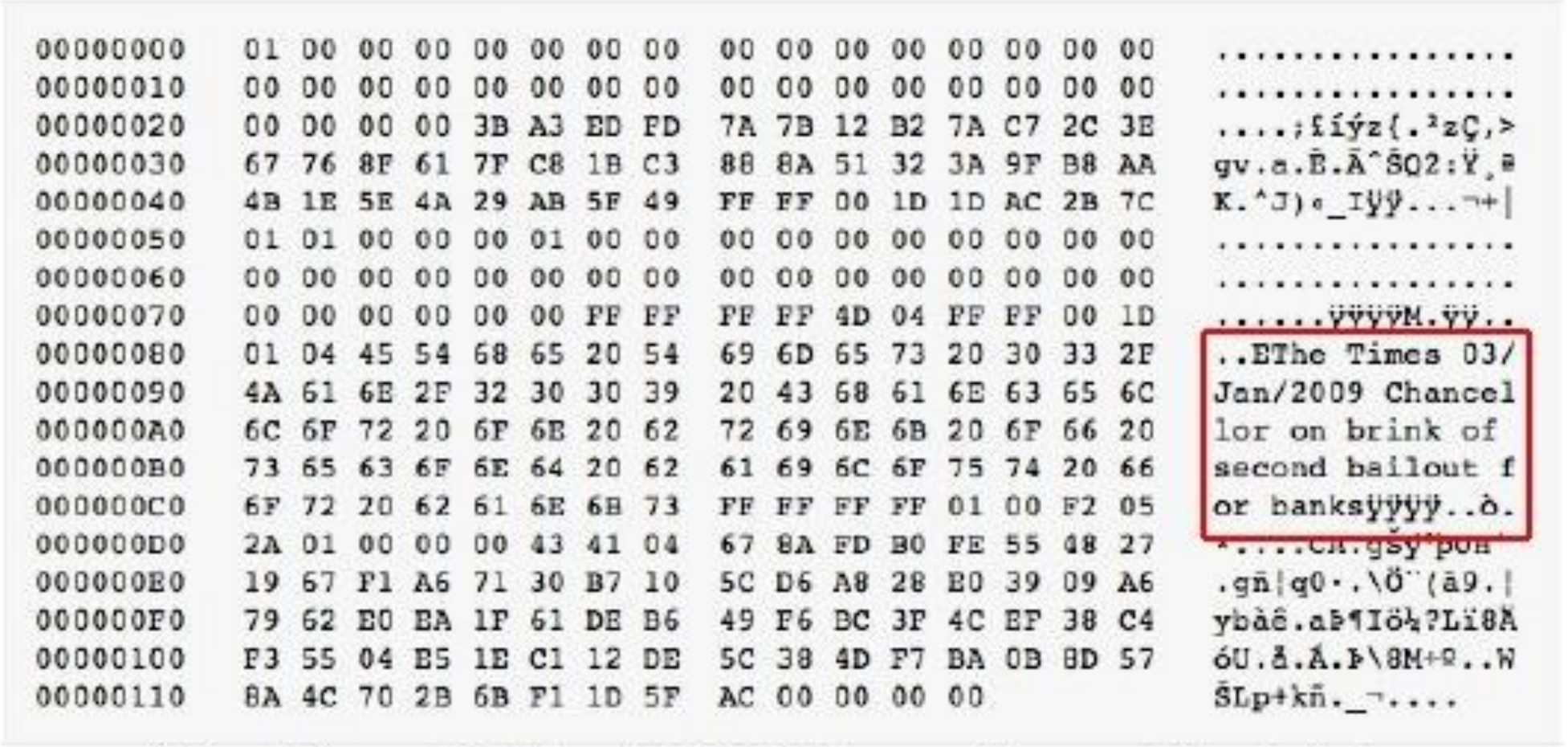
Michael Sheen
Frost, Nixon and me
Magazine

Working mums
So that's how she does it
Body&Soul

Detox in style
The best spas on the planet
Travel

Salmon Rushdie
I Won't Marry Again
Pages 22, 23

The Genesis block code



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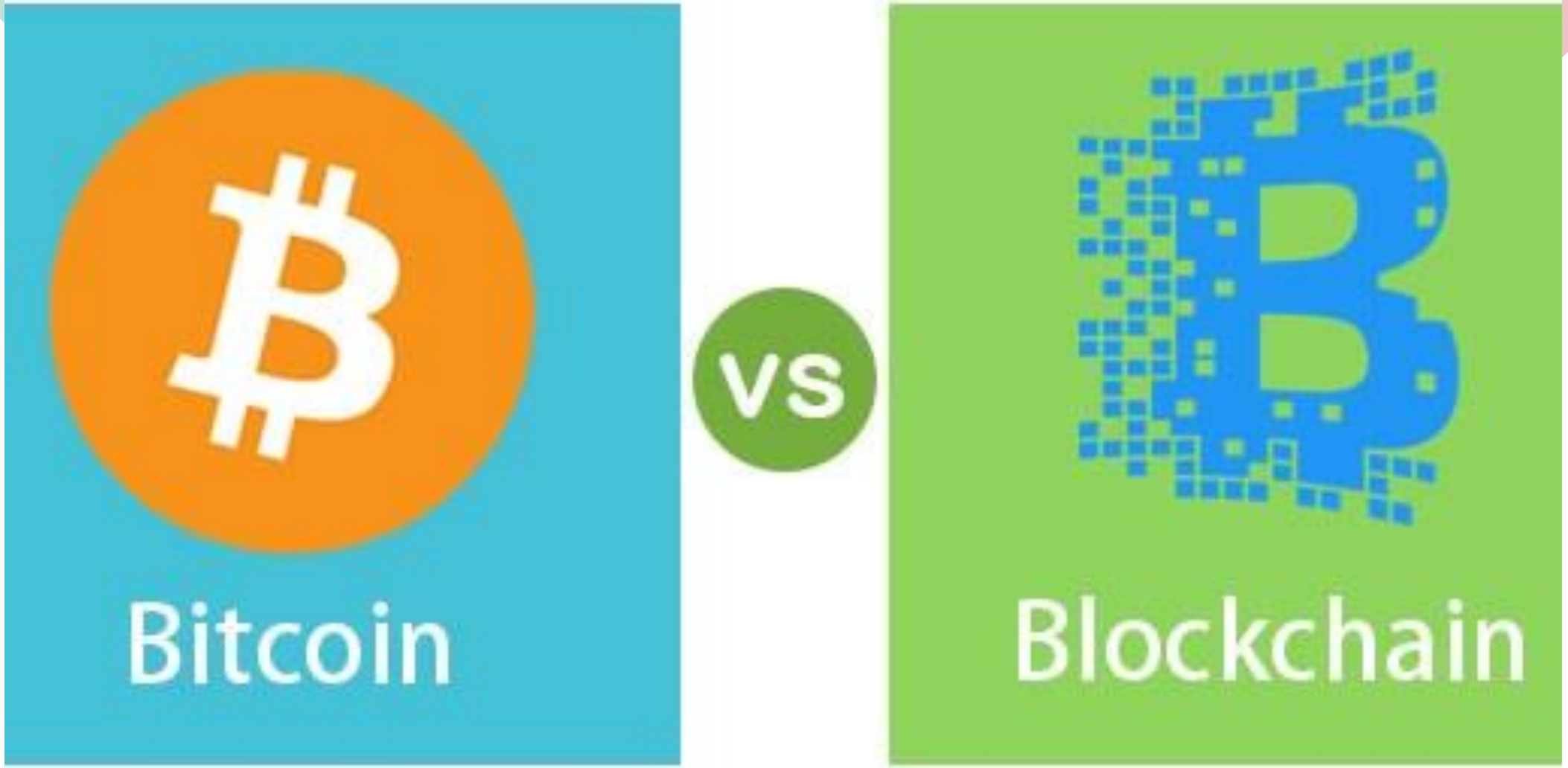
"The Times 03/Jan/2009 Chancellor on the brink of second bailout for banks"


Bitcoin
VS
Blockchain

Understanding Bitcoin

Bitcoin's fixed supply and its implications on its value.

Unlike fiat currencies, Bitcoin has a fixed supply. The maximum number of Bitcoins that can ever exist is 21 million. This limit creates a scarcity element, similar to that of gold or other precious metals.

The Role of Miners: Understanding the Bitcoin mining process.

Miners validate new transactions and record them on the global ledger. For this service, miners are rewarded with newly minted Bitcoin, in a process known as block rewards. However, this process consumes significant computational resources and energy.

