World Wide Journal of Multidisciplinary Research and Development (May-2025)

WWJMRD 2025; 11(05): 23-34
www.wwjmrd.com
International Journal
Peer Reviewed Journal
Refereed Journal
Indexed Journal
Impact Factor SJIF 2017: 5.182 2018: 5.51, (ISI) 2020-2021: 1.361
E-ISSN: 2454-6615

Alessandro Raffelini
DeFi Asset Management Ltd
Quanxum Lab (London)

Correspondence:
Alessandro Raffelini
DeFi Asset Management Ltd
Quanxum Lab (London)

A Fiscal-Monetary Framework for The Era of Coexistence: Fiat and Cryptocurrency in National Reserve Strategies

Alessandro Raffelini

Abstract
This study examines the fiscal and monetary implications of integrating Bitcoin (BTC) into national sovereign reserves, with a focus on its potential impact on debt sustainability, interest rate dynamics, and fiscal credibility. The paper introduces two key models. The first, ***BTC Price-to-Liquidity Market Model (Bd_t Model)*** predicts the future value of Bitcoin over the next decade (2025–2035). It incorporates long-term scarcity effects driven by Bitcoin's programmed supply issuance, drawing inspiration from the Stock-to-Flow model (PlanB, 2019). However, my approach diverges because it extends the analysis by integrating macroeconomic variables such as real interest rates, inflation rates and capital allocation trends, while also capturing cyclical market behavior through a sinusoidal adjustment. The second model, the ***BTC Fiscal Framework Debt-to-GDP Model***, is a forward-looking macro-fiscal simulation tool designed to evaluate the long-term effects of incorporating BTC into a nation's fiscal reserve strategy. Specifically, it assesses how Bitcoin holdings might influence real interest rates and inflation credibility, thereby affecting overall fiscal dynamics. Using empirical U.S. fiscal data, the study simulates debt-to-GDP ratios from 2024 to 2035 under two scenarios: a baseline scenario and a stagflation scenario. In addition to the Bd_t Model's value forecasting capabilities, the paper's key contribution is the derivation of an Adjustment Effect (AE) a quantifiable measure of fiscal improvement and debt mitigation attributed to Bitcoin reserve adoption. The AE is modeled as a function of real interest rates, inflation expectations, and the volatility-adjusted reserve value of Bitcoin. Simulation results indicate that incorporating BTC as a reserve asset could reduce the U.S. debt-to-GDP ratio. Even under stagflationary pressures BTC backed fiscal paths show significantly improved debt sustainability compared to traditional reserve strategies alone.

Keywords: BTC price, BTC demand, U.S. GDP, Sovereign debt, Inflation, Interest rate, National reserves, United States, Fiscal policies, Fiscal model, Policymakers.

1. Introduction

The collapse of the Bretton Woods system provides critical lessons for rethinking the architecture of a more resilient and equitable global financial order. Its downfall was driven largely by the emergence of a de facto dollar standard, which depended on the United States to maintain price and monetary stability. However, U.S. inflationary policies during the 1960s and 1970s undermined confidence in the system. Surplus countries grew increasingly unwilling to absorb excess dollar reserves or revalue their currencies, leading to imbalances that ultimately caused the system's breakdown. This historical failure exposed the inherent fragility of a global reserve framework tethered to the currency and policies of a single sovereign issuer. In response to these structural vulnerabilities—and the continued dominance of the U.S. dollar, particularly in developing economies—this paper proposes a new paradigm: a model of monetary coexistence and decentralized reserve diversification. Unlike traditional arrangements based solely on fiat currencies or gold, the proposed framework introduces Bitcoin (BTC) as a transparent, scarce, and programmable reserve asset. Bitcoin's fixed supply and decentralized governance make it uniquely suited to enhance monetary resilience, especially in countries facing persistent current-account deficits, rising debt burdens, or constrained monetary autonomy.

Findings, based on simulated fiscal scenarios explained in this study, suggest that the strategic integration of Bitcoin (BTC) reserves—even in developed economies—can enhance fiscal credibility, reduce sovereign risk premiums, and contribute to more stable debt trajectories. These effects are especially pertinent in a global environment where elevated debt-to-GDP ratios and limited tax capacity restrict fiscal flexibility, constrained monetary policy options, excessive fiscal deficits, or chronic currency instability. This study presents both a theoretical and empirical framework for analyzing these dynamics. While fiat currencies remain fundamental to government operations and the conduct of monetary policy, Bitcoin is emerging as a functional complement rather than a substitute. By linking monetary innovation to fiscal resilience, this research opens new pathways for reimagining the composition of sovereign reserves in the digital age. It provides a forward-looking model for policymakers seeking to enhance financial stability not only through traditional instruments but also by embracing Bitcoin (BTC) reserves.

2. Research

Although traditional factors influencing sovereign debt—such as interest rates, real economic growth, and primary fiscal balances—have been the subject of extensive research, there remains a scarcity of studies that consider the fiscal impacts of unconventional reserve assets like Bitcoin and other digital currencies (Krause D. 2024). Bitcoins as macro-fiscal strategic reserves asset at the state level in the macro-fiscal context is underexplored, including the implications on inflation expectations, state borrowing spreads in credit markets, and long run sustainability of public debt. This nascent field of inquiry brings important new lenses for reframing sovereign balance sheet management and reserve diversification in the light of a digitalizing global financial system. Much of the literature on sovereign debt dynamics has focused on short-run, identity-based decompositions of changes in debts ratios —essentially decomposing a change in a debt-to-GDP ratio into its various components such as interest payments, primary deficits and GDP growth. A respray of this analytical framework can be found in works like Cochrane (2019) or Hall and Sargent (2011) for the U.S.A. and Das and Ghate (2022) for India.

Nikhil Patel and Adrian Peralta-Alva (2024) emphasize that public debt-to-GDP ratios have fluctuated especially in 2020, due to the type of fiscal measures taken, and fell again between 2021 and 2022. To more formally investigate the sources of these dynamics, they propose a structural decomposition analysis employing a decomposition method based on a SVAR identified using narrative sign restrictions. This approach provides additional information on how macroeconomic shocks, and specifically those regarding growth, may combine with fiscal variables and trends in public indebtedness in advanced economies. The most recent existing literature has primarily focused on the dynamics of the debt-to-GDP ratio and its interaction with core fiscal and macroeconomic variables—such as interest rates, primary balances, and GDP growth—with the aim of assessing public debt sustainability. Important contributions in this area include studies by Escolano (2010), Genberg and Sulstarova (2008).