Bitcoin's Volatility

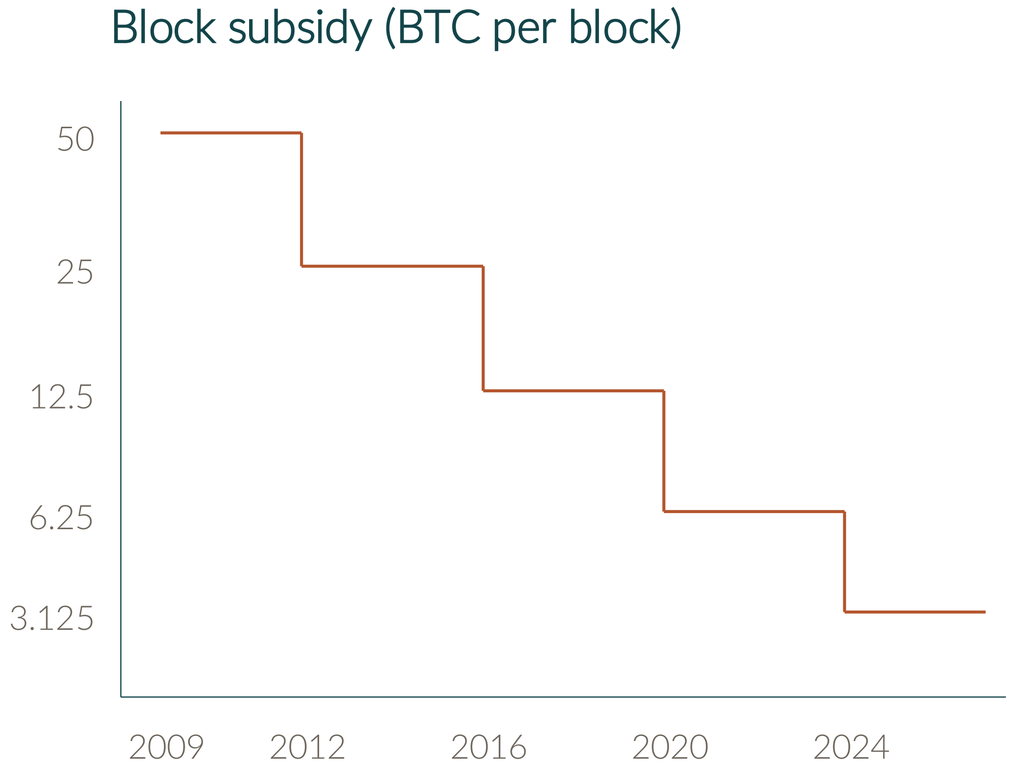
Bitcoin is generally more volatile than traditional asset classes like the S&P 500 or other national stock markets. The price of Bitcoin can fluctuate significantly in a very short time, making it possible for investors to experience rapid gains or losses.

Bitcoin’s supply rule creates engineered scarcity

21 million

asymptotic maximum BTC under the protocol’s issuance schedule

- New BTC enters circulation through block rewards paid to miners.
- The issuance rate declines over time according to protocol rules.
- Predictable scarcity does not guarantee demand, price stability or purchasing power.



Subsidy halves about every 210,000 blocks; the simplified chart shows completed halvings through 2024.

Is Bitcoin Money?

Bitcoin Is A Cryptocurrency, But Is It Money?

“What is Money?”

What is Money

1 **Medium of Exchange**

Money acts as an intermediary in transactions, allowing people to exchange goods and services without the need for barter (direct exchange of one good for another).

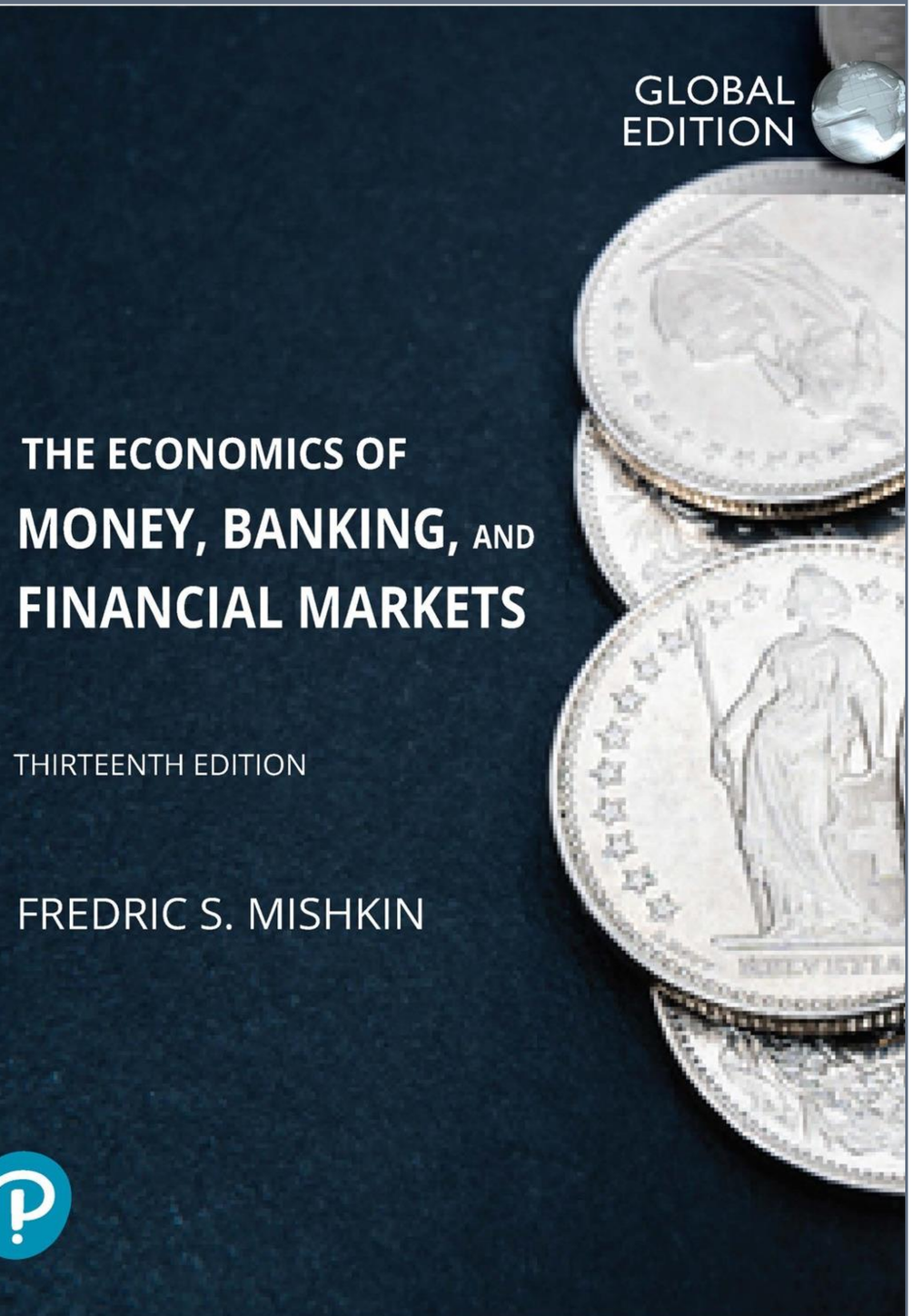
2 **Unit of Account**

Money provides a common unit of measurement for pricing goods and services. It enables easy comparison of the value of different products and allows for a standardized way of expressing prices, wages, and other financial transactions.

3 **Store of Value**

Money can be held and saved to be used in the future. It serves as a store of value because people can use it to preserve purchasing power over time.

Is Bitcoin Money?



Textbook:

1 **Medium of Exchange: YES**

2 **Unit of Account: NO**

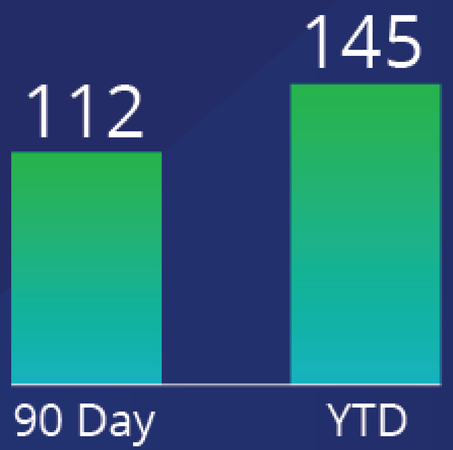
"The price of Bitcoin has been extremely volatile, with its volatility estimated to be over seven times that of the price of gold and over eight times that of stock market indexes such as the S&P 500. ***Not surprisingly, no cryptocurrency has become a unit of account:*** *Almost no one quotes the prices of their products in terms of bitcoins or any other cryptocurrency.*

3 **Store of Value: NO**

In 2011, the price of a Bitcoin fluctuated between 30 cents and $32. It then rose to a peak of $255 on April 10, 2013, only to fall back down to $55 on April 17. On November 30, 2013, the price of a Bitcoin peaked at $1,125, but it fell to around $200 by June 2015, and then took off to a peak value of nearly $20,000 in December 2017. By 2020, it had fallen to a value below $7,000." ***The high volatility of the value of the cryptocurrencies means that they do not function well as a store of value***