To date, no research framework comprehensively examines how the evolution of digital money and the integration of Bitcoin as a strategic reserve asset might form part of an interlinked system that supports debt sustainability, especially in developing or highly indebted economies. In the past of course notable economists have proposed meaningful studies about models to produce policy rules and discussed how sovereign debt may be impacted by different fiscal dynamics. Economists have elaborated different discrete time multiplier-accelerator models: Samuelson (1939), Hicks (1950), Hommes (1993), Hommes (1995), Kotsios and Leventidis (2004), Puu et al. (2005), Puu (2007), Kostarakos and Kotsios (2017) and Kostarakos and Kotsios (2018). Most recently, Spyrakis and Kotsios (2021) propose a novel approach in which a highly indebted country may overcome recessionary pressures and simultaneously reduce its debt burden through dynamic feedback control mechanisms— though such approaches remain underexplored in the context of digital monetary assets. In the '*Model of Coexistence of Fiat and Cryptocurrency in an Economic Area*' (Raffelini, A. 2021), it is argued that fiat money and cryptocurrencies are not mutually exclusive but can coexist within the same fiscal and monetary ecosystem. The decision to adopt, hold, or transact with either or both shaped by a set of variables. These include the real costs faced by households and businesses, such as exchange rate volatility, inflation, and, crucially, the technological functionality of digital assets. The model posits that the endogenous adoption of cryptocurrencies is primarily driven by the rate of technological advancement, which directly enhances the utility, accessibility, and perceived trustworthiness of digital currencies. This innovation factor is formally embedded within an extended version of the Keynesian money demand function, reflecting its structural importance in shaping monetary preferences. Crucially, the model demonstrates that economies may evolve toward multiple potential monetary equilibria—some of which may be unstable, while others represent stable coexistence points. These stable equilibria emerge when the marginal utility of holding both fiat and cryptocurrency is maximized, and the economic agents perceive comparable functional benefits from each. By integrating a technology adoption variable—also referred to as the functionality factor—into the demand for money, the model defines what can be termed the '*functioning demand curve of cryptocurrency*.' And the '*Frontier curve of functionalities*. The central hypothesis is that this technology factor is the most powerful endogenous driver of future money creation. It reflects the influence of a broad suite of innovations, including blockchain technology, decentralized finance (DeFi), artificial intelligence (AI), the Internet of Things (IoT), mobile financial infrastructure, and quantum computing. In the Model of Coexistence of Fiat and Cryptocurrency.

The model redefined the traditional Keynesian theory which explains the demand for money (Md) as a function of the interest rate (i) and income (Y):

$$Md=L(i,Y)$$

Where:

i = nominal or real interest rate (opportunity cost of holding

money),
Y = real income

- As interest rates rise, the opportunity cost of holding money increases, leading to a fall in Md.
- As income increases, transactional needs rise, leading to an increase in Md.

The Model extends the classical function by incorporating innovation (I) representing technological adoption and financial digitalization —into the money demand function to derive the demand of cryptocurrencies like Bitcoin:

$$Md=L(i,Y,I)$$

Where:

I = innovation index and captures factors such as: i) the degree of blockchain integration, ii) usage of mobile payment platforms, iii) deployment of AI in financial services, iv) availability and adoption of decentralized finance (DeFi) tools, v) penetration of digital wallets and stablecoins.

When ***I*** increases, it typically reduces the cost of using digital assets, improves accessibility, and enhances transactional efficiency.

Thus, we can expect: $\frac{\partial M_d}{\partial I} > 0$

As technological innovation increases — especially innovations related to financial technology, digital payments, or blockchain infrastructure — the demand for money, particularly digital or programmable forms of money like cryptocurrency, also increases. The model posits that the quantity of cryptocurrency (denoted as ***Qcy*** or ***Bd***) and fiat currency (***Dcy*** or ***Md***) required within a given economic region is contingent upon the volume of digital currency that sellers opt to accept and households choose to hold, which directly impacts the demand for fiat currency, causing it to fluctuate accordingly. The equilibrium is determined by several factors, including the transaction and administrative costs associated with holding and exchanging cryptocurrency compared to fiat, income spent in cryptocurrency (***y***), inflation (***π***), the functionalities of the cryptocurrency (***I***), and the interest rate (***i***).

Equilibrium Condition in an Economic Area:

$$Bd=Md = F \Rightarrow \text{Stable Equilibrium}$$

This occurs when:
The demand for fiat equals the demand for cryptocurrency and both reflect the maximum utility agents can get in an economic Area.

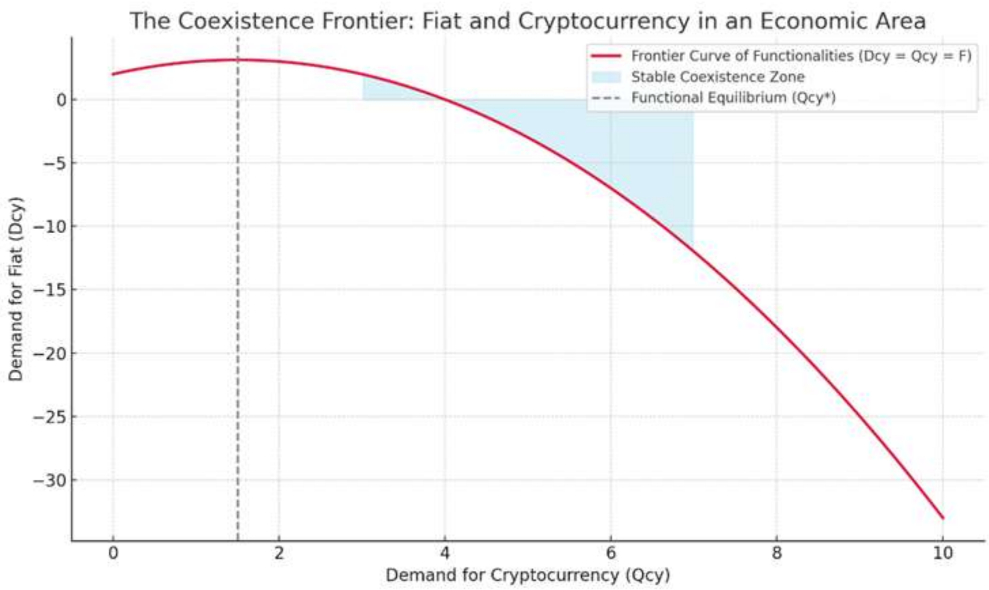
The Frontier Curve of Functionalities of BTC:

The Model of Coexistence of Fiat and Cryptocurrency in an economic Area (Raffelini, A., 2021) introduces a critical condition for stable monetary coexistence between fiat and cryptocurrency (such as Bitcoin). The Frontier Curve of Functionalities of cryptocurrency (Fig.1) defines all the points in an economic area where users receive equal marginal utility from both forms of money and defines a stable coexistence economic monetary digital region.

$$F = \left\{ (Qcy, Dcy) \in \mathbb{R}^2 \;\middle|\; \frac{\partial U}{\partial Qcy} = \frac{\partial U}{\partial Dcy},\ t = t^* \right\}$$

Where:

- Q_{cy}: Quantity of cryptocurrency demanded.
- D_{cy}: Demand for fiat currency.
- $\frac{\partial U}{\partial Q_{cy}}$: Marginal utility of holding cryptocurrency.
- $\frac{\partial U}{\partial D_{cy}}$: Marginal utility of holding fiat currency.
- $t = t^*$: A threshold level of technological adoption or functionality required for equilibrium.
- F: The **frontier curve**—a boundary in the economy where **utility is equalized** between fiat and crypto, defining **stable coexistence**.