Bitcoin Seems Less Volatile Than Many S&P500 stocks

Number of S&P500 Companies with Higher Volatility vs Bitcoin



Percentage of S&P500 Companies with Higher Volatility vs Bitcoin

CRYPTO WORLD

Bitcoin's volatility falls below Nasdaq and S&P 500's for first time since 2020

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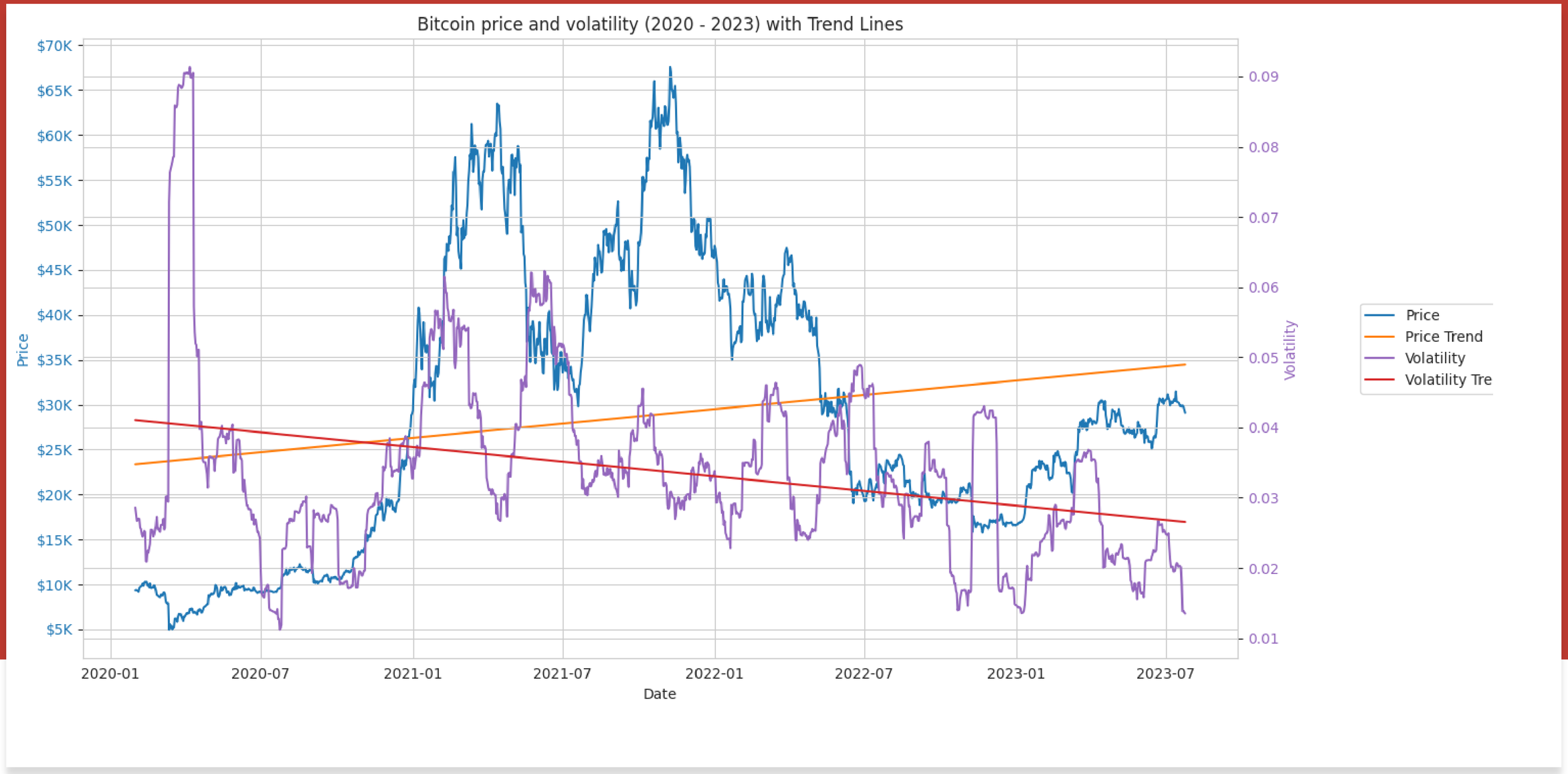
Bitcoin price and volatility (2020 - 2023) with Trend Lines
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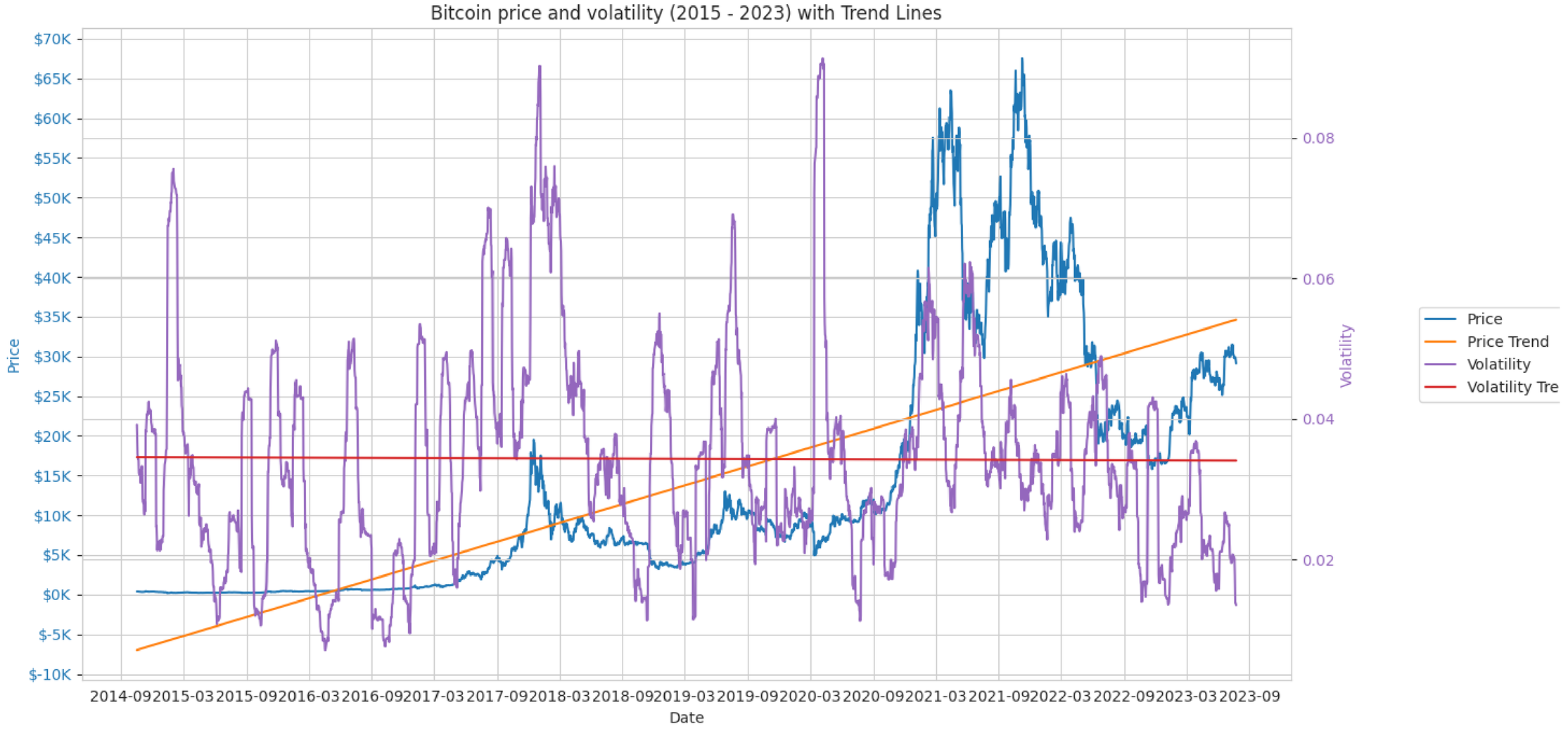
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Not forever blowing

Historical asset bubbles, multiple of starting price* on relevant exchange

Sources: "New Evidence on the First Financial Bubble", Rik Frehen, William Goetzmann, Geert Rouwenhorst; "Famous First Bubbles", Peter Garber; Thomson Reuters; Bloomberg

*Three years prior or earliest available price
†Post-peak data unavailable

Economist.com

The Economist

Historical asset bubbles, multiple of starting price*

Sources: "New Evidence on the First Financial Bubble", R. Frehen, W. Goetzmann, G. Rouwenhorst; "Famous First Bubbles", P. Garber; Coinbase

*Three years prior or earliest available price †Post-peak data unavailable

SWOT Analysis of Bitcoin

Strength

Weakness

Opportunities

Threats

SWOT Analysis of Bitcoin: Strengths

1 **Decentralization**
Bitcoin operates on a decentralized network known as blockchain, which makes it resistant to censorship or control by any single entity.

2 **Security & Privacy**
Cryptocurrency can’t be tracked or stolen.

3 **Liquidity**
Bitcoin is highly liquid and can be easily bought, sold, and converted into cash or other cryptocurrencies.

4 **Limited Supply**
There will only ever be 21 million bitcoins, which can potentially prevent inflationary issues

5 **Global Accessibility**
It can be sent anywhere in the world, at any time, irrespective of national borders, making it a globally accessible asset.

SWOT Analysis of Bitcoin: Weakness

1 **Volatility**
Bitcoin prices are known for being highly volatile, which can make it a risky investment.

2 **Lack of Regulatory Oversight**
While some see this as a strength, the lack of regulation can also be a weakness, as it might lead to fraudulent activities or misuse.

3 **Technical Complexity**
While strides are being made to simplify it, Bitcoin technology can be complex and intimidating for average users.

4 **Environmental Impact**
The process of mining Bitcoin requires substantial computational power, leading to significant energy consumption and carbon emissions.

5 **Slow transactions**
Bitcoin process ten transactions per second while Visa, the credit-card company can do as much as 24,000 per second

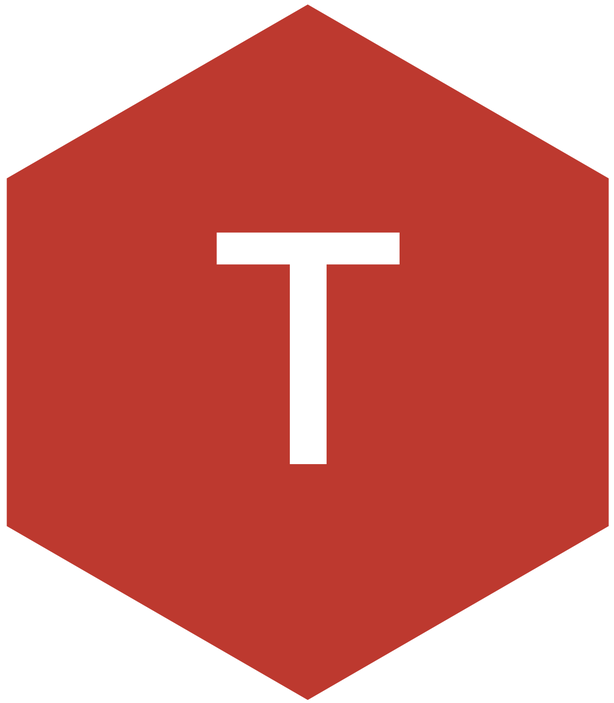
SWOT Analysis of Bitcoin: Opportunities

1 **Increasing Acceptance**
More businesses and countries are starting to accept Bitcoin as a valid form of payment.

2 **Financial Inclusion**
Bitcoin could provide financial services to people who are currently unbanked or underbanked.

3 **Safety**
Safety from compromising data breaches

SWOT Analysis of Bitcoin: Threats



1 **Regulatory Risks**
Governments and regulatory bodies around the world might impose restrictive regulations on Bitcoin usage or trading.

2 **Reputational Risks**
Bitcoin has been associated with illicit activities in the past, which could harm its reputation and discourage adoption.

3 **Exchange Fraud / Hacks**
Since the early days of Bitcoin there have been many bitcoin exchange frauds all around the world and people lost all their bitcoins such as Mt.Gox,, Thodex (Turkey). BitConnect etc

Recap

1 Bitcoin's future is uncertain; it may become a stable asset like gold or burst spectacularly as a bubble.

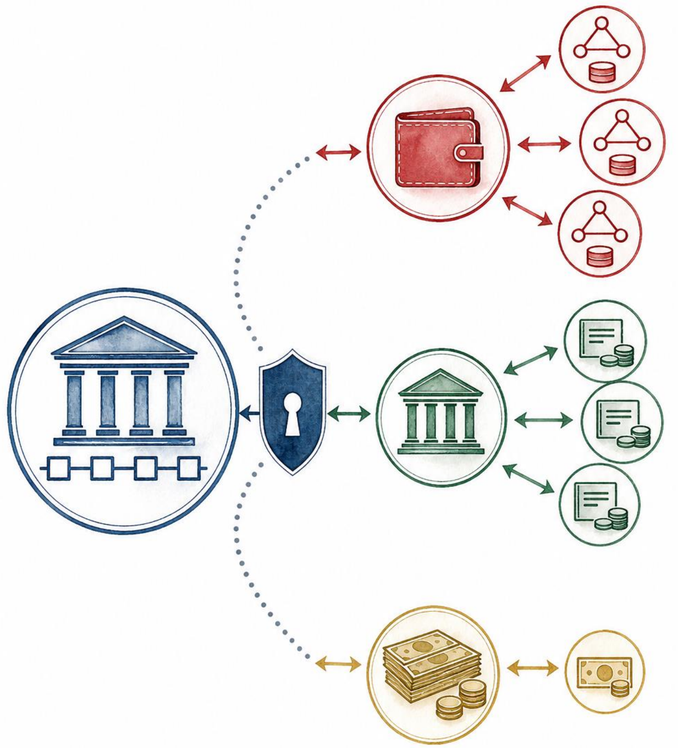
2 The dream of Bitcoin as a new form of money, independent of governments and central banks, remains elusive.

3 Blockchain technology can be used in a wide variety of sectors and applications beyond just cryptocurrencies like Bitcoin.

CBDCs, stablecoins and payment systems

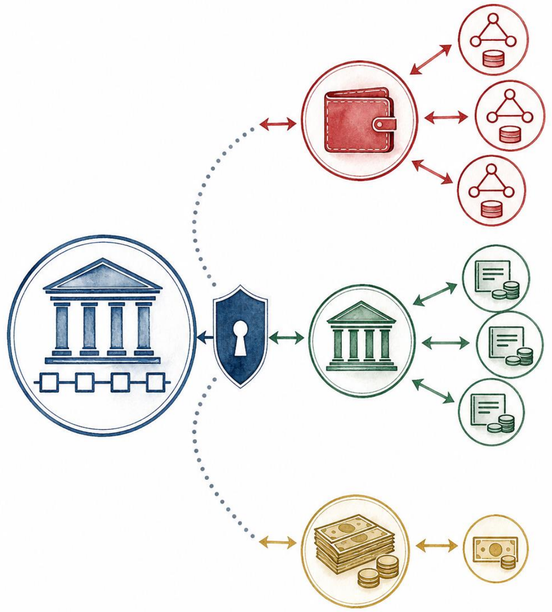
Who issues the money—and which rail moves it?

Public money • private claims • reserves • payment rails • adoption



A CBDC is a digital central-bank liability

A CBDC is electronic central-bank money, denominated in the national unit and available under a specified access design.



Field	CBDC
Issuer	Central bank
Liability	Claim on the central bank
Form	Electronic rather than a physical note or coin

Definition paraphrased from the Bank of England wording quoted in the source deck.

Central Bank Digital Currency

According to Bank of England, Central bank digital currency (CBDC) is money that a country's central bank can issue. It's called digital (or electronic) because it isn't physical money like notes and coins. It is in the form of an amount on a computer or similar device.

CBDC vs CC

1. **Central Authority:** Cryptocurrencies operate on a decentralized network and do not have any central authority controlling them. In contrast, Central Bank Digital Currencies (CBDCs) are issued and regulated by a country's central bank, making them centralized.

2. **Anonymity:** Cryptocurrencies, especially ones like Bitcoin, provide a certain degree of anonymity to users, with transactions being pseudonymous. On the other hand, CBDCs are likely to be designed in a way that allows the central bank or the government to trace transactions, thereby reducing anonymity.

3. **Stability:** Cryptocurrencies are known for their volatility with prices fluctuating dramatically in short periods. CBDCs, being tied to a nation's fiat currency, are expected to have the same value and stability as their physical counterparts.

4. **Legal Status:** Cryptocurrencies do not have legal tender status in most countries. That means they are not officially recognized as a medium for commercial exchange. However, CBDCs, once implemented, would have legal tender status, making them an officially recognized form of digital currency.

5. **Use Case:** Cryptocurrencies were initially created as an alternative to traditional currencies and are used for a variety of purposes, including investment, remittances, and sometimes for transactions where anonymity is desired. CBDCs, on the other hand, are envisioned to digitize the existing currency fully, thereby making transactions and money transfers more efficient and inclusive.

CBDC vs CC

1. **Digital Nature:** Both cryptocurrencies and CBDCs are fundamentally digital, which means they exist solely in electronic form and are transacted over the internet. This property makes them efficient and accessible from anywhere in the world.

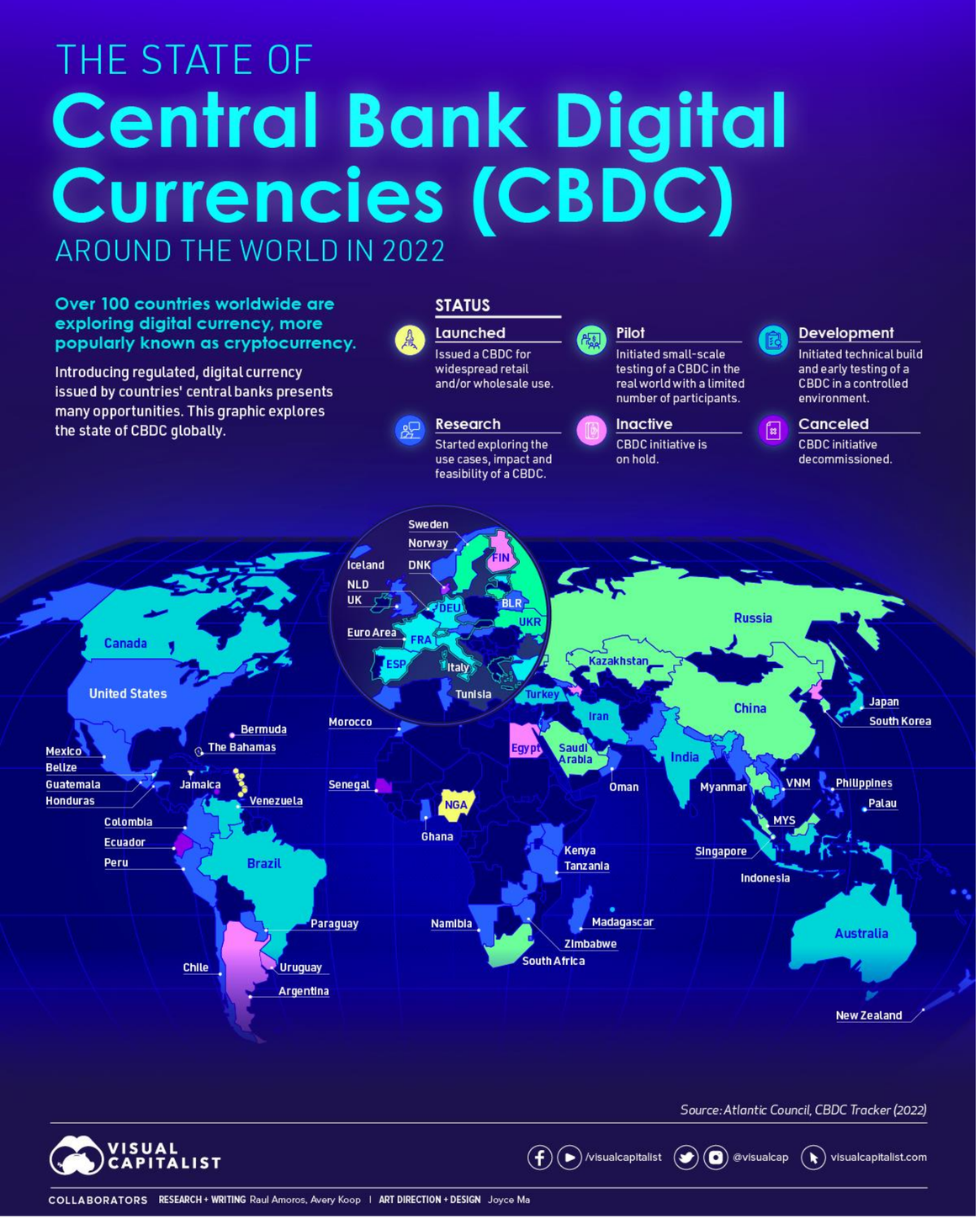
2. **Secure Transactions:** Cryptocurrencies and CBDCs both leverage cryptographic techniques to secure transactions, ensuring that they are tamper-proof and secure against fraud.