Where:

i) Red Curve: The frontier of functionalities Dcy=Qcy*=F shaped by volatility, income, inflation.
ii) Vertical Dashed Line: Marks the functional equilibrium where crypto utility is maximized given the macro context.
iii) Blue Zone: Represents a stable coexistence economic region where fiat and crypto interact with shared adoption and functionality.
iv) The curve bends due to utility penalties (e.g., high volatility or inflation) that can be stabilized by a Bitcoin reserve.

The Frontier Curve of Functionalities is more than a mathematical construct. It outlines the boundary conditions under which fiat and crypto can stably coexist in a real-world economy. Indeed, ***inside the Frontier*** households and businesses predominantly use fiat currency. Cryptocurrency adoption is low because technology is not advanced enough, or utility is insufficient. Crypto's volatility or lack of infrastructure may make it unattractive. ***Outside the Frontier***, cryptocurrency use is widespread, possibly too dominant, and could begin to undermine monetary policy. Fiat loses its effectiveness, creating instability—especially if the state is unprepared for decentralized finance. ***On the Frontier***: This is the sweet spot: Fiat and crypto provide equal marginal utility. The technological factor is sufficiently high. Policy, trust, and usage are balanced. For central banks: This curve helps model how much innovation is needed before crypto can support monetary stability. For regulators: It defines the risk zone of under- or over-adoption of cryptocurrency. For technologists and innovators: It confirms that increasing real-world functionality (e.g., fast payments, smart contracts, DeFi) can push the system toward the coexistence frontier.

3. BTC Price to Liquidity Market Model (Bd_t Model)

As many global economies confront persistently high debt levels, ongoing monetary tightening, and fiscal uncertainty, policymakers face the urgent challenge of restoring debt sustainability without undermining economic growth or eroding monetary credibility. Especially the USA is expected to have lasting fiscal imbalances and high debt-to-GDP ratios for the entire next decade as a result of demographic change, taxation pressures and increasing entitlement costs. In this scenario Bitcoin (BTC) might develop into a new fiscal stabilizer. This paper presents, indeed, a forward-looking macro-fiscal simulation model: the '*BTC Fiscal Framework debt to GDP Model (BTC to GDP Model)*'coupled with a '*BTC Price to Liquidity Market Model (Bd_t Model)*.' To demonstrate the long-term implications of the inclusion of BTC reserves in any national fiscal policy structure. The Bd_t. *Model* is simply essential to calculate the Bitcoin's price trajectory from 2025 to 2035 as we need to connect all key macroeconomic variables with the flow of global capital, real rates, Bitcoin's predetermined scarcity post halving and also, systemic inflationary pressures that are essential to do the foundation of the BTC fiscal Framework. This model synthesizes, therefore, a simulation framework model to predict the ideal value of Bitcoin for the next 10 years, ranging from 2025 to 2035. The framework connects global capital flows, real interest rates, the scarcity dynamics of Bitcoin, post halving, and inflationary forces in a model of demand-driven pricing scheme. So, this is the demand-side anchor for bitcoin price prediction and penalty inflation rates to build the BTC Fiscal Framework Debt to GDP. Therefore, the Bd_t model incorporates long-term scarcity effects driven by Bitcoin's programmed supply issuance, drawing inspiration from the Stock-to-Flow model (PlanB, 2019). However, our approach diverges because it extends the analysis by integrating macroeconomic variables such as real interest rates, inflation rates and capital allocation trends, while also capturing cyclical market behavior through a sinusoidal adjustment.

3.1. Bitcoin Demand Index (Bd_t)

The Bitcoin Demand Index (Bd_t) is a synthetic metric designed to quantify the net demand pressure exerted on Bitcoin's price over time. It captures the intersection of macro-financial conditions—particularly liquidity availability, opportunity cost of capital, and asset scarcity—that collectively influence Bitcoin's equilibrium valuation.

Mathematically, the index is defined as:

$$\boldsymbol{Bd_t = (I \cdot Y) / (\pi_t - i_t) \cdot S_t}$$

Where:

- $\boldsymbol{Bd_t}$ – BTC Demand Index at year t
- $\boldsymbol{I}$ – Scaling constant (can be normalized to 1)
- $\boldsymbol{Y}$ – Capital allocated to Bitcoin (in % or dollar terms of global investable capital)
- $\boldsymbol{\pi_t}$ – Inflation rate at time t
- $\mathbf{i_t}$ – Nominal interest rate at time t
- $\boldsymbol{S_t}$ – Scarcity index of Bitcoin at time t

The denominator ($\boldsymbol{\pi_t - i_t}$) captures real interest rate pressure — if interest rates rise faster than inflation, opportunity cost increases, reducing demand for Bitcoin.

The numerator ($\boldsymbol{I \cdot Y}$) represents total investment flowing into BTC — driven by macro liquidity, policy shifts, or reallocation trends.

$\boldsymbol{S_t}$ amplifies the price signal by reflecting BTC scarcity, particularly post-halving effects, which reduce new issuance and increase relative demand for a fixed supply asset. Based on the relationships explained, we can argue that when real rates are negative, demand rises sharply because fiat alternatives yield less or even erode capital. As $\boldsymbol{Y}$ increases (more capital flows into BTC), and $\boldsymbol{S_t}$ tightens (post-halving), $\boldsymbol{Bd_t}$ rises non-linearly, supporting potential price appreciation in alignment with logarithmic models of scarcity-driven asset valuation.

The scarcity index $\boldsymbol{S_t}$ is a core component of the ***Bd_t model***, accounting for Bitcoin's declining issuance through halving events. The model applies to a multiplicative scarcity effect using a base scarcity function scaled by an exponential multiplier dependent on the number of halvings (n).

The formula is defined as follows:

$$S_t = \begin{cases} base\_scarcity_t & \text{if } t < 2025 \\ base\_scarcity_t \times 2^n & \text{if } t \geq 2025 \end{cases}$$

Where:
Base $scarcity_t = 660{,}000 \times \exp(-0.05 \times (t - 2020))$
n is the number of halving events occurred by year t
The term 2^n captures the compounding scarcity effect introduced by halving cycles.

Model-Derived Multipliers (Base 2^n)

Block Reward (BTC)	Years Covered	Multiplier Used
25.0	2012–2015	2
12.5	2016–2019	4
6.25	2020–2023	8
3.125	2024–2027	16
1.5625	2028–2031	32
0.78125	2032–2035	64

Before 2025: The model assumes BTC was still in a "price discovery" phase, so halving effects are already absorbed into market price and no extra multiplier is applied.

From 2025–2028: post-2024 halving, supply becomes tighter, and the model amplifies scarcity.

From 2028 onward: As supply gets extremely constrained and demand potentially institutionalized, reflecting compounding scarcity impact.

3.2. BTC Price Prediction Model

The BTC price is predicted from liquidity (Bd_t) using a log-log regression model adjusted by a Gaussian-modulated 4-year cycle signal.