3. **Transaction Validation:** Both forms of currency use specific mechanisms for transaction validation. In the case of cryptocurrencies, it's typically through a decentralized network of miners. For CBDCs, it would be through a system approved by the central bank, which may or may not be decentralized.

4. **Traceability:** Each transaction made with cryptocurrencies or CBDCs is recorded on a type of ledger (like a blockchain), providing a transparent history of transactions. This feature can help reduce financial crimes such as money laundering and fraud.

5. **Inclusion:** Both cryptocurrencies and CBDCs have the potential to increase financial inclusion. They can provide access to financial services for populations that are currently unbanked or underbanked, particularly in areas with high mobile phone penetration but limited access to traditional banking infrastructure.

CBDC: An Example



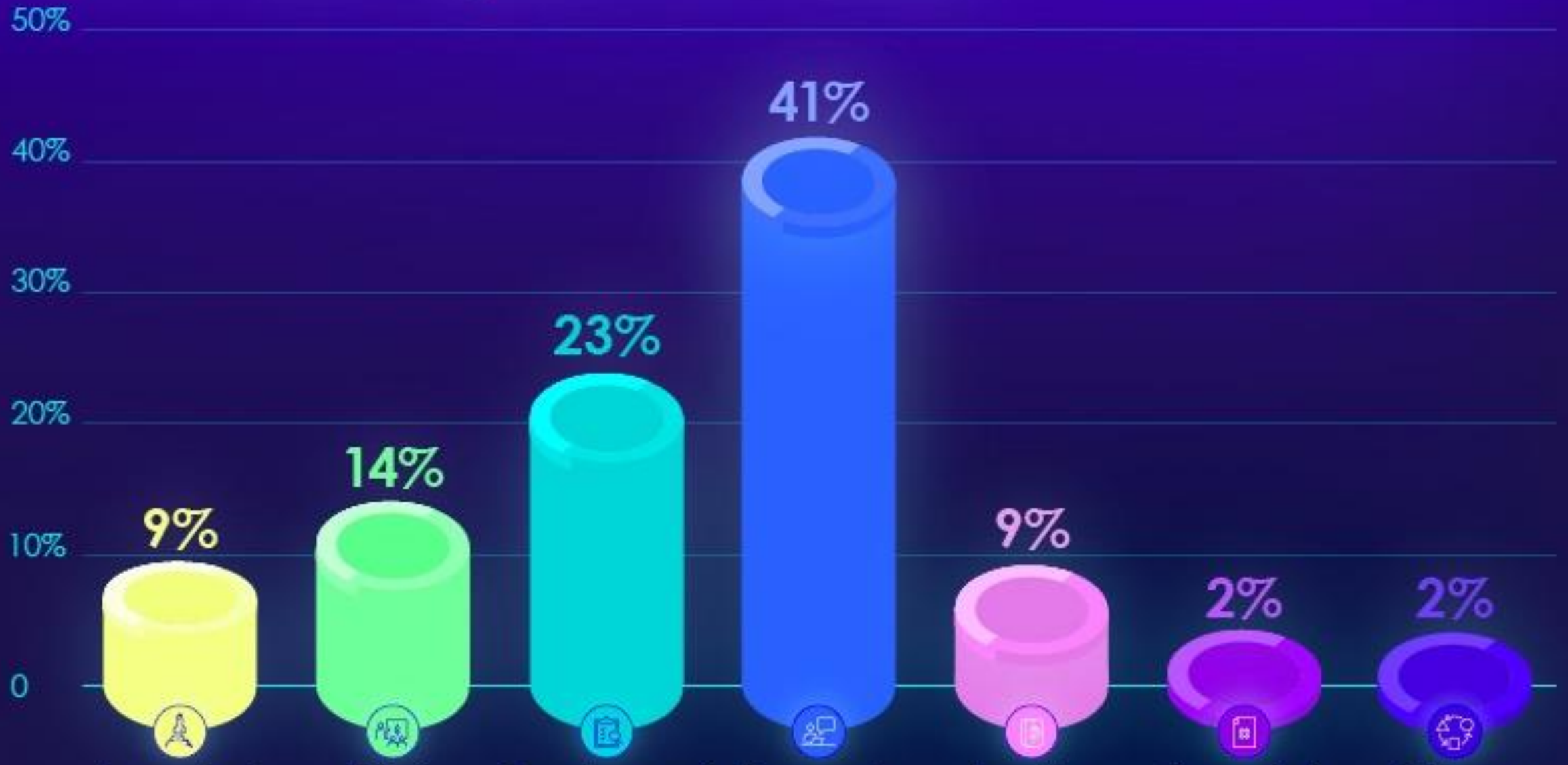
By 2022, **105 countries** are currently exploring centralized digital currencies. Together, they represent **95%** of global GDP.

Just **9%** of countries have launched a digital currency to date. Nigeria, The Bahamas, Jamaica, Sweden, Lithuania, Ukraine…

For example, Nigeria, launched in October 2021 but The eNaira app has accumulated 700,000 downloads as of April 2022. That's equal to **0.35%** of the population, though not all of the downloads are users in Nigeria

Conversely, **33.4 million** Nigerians were reported to be trading or owning crypto assets, despite the Central Bank of Nigeria's attempts to restrict usage

Status on CBDC Progress in 109 countries



Source: Atlantic Council, CBDC Tracker (2022)

A digital pound would pair public money with private interfaces

Central bank

Issues the digital pound and operates the core ledger.

Wallet providers

Private firms run wallets, onboarding and customer support.

Service providers

Private firms can build optional services around payments.

The issuer can remain public even when the user experience is private.

Fintech can change the interface, the rail or the monetary claim

Interface

Apps simplify onboarding, checkout and personal finance.

Payment rail

Instant networks change how instructions and settlement move.

Monetary claim

Deposits, e-money, stablecoins and CBDCs expose users to different issuers.

Ask what technology moves the payment—and whose liability settles it.

Stablecoins target par through different risk structures

Fiat-backed

USDC and USDT aim for redemption at par against reserve assets.

Crypto-backed

DAI uses over-collateralised crypto positions and protocol rules.

Algorithmic

Supply incentives without robust collateral have repeatedly proved fragile.

Stablecoin describes a target price—not a common balance sheet.

A stablecoin peg depends on reserves, redemption and arbitrage

Reserves

High-quality liquid assets make redemption more credible.

Redemption

Eligible holders must be able to exchange tokens for the reference asset.