First equation:

$$\ln(\hat{P}_t) = \alpha + \beta_1 \times \ln(Bd_t) + \beta_2 \cdot cycle_t$$

Second equation:

$$\hat{P}_t = e^{xp}(\ln(\hat{P}_t))$$

Where:
- α and β_1 are regression coefficients calibrated using actual BTC prices from 2020 to April 2025.
- $Bd_t = (I \cdot Y) / (\pi_t - i_t) \cdot S_t$
- $cycle_t$: Gaussian-modulated 4-year cycle signal

The **cycle term** modulates demand based on proximity to historical and projected halving dates, assuming that market sentiment and investor behavior exhibit predictable cyclicality post-halving. The cycle signal is constructed as:

$$\text{cycle}_t = \sum_{h \in \mathcal{H}} \exp\left(-\frac{1}{2}\left(\frac{t-(h+\delta)}{\sigma}\right)^2\right)$$

Where:
- h = {2012, 2016, 2020, 2024, 2028, 2032} is the set of known and forecasted Bitcoin halving years.
- t is the current time expressed in decimal years.
- δ is the assumed delay between a halving and the typical price peak (0.67 years as conventional parameter).
- σ is the standard deviation of the cycle peak in years, controlling the smoothness and duration of the effect (σ = 6 months = 0.5 years)
- The function ***exp*** $(-x^2 / 2)$ produces a bell-shaped (Gaussian) curve, commonly used in time-series modeling for delayed reactions.

We have introduced the $cycle_t$ to reflect the empirically observed pattern where Bitcoin price rallies occur following protocol-defined halving events, with peaks commonly occurring several months afterward. This cycle captures investor behavior, media attention, and macroeconomic feedback loops that amplify post-halving bull markets. This function ($cycle_t$) indeed assumes that each Bitcoin halving contributes a delayed but transient increase in market sentiment and price pressure. Instead of modeling this with a simple sine wave (which is periodic but disconnected from real economic events), this approach uses Gaussian curves to model localized peaks around specific historical events.

Each halving event generates a **Gaussian-shaped impulse** centered at a future date h+δ, where δ represents the empirically observed delay between the halving and the typical price peak. This reflects the **time lag required for the market to absorb the supply shock** and adjust through renewed price discovery. The width of the Gaussian pulse is controlled by the parameter σ, which governs the temporal dispersion of each halving's impact. The overall cycle modulation, *cycle*t, is computed as the **sum of these overlapping effects**, allowing for cumulative influence if halvings occur in close succession.

In parallel, the model assumes a logarithmic relationship between the price level and the demand proxy Bd_t, which captures the compounded effect of increasing capital allocation, macroeconomic liquidity, and Bitcoin's structural scarcity. This log-log formulation acknowledges a fundamental property of monetary assets: price reacts non-linearly to changes in demand when supply is inelastic. As visualized in Figure 2, this has also important implications for fiscal modeling and plays a foundational role in the BTC-to-GDP framework: it highlights that early reserve accumulation leads to larger fiscal signaling benefits through the Adjustment Effect (AE) based also on the assumption of BTC price increasing.

3.3. BTC Fundamental Deviation Index ($BFDI_t$)

The BTC Fundamental Deviation Index ($BFDI_t$) measures the relative difference between Bitcoin's model-predicted fundamental price and its observed market price at any point in time t.
Formally:

$$BFDI_t = (\hat{P}_t - P_{t,\ actual}) / P_{t,\ actual}$$

Where:
- $\hat{P}_t$ is the model-predicted BTC price in year t.
- $P_{t,\ actual}$ is the observed or simulated real BTC market price in year t.

$BFDI_t$ Value	Interpretation	Economic Meaning
Positive (>0)	BTC is undervalued relative to model	Likely hidden monetary debasement, delayed capital inflows, or emerging adoption phase.
Negative (<0)	BTC is overvalued relative to model	Likely speculative overshooting, excessive liquidity, or short-term macro euphoria.

$BFDI_t$ highlights structural distortions in monetary systems that are not captured by traditional CPI inflation metrics. Persistent positive $BFDI_t$ suggests hidden fiat debasement forces that have not yet been fully priced into the Bitcoin market. Extended positive deviations tend to precede price catchups, where Bitcoin gradually re-prices to align with fundamental liquidity conditions. As Bitcoin increasingly serves as a monetary base alternative, $BFDI_t$ provides a quantifiable framework to evaluate its credibility and maturity within broader macro-financial systems. To build and validate the capital allocation assumptions (Y), we have trained the Bd_t Model projections for 2025–2035 against empirical market data 2020-2024. For modeling purposes, we assume global financial wealth to be approximately $300 trillion, held constant over the projection horizon to maintain analytical clarity. The model projects that capital allocation to Bitcoin could rise to 10% by the end of 2035, conditional upon its broader adoption as a strategic reserve asset by sovereign states and the continued expansion of institutional investment flows. In parallel, we incorporate moderate assumptions for nominal interest and inflation rates throughout the forecast period to support internal model consistency (see Table 1). The assumption regarding capital inflows is pivotal: if Bitcoin fails to attract a substantial share of global capital—due to regulatory resistance, technological shortcomings, or macroeconomic headwinds—the model's output would necessitate a fundamental downward revision.

Tab. 1: Assumptions $\bar{Bd}_t$ **Model** 2020 -2035.

Year	Capital Allocation	Nominal Interest Rate (%)	Inflation (%)
2020	0.043	4.00	2.00
2021	0.400	3.80	2.00
2022	0.133	3.50	2.00
2023	0.0006	3.20	2.00
2024	0.008	3.00	2.00
2025	0.009	2.80	2.20
2026	0.010	2.90	2.20
2027	0.015	3.00	2.20
2028	0.020	3.50	2.20
2029	0.040	3.60	2.20
2030	0.045	3.50	2.20
2031	0.050	3.40	2.20
2032	0.055	3.50	2.50
2033	0.060	3.30	2.80
2034	0.080	3.40	3.00
2035	0.100	3.60	3.20

Assumptions' explanations:

The BTC capital allocation is modeled under total wealth over the years of approximately 300T (constant per simplicity over the years). From that base, we extrapolate a continuous growth of adoption — reaching 10% by 2035 — mimicking the growing endorsement by institutions, the geopolitical hedge, and the reserve currency arms races. For the model, we use a ***nominal interest rate***, with a much shallower discount function, starting at 4.0% in 2020 and levelling off to a 2.8% in 2025, with a strong return to 3.3–3.6% for 2029–2035. This path combines temporary deflationary forces and structural monetary tightening, in line with the IMF World Economic Outlook and US CBO Long-Term Budget Baselines. In this scenario, ***inflation*** is expected to remain stable and anchored at 2.0 percent annually until 2025 and to then increase gradually in the late 2020s and early 2030s, reaching 3.2 percent by 2035. This trajectory is consistent with the balanced view of policy trade-offs and structural relationships we observe under the Federal Reserve's long-run inflation guidance.

3.4. Volatility Bands

To provide a probabilistic context around predicted BTC prices, we introduce volatility bands—visualized in rainbow-colored layers—which represent the model's expected range of price fluctuations. These bands are constructed using the following expression:

$$P_t \pm \sigma = P_t \times e\text{^}(\pm\sigma)$$

Where:
- P_t is the predicted price at time t
- σ (sigma) is the standard deviation of the log returns.

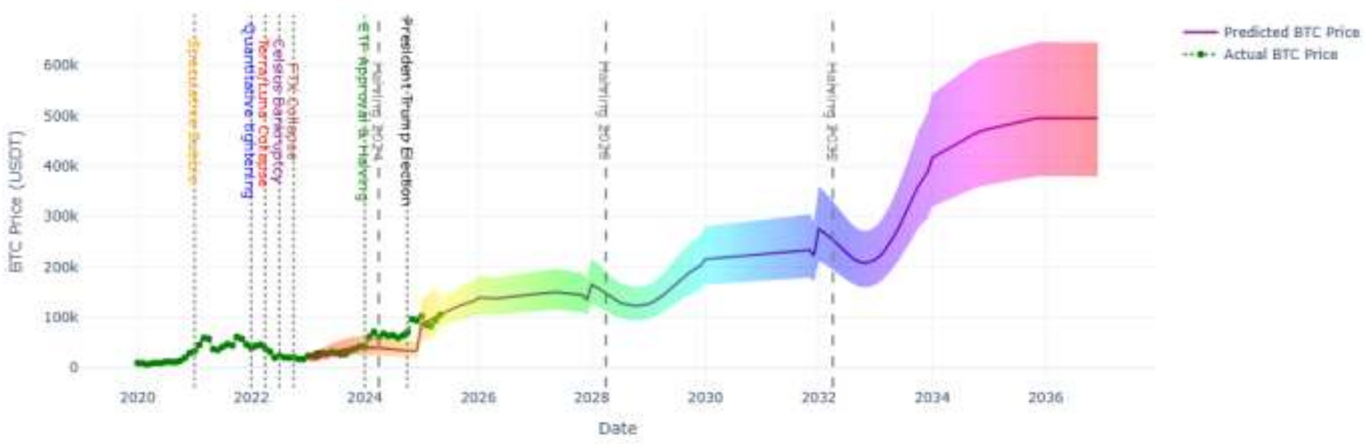
The standard deviation σ is derived in two distinct phases:
1. Historical Volatility: Based on observed log returns between 2020 and 2025.
2. Forecast Volatility: Derived from projected price dynamics from the model trained on the above volatility.

This method allows us to construct confidence bands around the predicted price path, providing insight into the expected range of fluctuation. It captures both past market dynamics and future uncertainty, offering a robust way to visualize and quantify risk.

3.4. Model results Visualization

In Figure 2, the BTC-to-liquidity market model is displayed, structured around the BTC Demand Index (Bd_t). This index serves as a synthetic proxy derived from key macro-financial components: capital allocation flows (Y), real interest rates, inflation rates, and a base scarcity index aligned with Bitcoin's issuance schedule. The model illustrates the evolving relationship between liquidity-driven demand conditions and projected BTC price levels over the 2025–2035 horizon. Through this framework, the figure captures how structural economic variables and market liquidity can influence Bitcoin's valuation trajectory over time.

Fig:2 BTC-to-Liquidity Market Model – Bd_t Model - A. Raffelini 2025



The purple curve represents the predicted BTC prices generated by the $\mathbf{Bd_t}$ model, while the green dotted curve tracks actual BTC market prices from 2020 to 2025 (last price 19/05/25).

i) Historical Fit and Deviation (2023–2024)

Q1–Q2 2023:

The model initially underestimates actual market performance. Starting from ~$19.7K in January, the predicted price gradually rises toward ~$23.4K by April. However, actual BTC prices surge beyond predictions—particularly in March and April—reflecting early bullish sentiment.

Q3–Q4 2023:

The divergence continues as actual BTC prices outperform the model, peaking near ~$42K in December while the model forecasts only ~$31.8K. This deviation likely corresponds to speculative momentum tied to ETF expectations and global liquidity shifts.

Early 2024:

Predictions begin realigning with observed prices by March 2024. The ETF approval and halving anticipation are well captured, with model and market prices converging in Q2—indicating the model's structure captures cyclical behavior.

ii) Post-Halving Acceleration and Growth Curve (2025–2027)

***2025*:**

After the halving in April 2024, the model forecasts a strong upward trajectory—from ~$90K in early 2025 to ~$130K by year-end. Actual prices track this path closely by May 2025, indicating effective calibration and predictive power during early adoption phases.

2026–2027:

The model stabilizes BTC prices in the ~$130K–$150K range, with narrower confidence bands. This reflects increased market maturity, reduced volatility, and more structurally anchored investor behavior.

iii) Second Growth Wave (2028–2031)

In 2028, coinciding with the next halving, a mild correction is projected. From there, the model anticipates a renewed upward climb, driven by amplified scarcity effects.

iv) Exponential Scarcity Impact (2032–2035)

Post-2032 halving, the model enters an exponential growth phase. Due to the scarcity multiplier and compounding liquidity assumptions, BTC prices rise toward ~$500K by 2035. Confidence bands narrow significantly, indicating increased model certainty in long-term trends.

Conclusion

The ***Bd_t*** Model effectively captures the macro-driven, cyclical, and supply-constrained nature of Bitcoin's valuation.

- Short-Term Deviation: The model underestimates speculative and sentiment-driven surges (e.g., mid-to-late 2023).
- Mid-Term Convergence: From late 2024, actual and predicted prices begin converging, validating the model's assumptions.
- Long-Term Trajectory: Rooted in capital flows, real interest dynamics, and programmed scarcity, the model forecasts a structurally rising BTC valuation.

4. BTC Fiscal Framework Debt to GDP Model

Following the development of the ***Bd_t Model***, this study introduces a second, forward-looking fiscal framework that incorporates Bitcoin (BTC) as a national strategic reserve asset, complementing traditional holdings such as gold. Therefore, we introduce a formal mathematical framework linking BTC reserves to public debt, interest rates, inflation rates and, indirectly, BTC Fundamental Deviation Index (BFDI). Using empirical U.S. fiscal data, the study simulates the evolution of the U.S. Debt-to-GDP ratio under two scenarios: one without BTC reserves and one with BTC reserves representing 5% of the total BTC supply. The core contribution is the derivation of an **Adjustment Effect (AE)**, a quantifiable improvement in fiscal sustainability resulting from BTC reserves. The AE is modeled as a function of real interest rates, inflation and the volatility-adjusted market value of BTC holdings. Simulations demonstrate that integrating BTC into national reserves softens debt accumulation dynamics and lowers borrowing costs by enhancing market confidence.

The results suggest that BTC, as a decentralized and absolutely scarce asset, could serve as a complementary reserve instrument—particularly valuable for emerging economies or those facing constraints in monetary sovereignty and currency credibility. Expanding upon the theoretical framework, we introduce the concept that Bitcoin's absolute scarcity, capital allocation and general adoption —cemented by its Bd dynamics explained earlier—serves as a structural stabilizing buffer within sovereign reserve portfolios. Unlike fiat currencies or even gold, Bitcoin is immune to discretionary supply manipulation, positioning it as a credible, transparent, and non-inflationary monetary anchor.