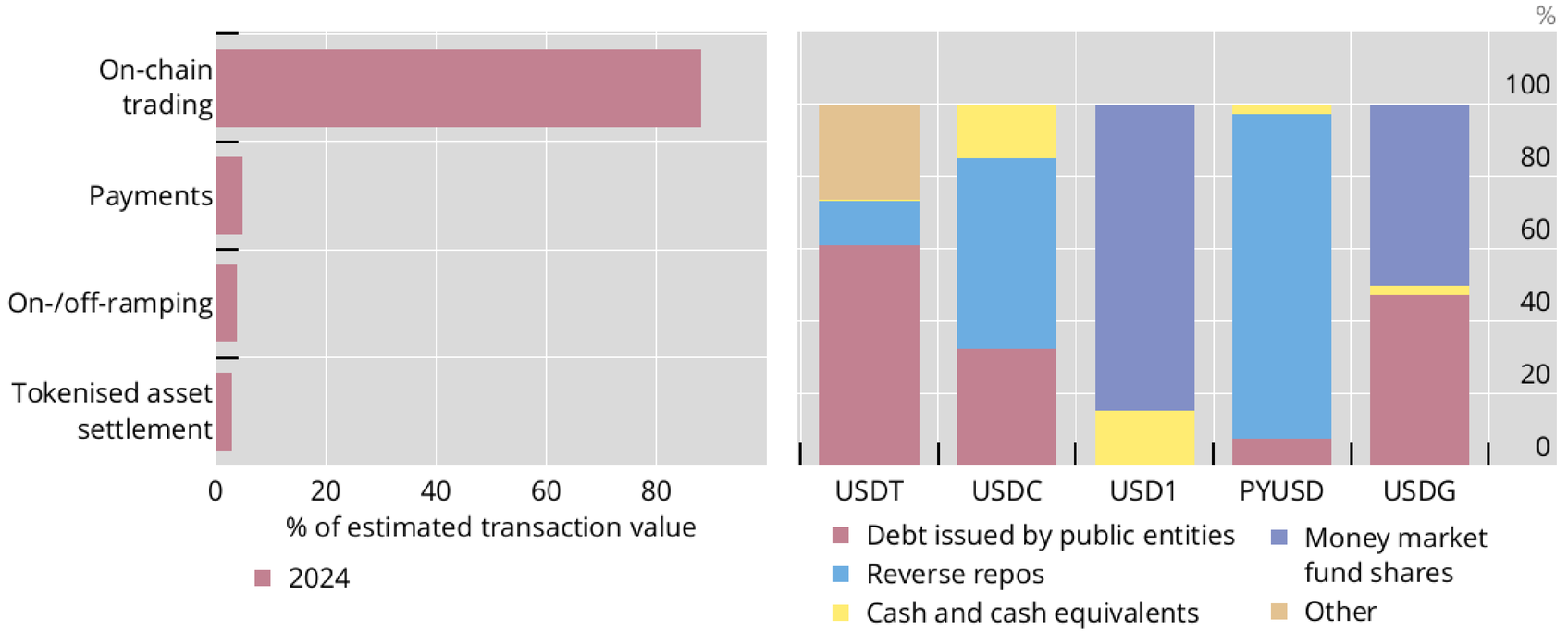
Arbitrage

Traders buy below $1 or sell above $1 when conversion is reliable.

The peg is a balance-sheet promise supported by market plumbing.

Stablecoins mostly serve crypto markets—and reserves differ

Stablecoin use focuses on crypto trading, with coins backed by low-risk assets — Graph 1

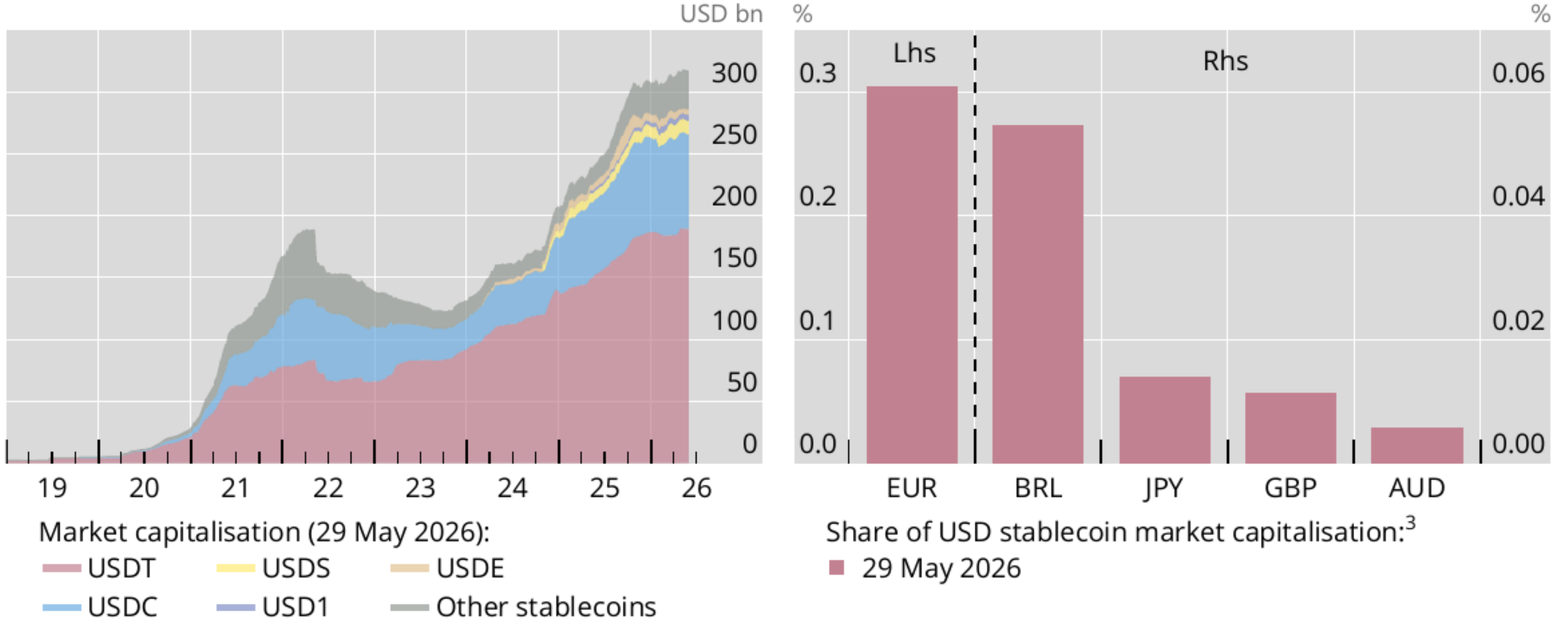


Trading dominates current use; reserve quality and disclosure differ sharply across issuers.

Source: BIS Annual Economic Report 2026, Chapter III, Graph 1.

Two US dollar coins dominate stablecoin growth

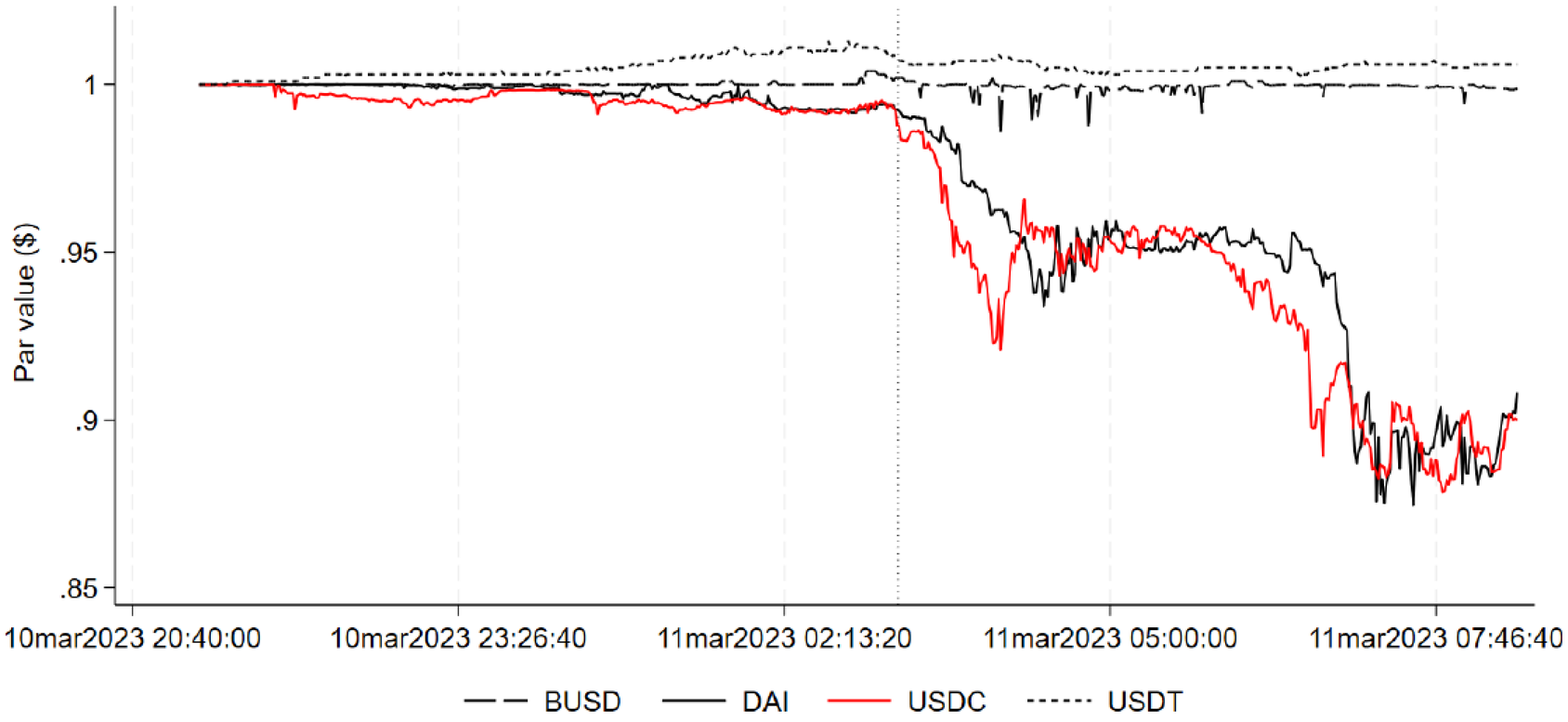
Stablecoin market growth concentrated in two US dollar-pegged coins[1] Graph 2



At end-May 2026, the market was about $320bn; USDT and USDC dominated while non-dollar coins remained tiny.

Source: BIS Annual Economic Report 2026, Chapter III, Graph 2.

USDC’s SVB depeg exposed reserve-access risk



After Circle disclosed $3.3bn at SVB, USDC traded below par until confidence in access to reserves recovered.

Sources: BIS Working Papers No 1164, Figure 15; Federal Reserve, 17 December 2025.

M-Pesa made the agent network part of the payment system

Cash bridge

Agents convert physical cash into mobile value and back again.

Reach

Kenya reported 94.2m registered accounts and 572,104 agents in June 2026.

Activity

June cash-in/out value reached KSh 682.5bn across 212.5m transactions.

The breakthrough was not only the app—it was trusted last-mile distribution.

UPI and Pix show how public rails can support private fintech

UPI · India

23.2bn interoperable bank-account payments in May 2026.

Pix · Brazil

More than 170m individual users by January 2026.

Fintech layer

Banks and apps compete on service while the shared rail preserves interoperability.

A faster payment system is infrastructure—not a new currency.

The crucial question is: whose liability is the money?

Payment form	Whose liability?	Main risk or safeguard
Bank deposit	Commercial bank	Bank solvency; deposit insurance and supervision.
Mobile money	E-money issuer or trust	Safeguarding, agent liquidity and operational resilience.
Stablecoin	Private issuer or protocol	Reserve, redemption, governance and market risk.
Retail CBDC	Central bank	Privacy, access and effects on bank funding.
Payment rail	Not money itself	Moves another claim and relies on final settlement.

Which design could dominate future payments?

Bitcoin, another cryptocurrency, or a central-bank digital currency?

1 Money functions
Which object can mediate exchange, price contracts and preserve purchasing power?

2 Issuer and legal status
Does the holder have a claim—and on whom?

3 Stability and access
How does the user convert, transfer and recover value in stress?

Will Bitcoin (or Other Currencies) Become the Money of the Future?

Data Revolution and Finance

Big Data and Finance

The data revolution is having a profound impact on finance. The vast amounts of data that are being generated by financial transactions, market movements, and other sources are being used to develop new products and services, improve risk management, and make better investment decisions

Credit scoring: Big data is being used to develop new credit scoring models that are more accurate than traditional credit scoring models. These new models can take into account a wider range of factors, such as social media activity and internet browsing history, to provide a more comprehensive assessment of a borrower's creditworthiness.

Fraud detection: Big data is being used to develop new fraud detection systems that can help to protect financial institutions from fraud. These systems can analyze large amounts of data to identify patterns that may indicate fraudulent activity.

Market monitoring: Big data is being used to monitor financial markets for signs of instability. These systems can track trading patterns, social media sentiment, and other data to identify potential risks.

Early warning systems: Big data is being used to develop early warning systems that can help to prevent financial crises. These systems can track economic indicators, financial market data, and other data to identify potential problems early on.

Algorithmic Trade

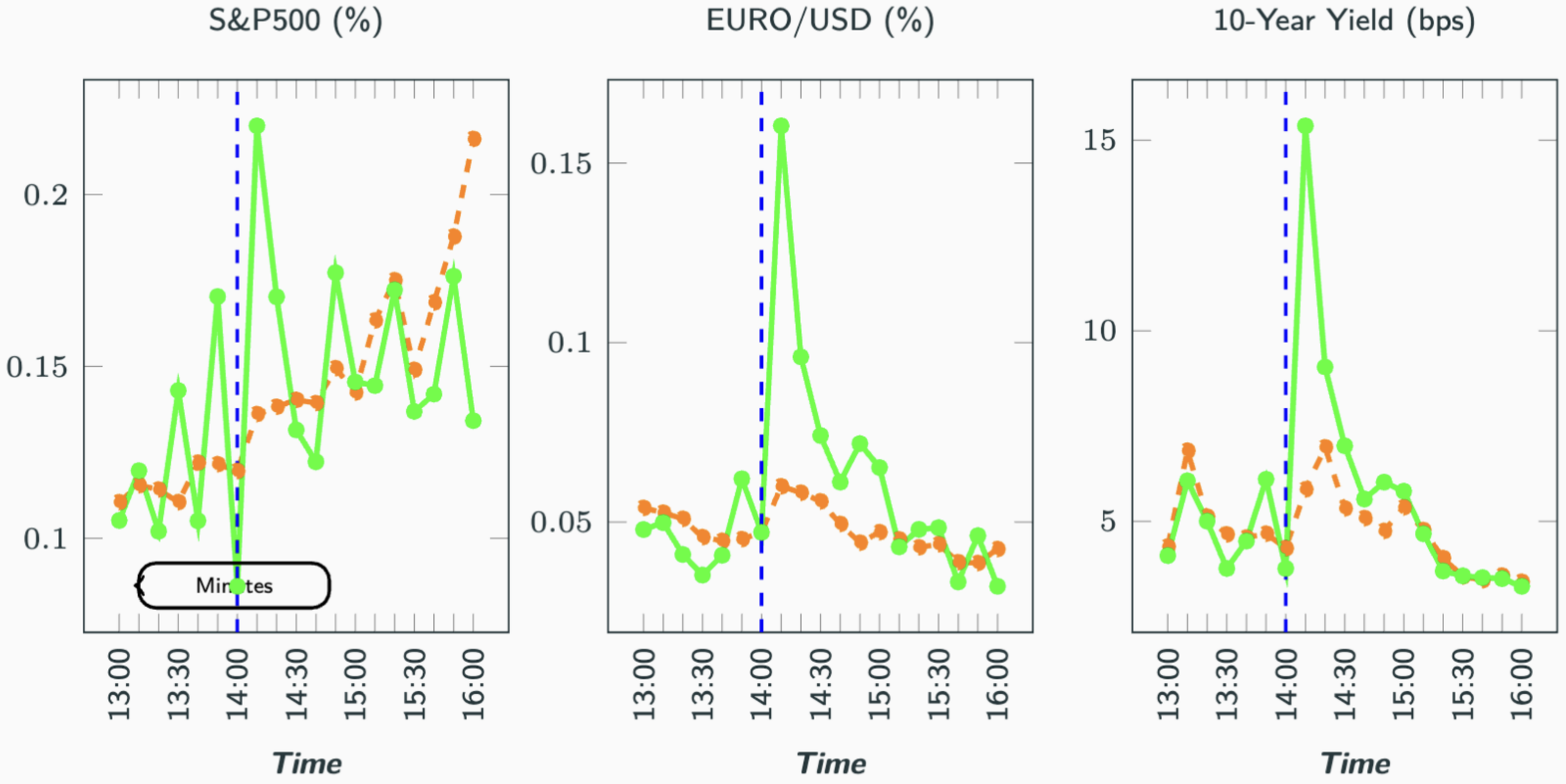
In today's fast-paced financial world, algorithmic trading is a game-changer. In 2020, it was estimated that 85% of all trading in the forex markets was performed by algorithms rather than humans.

Algorithmic trading has a number of benefits. It can help to improve trading efficiency by automating trading decisions. It can also help to improve profitability by identifying trading opportunities that would otherwise be missed.

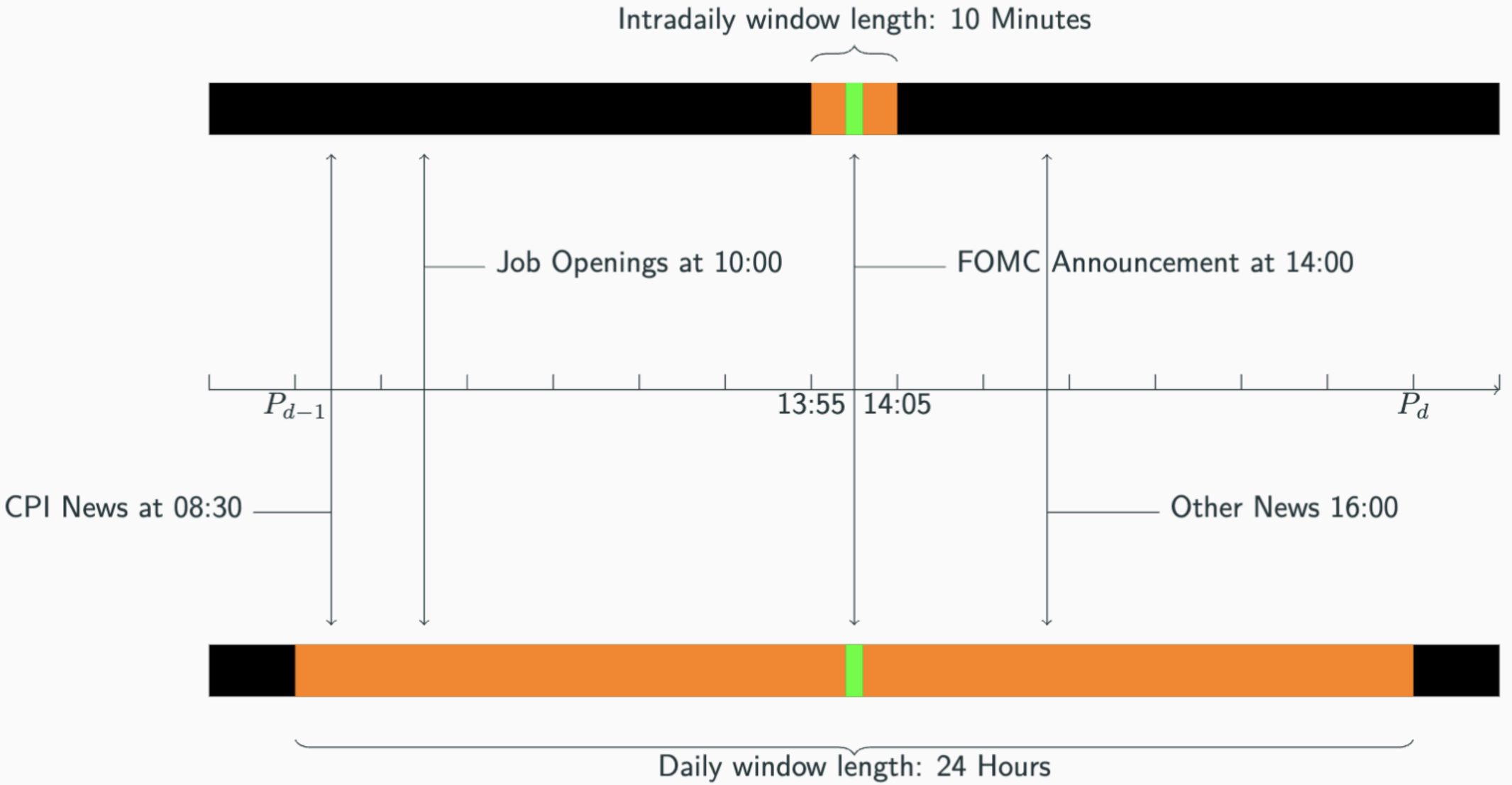
Growth of the financial markets: The growth of the financial markets is creating new opportunities for algorithmic trading. As the markets become more complex, algorithmic trading can help traders to stay ahead of the curve.