From a fiscal perspective, these features translate into enhanced reserve signaling power, which improves investor confidence, lowers sovereign risk premiums, and reduces interest rates on public debt and inflation expectations and distortion effects. As borrowing costs decline, governments are able to finance expenditures with reduced fiscal drag, fostering healthier primary balances and moderating the pace of debt accumulation. Most notably, the model demonstrates that Bitcoin's inclusion in national reserves—when paired with sustainable deficit reduction and steady GDP growth—can materially flatten the slope of the Debt-to-GDP trajectory. In doing so, Bitcoin contributes not only to monetary diversification but also to long-term fiscal resilience in both emerging and advanced economies.

4.1. Debt-to-GDP Evolution Equation

The fundamental formula for public debt dynamics is:

$$D_{t+1} = D_t + d - g$$

Where:

- D_t = Debt-to-GDP ratio at time t
- d = Fiscal deficit as a percentage of GDP
- g = Nominal GDP growth rate.

This formula reflects the idea that debt increases by the fiscal deficit but is offset by GDP growth, which increases the denominator (GDP) and thus reduces the ratio.

We can rewrite the formula of any state reserve R as:

$$R = \alpha G + \gamma B_{eff} - \beta D$$

Where:

R: Reserve credibility score (or sovereign reserve strength). It is a composite metric to assess the state's fiscal credibility based on its reserves and debt.

G: Value of traditional reserve assets (e.g., gold, foreign currency).

B: Bitcoin holdings. It reflects the total BTC held by the state as part of its reserves.

Beff: Effective BTC reserves, adjusted for volatility. It reflects the risk-weighted contribution of BTC to the national reserve.

D: Public debt (as a ratio Debt-to-GDP).

α, β > 0: Positive coefficients capturing the influence strength of gold, BTC, and debt on fiscal credibility:

- α: Weight of gold reserves in enhancing fiscal strength.
- γ: Weight of Bitcoin reserves via Beff.
- β: Weight of debt in reducing credibility.

An increasing fiscal deficit D diminishes R, potentially weakening fiat's role unless offset by assets like BTC or gold. This function reflects how BTC strengths fiscal resilience, while excessive debt weakens it.

4.2. BTC Fiscal Framework Debt-to-GDP Model

This model introduces a novel, structured fiscal simulation framework that integrates Bitcoin (BTC) as a strategic reserve asset to enhance sovereign debt sustainability. By linking BTC reserve accumulation to fiscal variables through the Adjustment Effect (AE), we quantify its ability to moderate debt trajectories under varying macroeconomic conditions.

Equation Debt-to-GDP Model:

1) $$Debt_t = Debt_{t-1} + (Deficit_t - GDP\ Growth_t) - AE_t$$

The Adjustment Effect (***AEt***) is a core component of the model where Bitcoin (BTC) reserves to improve fiscal performance by reducing the effective deficit and supporting debt sustainability. The adjustment effect reflects, therefore, how much the BTC reserve reduces the effective deficit by lowering borrowing costs and improving fiscal credibility.

2) $$AE_t = \delta \cdot \left(\frac{\gamma \cdot B_{\text{effective}}}{i_t - \pi} \right)$$

Where:

- δ: Scaling factor for adjustment effect.
- γ: Weight of BTC reserves.
- $B_{\text{effective}} = \frac{B}{1+\sigma_B}$: Volatility-adjusted BTC reserves.
- i_t: Dynamic interest rate.
- π: Inflation rate.

$$AE \text{ grows because: } \begin{cases} \text{Higher } B_{\text{effective}} \Rightarrow \text{Stronger numerator} \\ \text{Lower } i_t \Rightarrow \text{Smaller denominator} \\ \text{Stronger } \delta \Rightarrow \text{Amplifies AE} \end{cases}$$

Effective BTC Reserve:

3) $$B_{eff} = \frac{B}{1 + \sigma_B}$$

B = Nominal Bitcoin reserve holdings.
σB = Volatility of Bitcoin.

Interpretation: Higher BTC volatility reduces its credibility as a stabilizing reserve. The adjusted reserve (B*eff*) is a proxy for how much BTC strengthens the fiscal balance sheet.

Dynamic Interest Rate Function:
This function shows how interest rates react to fiscal strength: debt increases rates, reserves reduce them.

4) $$i_t = \min\left(\max\left(i_0 + \lambda \cdot (D_t - \alpha G - \gamma B_{\text{effective}}),\ i_{\min}\right),\ i_{\max}\right)$$

Where:
i_0 = Baseline interest rate (10Y T-bond rate).
λ = Market sensitivity to reserve-debt dynamics.
Dt = Debt-to-GDP at time t.
G = Gold reserve level.
α = Gold reserve weight.
γ = BTC reserve weight.
B*effective* = Adjusted BTC reserves.
imax, imin = Upper lower bounds on interest rates

Deficit Path Over Time:

Without BTC Reserves:

5) $\boldsymbol{Def^{(noBTc)}_t = max(Def_0 - r\cdot(t - t_0), Def_{min}) + \pi_{penalt}y_{,t}}$

With BTC Reserves:

6) $\boldsymbol{Def^{(BTc)}_t = max(Def_0 - r\cdot(t - t_0), Def_{min}) - AE_t}$

Def_t : Fiscal deficit in year *t*, as a percentage of GDP
Def_0 : Initial baseline deficit
r : Annual rate of deficit reduction
t_0 : Base year of fiscal policy (e.g., 2024)
Def_{min} : Minimum allowed deficit floor (3%)
$\pi_{penalt}y_{,t}$: Inflation credibility penalty (added when no BTC reserve exists)
AE_t : Adjustment effect from BTC reserves (fiscal improvement from trust gain)

Without BTC Reserves:

7) $\boldsymbol{Debt_t^{noBTc} = Debt_{t-1}^{noBTc} + (Deficit_t^{noBTc} - GDPGrowth_t)}$

With BTC Reserves:

8) $\boldsymbol{Debt_t^{BTc} = Debt_{t-1}^{BTc} + (Deficit_t^{BTc} - GDPGrowth_t)}$
Where:

$Debt_t$: Debt-to-GDP ratio at time t (it tracks the level of government debt relative to national output).
$Debt_{t-1}$: Debt-to-GDP in the previous year (Baseline for calculating next year's debt).
$Deficit_t$: Nominal GDP growth (%) (Increases debt when government spends more than it earns).
GDP*Growth*$_t$: Nominal GDP growth (%) (Reduces the debt ratio by growing the economy's denominator).
AE_t: Reflects how BTC reserves improve market trust, lower borrowing costs, and reduce debt accumulation. (Only used in BTC scenario).

Without BTC Reserves:
Debt grows based on the difference between the deficit and GDP growth.

With BTC Reserves:
Same structure, but includes a negative AE term that reduces effective deficit.

AE depends on:

i) Size and credibility of BTC reserves (adjusted for volatility)
ii) Interest rate gap between nominal rates and inflation
iii) Mechanically, this can flatten or reverse debt growth even with the same deficit path.

4.2 Simulation of U.S. Debt-to-GDP trajectory (2025-2035)
By applying the proposed model to the U.S. Debt-to-GDP trajectory over the period 2025–2035, we have derived a forward-looking macro-fiscal simulation framework which examines the long-term impact of integrating BTC reserves into national fiscal policy reaching 5% of BTC supply by 2035.
We evaluate how BTC holdings, via their effect on interest rates, inflation and net effect on balance sheet, can alter the trajectory of U.S. debt and deficits under two key macroeconomic scenarios based on the assumptions in the Tables 2 and 3.

We consider two scenarios:

i. **Baseline Scenario**: Moderate nominal GDP growth, gradually falling deficits, and stable inflation.

ii. **Stagflation Scenario**: Persistently higher inflation paired with sluggish real growth.

The two scenarios have been simulated:

i) Without Bitcoin Reserves
ii) With Bitcoin Reserves, where BTC holdings improve fiscal credibility and lower effective deficits via an Adjustment Effect (AE).

Tab 2. Model Assumptions (1/2).

Year	Scenario	Nominal GDP Growth (%)	Inflation Rate (%)	Real Rate (%)	Initial Deficit (Def_0, %)	Deficit Reduction (r, % per year)	Deficit Floor (Def_{min}, %)
2024	Baseline	4.5	2	1	6.3	0.5	3

2025	Baseline	4.3	2.2	0.6	6.3	0.5	3
2026	Baseline	4.3	2.2	0.7	6.3	0.5	3
2027	Baseline	4.4	2.2	0.8	6.3	0.5	3
2028	Baseline	4.5	2.2	1.3	6.3	0.5	3
2029	Baseline	4.5	2.2	1.4	6.3	0.5	3
2030	Baseline	4.5	2.2	1.3	6.3	0.5	3
2031	Baseline	4.5	2.2	1.2	6.3	0.5	3
2032	Baseline	4.5	2.5	1	6.3	0.5	3
2033	Baseline	4.5	2.8	0.5	6.3	0.5	3
2034	Baseline	4.5	3	0.4	6.3	0.5	3
2035	Baseline	4.5	3.2	0.3	6.3	0.5	3
2024	Stagflation	4.5	3.5	1	6.3	0.25	3
2025	Stagflation	4.3	3.5	0.6	6.3	0.25	3
2026	Stagflation	2.5	3.5	0.7	6.3	0.25	3
2027	Stagflation	2.5	3.5	0.8	6.3	0.25	3
2028	Stagflation	2.5	3.5	1.3	6.3	0.25	3
2029	Stagflation	2.5	3.5	1.4	6.3	0.25	3
2030	Stagflation	2.5	3.5	1.3	6.3	0.25	3
2031	Stagflation	2.5	3.5	1.2	6.3	0.25	3
2032	Stagflation	2.5	3.5	1	6.3	0.25	3
2033	Stagflation	2.5	3.5	0.5	6.3	0.25	3
2034	Stagflation	2.5	3.5	0.4	6.3	0.25	3
2035	Stagflation	2.5	3.5	0.3	6.3	0.25	3

The assumptions reported in Tab 3 are the following:

1. Nominal GDP Growth (%)

- Reflects total GDP growth without adjusting for inflation.
- Baseline assumes consistent growth around 4.3%–4.5%.
- Stagflation assumes a sharp drop to 2.5% post-2025 to simulate economic stagnation.

2. Inflation Rate (%)

- Used to adjust interest rates and real debt burdens
- Baseline ranges from 2.0% to 3.2%, indicating stable inflation.
- Stagflation holds steady at 3.5%, reflecting inflation persistence.

3.Real Interest Rate (%)

Defined as Real Rate = Nominal Rate - Inflation.

- Used to model borrowing cost after adjusting for inflation.
- Gradually increases in the baseline; fixed in stagflation.

4. Initial Deficit (Def_0, %)

- Represents the starting primary deficit as % of GDP: 6.3%. We consider the same across both scenarios, simulating high initial debt burden and constant for simplicity.

5. Deficit Reduction Rate (r, % per year)

Rate at which the government reduces its deficit each year:

- Baseline: 0.5% per year (faster improvement).
- Stagflation: 0.25% per year (slower due to economic stress).

6. Deficit Floor (Def_{min}, %)

Minimum floor to which deficits can be reduced:

- Baseline: 3%
- Stagflation: 3% (realistic constraint under pressure)

Tab 3. Model Assumptions (2/2).

Year	Scenario	Base Nominal Interest Rate (i_0, %)	Interest Rate Sensitivity (λ)	Adjustment Responsiveness (δ)	BTC Reserve Accumulation (% GDP)	Penalty Inflation (10%)
2024	Baseline	3.11	0.015	0.4	-	3.07
2025	Baseline	3.11	0.015	0.4	0.0083	3.074
2026	Baseline	3.11	0.015	0.4	0.0166	2.8166
2027	Baseline	3.11	0.015	0.4	0.0250	2.5592
2028	Baseline	3.11	0.015	0.4	0.0333	2.3018
2029	Baseline	3.11	0.015	0.4	0.0416	2.0444
2030	Baseline	3.11	0.015	0.4	0.0500	1.787
2031	Baseline	3.11	0.015	0.4	0.0500	1.5296
2032	Baseline	3.11	0.015	0.4	0.0500	1.2722
2033	Baseline	3.11	0.015	0.4	0.0500	1.0148
2034	Baseline	3.11	0.015	0.4	0.0500	0.7574
2035	Baseline	3.11	0.015	0.4	0.0500	0.5
2024	Stagflation	3.11	0.015	0.4	-	3.07
2025	Stagflation	3.11	0.015	0.4	0.0083	3.074
2026	Stagflation	3.11	0.015	0.4	0.0166	2.8166
2027	Stagflation	3.11	0.015	0.4	0.0250	2.5592
2028	Stagflation	3.11	0.015	0.4	0.0333	2.3018
2029	Stagflation	3.11	0.015	0.4	0.0416	2.0444
2030	Stagflation	3.11	0.015	0.4	0.0500	1.787
2031	Stagflation	3.11	0.015	0.4	0.0500	1.5296
2032	Stagflation	3.11	0.015	0.4	0.0500	1.2722
2033	Stagflation	3.11	0.015	0.4	0.0500	1.0148
2034	Stagflation	3.11	0.015	0.4	0.0500	0.7574
2035	Stagflation	3.11	0.015	0.4	0.0500	0.5

7. Base Nominal Interest Rate (i_0, %)
- Starting benchmark rate: 3.11% across all years.
- Used as the base for the dynamic interest rate function.

8. Interest Rate Sensitivity (λ)
- Measures how sensitive interest rates are to changes in debt or reserves.
- Fixed at 0.015, meaning a 1-point increase in debt-to-GDP increases interest rates by 0.015%.