However, algorithmic trading also has some risks. One risk is that algorithmic traders can amplify market volatility. Another risk is that algorithmic traders can be vulnerable to cyberattacks.

In terms of monetary policy, these technologies can offer central banks more granular, high-frequency data that can enhance their decision-making process. Yet, the increasing use of algorithms and AI in finance could also affect how monetary policy is transmitted through the financial system.



High-Frequency Data



High-Frequency Data

window corresponds to the first set of $\hat{s} < S^*$ regimes, and the second window corresponds to the second set of $S^* - \hat{s}$ regimes. The covariance matrices of each of the misspecified periods are given by:

$$\Omega_{r1} = \frac{1}{(1-\alpha\beta)^2} \begin{bmatrix} \beta^2 \frac{1}{\hat{s}} \sum_{s<\hat{s}} \sigma^2_{\eta,s} + \frac{1}{\hat{s}} \sum_{s<\hat{s}} \sigma^2_{\varepsilon,s} & \beta \frac{1}{\hat{s}} \sum_{s<\hat{s}} \sigma^2_{\eta,s} + \alpha \frac{1}{\hat{s}} \sum_{s<\hat{s}} \sigma^2_{\varepsilon,s} \\ . & \frac{1}{\hat{s}} \sum_{s<\hat{s}} \sigma^2_{\eta,s} + \alpha^2 \frac{1}{\hat{s}} \sum_{s<\hat{s}} \sigma^2_{\varepsilon,s} \end{bmatrix}$$

for the first window, and

$$\Omega_{r2} = \frac{1}{(1-\alpha\beta)^2} \begin{bmatrix} \beta^2 \frac{1}{S^*-\hat{s}} \sum_{s>\hat{s}} \sigma^2_{\eta,s} + \frac{1}{S^*-\hat{s}} \sum_{s>\hat{s}} \sigma^2_{\varepsilon,s} & \beta \frac{1}{S^*-\hat{s}} \sum_{s>\hat{s}} \sigma^2_{\eta,s} + \alpha \frac{1}{S^*-\hat{s}} \sum_{s>\hat{s}} \sigma^2_{\varepsilon,s} \\ . & \frac{1}{S^*-\hat{s}} \sum_{s>\hat{s}} \sigma^2_{\eta,s} + \alpha^2 \frac{1}{S^*-\hat{s}} \sum_{s>\hat{s}} \sigma^2_{\varepsilon,s} \end{bmatrix}$$

for the second one. The two matrices can be rewritten as

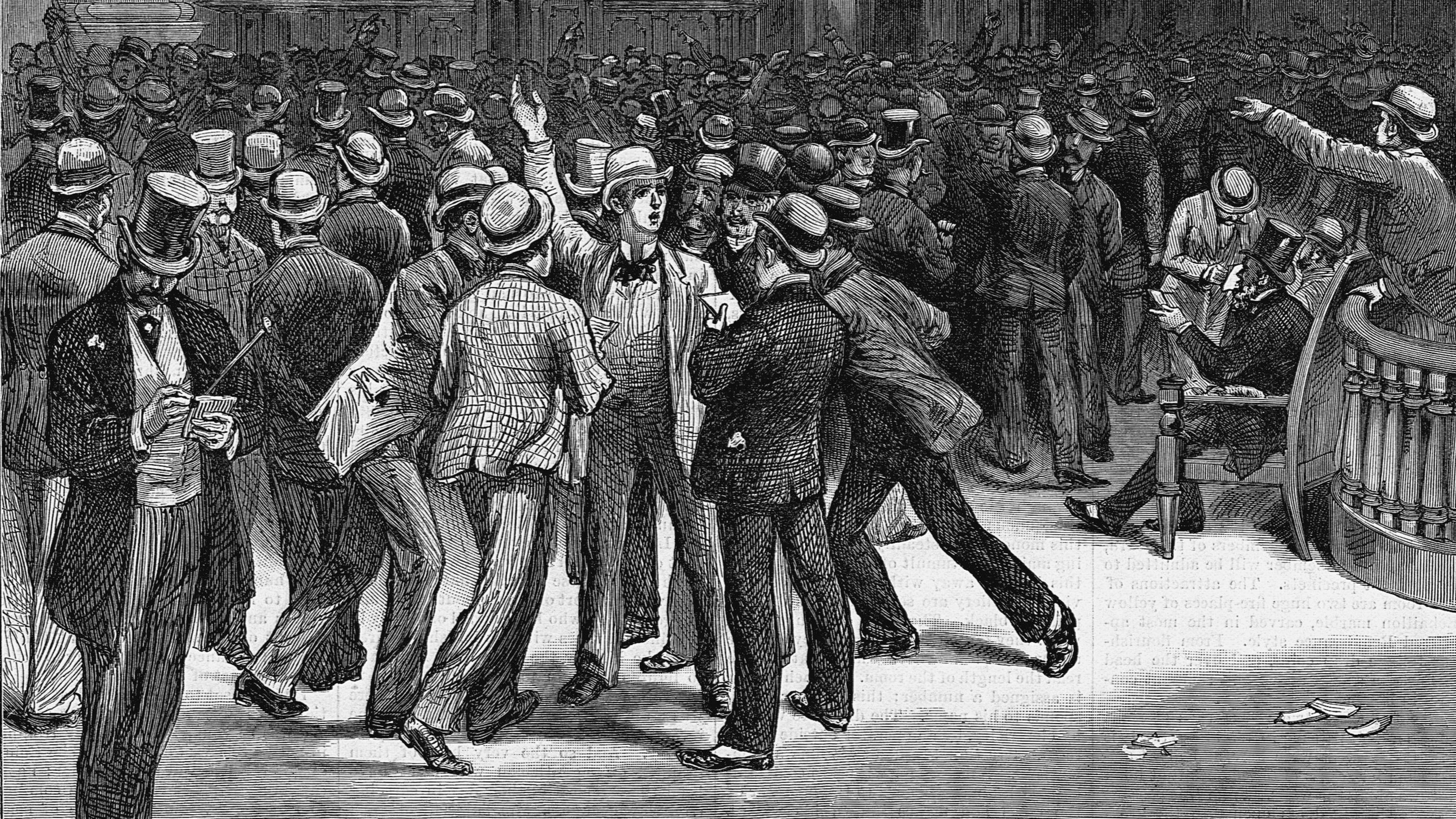
$$\begin{aligned} \Omega_{r1} &= \frac{1}{(1-\alpha\beta)^2} \begin{bmatrix} (1+\delta_{\eta,r1})\beta^2\sigma^2_{\eta,0} + (1+\delta_{\varepsilon,r1})\sigma^2_{\varepsilon,0} & (1+\delta_{\eta,r1})\beta\sigma^2_{\eta,0} + (1+\delta_{\varepsilon,r1})\alpha\sigma^2_{\varepsilon,0} \\ & (1+\delta_{\eta,r1})\sigma^2_{\eta,0} + (1+\delta_{\varepsilon,r1})\alpha^2\sigma^2_{\varepsilon,0} \end{bmatrix} \\ \Omega_{r2} &= \frac{1}{(1-\alpha\beta)^2} \begin{bmatrix} (1+\delta_{\eta,r2})\beta^2\sigma^2_{\eta,0} + (1+\delta_{\varepsilon,r2})\sigma^2_{\varepsilon,0} & (1+\delta_{\eta,r2})\beta\sigma^2_{\eta,0} + (1+\delta_{\varepsilon,r2})\alpha\sigma^2_{\varepsilon,0} \\ & (1+\delta_{\eta,r2})\sigma^2_{\eta,0} + (1+\delta_{\varepsilon,r2})\alpha^2\sigma^2_{\varepsilon,0} \end{bmatrix} \end{aligned}$$

where

$$\delta_{\eta,r1} = \frac{1}{\hat{s}} \sum_{s<\hat{s}} \delta_{\eta,s} \quad \text{and} \quad \delta_{\eta,r2} = \frac{1}{S^*-\hat{s}} \sum_{s>\hat{s}} \delta_{\eta,s} \tag{16}$$

$$\delta_{\varepsilon,r1} = \frac{1}{\hat{s}} \sum_{s<\hat{s}} \delta_{\varepsilon,s} \quad \text{and} \quad \delta_{\varepsilon,r2} = \frac{1}{S^*-\hat{s}} \sum_{s>\hat{s}} \delta_{\varepsilon,s} \tag{17}$$

High-Frequency Data

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