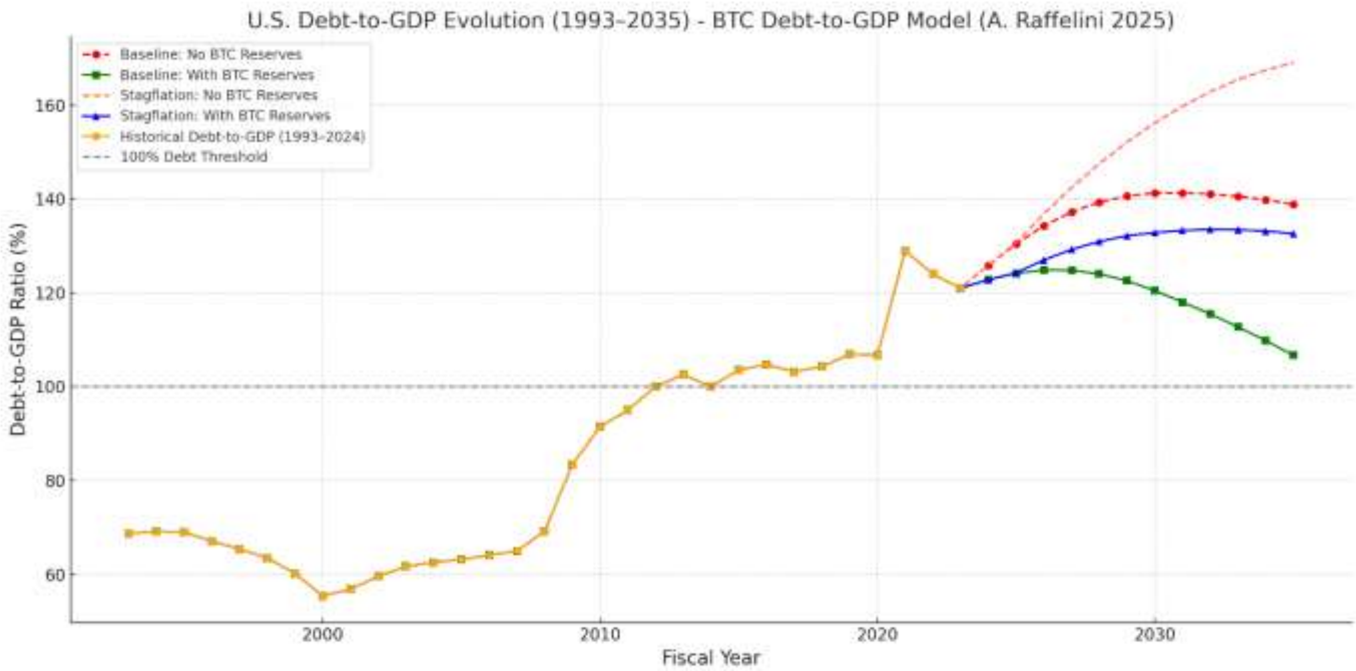
9. Adjustment Responsiveness (δ)
- Captures how effectively BTC reserves lower financing pressure.
- Fixed at 0.4: higher values imply a stronger "Adjustment Effect" (AE).

10. BTC Reserve Accumulation (% of GDP)
- Accumulation ramps up yearly to 5% of GDP by 2030, of total BTC supply.

11. Penalty Inflation (10%)
Proxy cost from inflation distortion on debt sustainability. Set as 10% of the inflation rate: if inflation = 3%, penalty = 0.3 * 10 = 3.0.

Declines over time in both scenarios as inflation moderates or BTC reduces the fiscal burden. Penalty inflation introduces, therefore, a **behavioral cost** that amplifies the benefits of fiscal credibility.

U.S. Debt to GDP Model simulation (2025 – 2035)
The chart below illustrates the projected evolution of the U.S. Debt-to-GDP ratio under four different fiscal policy scenarios from 2025 to 2035, incorporating Bitcoin (BTC) as a strategic reserve asset.



Red (Baseline, No BTC Reserves):
Debt continues to rise gradually, reaching higher levels by 2035 (~140%+), reflecting traditional fiscal pressure.
Green (Baseline with BTC Reserves):
BTC reserve accumulation significantly flattens the debt trajectory, with Debt-to-GDP falling below 110% by 2035. This reflects the Adjustment Effect (AE) from improved fiscal credibility and reduced borrowing costs.
Light Red (Stagflation, No BTC):
In adverse macro conditions (low growth, persistent inflation), debt rises steeply above 160%, signaling fiscal distress.
Blue (Stagflation with BTC Reserves):
While still increasing, the debt ratio remains considerably lower than the no-BTC counterpart, validating BTC's stabilizing role even in stagflation.
Orange (Historical Path):
Serves as context for the realism of the model's calibration.
Conclusion
The paper introduces two key models. The first, ***BTC Price-to-Liquidity Market Model ($\mathcal{B}d$ Model)*** predicts the future value of Bitcoin over the next decade (2025–2035). It incorporates long-term scarcity effects driven by Bitcoin's programmed supply issuance, drawing inspiration from the Stock-to-Flow model (PlanB, 2019). However, my approach diverges because it extends the analysis by integrating macroeconomic variables such as real interest rates, inflation and capital allocation trends, while also capturing cyclical market behavior through a sinusoidal adjustment. The second model, the ***BTC Fiscal Framework Debt-to-GDP Model***, is a forward-looking macro-fiscal simulation tool designed to evaluate the long-term effects of incorporating BTC into a nation's fiscal reserve strategy and evaluates its implications for public debt sustainability through simulations based on the U.S. debt-to-GDP trajectory. By analyzing four scenarios, Baseline and Stagflation, each with and without BTC reserves — the study demonstrates that a BTC reserve can significantly improve long-term debt metrics. At the core of the model is the Adjustment Effect (AE): an original dynamic mechanism through which BTC reserves enhance fiscal credibility, lower real borrowing costs, and mitigate inflationary penalties. Under baseline conditions, the integration of BTC reserves might reduce the U.S. debt-to-

GDP ratio by approximately 30 percentage points by 2035 compared to the trajectory without BTC under certain assumptions. Even with stagflation, a Bitcoin-backed fiscal trajectory is far more successful in containing debt. Its decentralized nature, fixed supply and immunity to discretionary monetary policy serve as a complement to other reserves. These qualities render it particularly attractive for economies with limited monetary sovereignty or high exposure to fiat currency depreciation. The findings support the notion that BTC reserves can function as a macro-financial stabilizer, particularly in economies burdened by high debt or constrained by traditional policy tools. The inclusion of BTC in sovereign portfolios offers a non-inflationary, programmatically scarce asset that strengthens investor confidence and dampens interest rate risk premiums. Moreover, during stagflation—where policy options are limited—BTC reserves, when appropriately scaled and adjusted for volatility, serve as a fiscal buffer. They reduce the inflation-linked debt service burden and enhance the sustainability of sovereign liabilities. In the long run, Bitcoin's inherent properties—finite issuance, decentralization, and growing institutional adoption—position it as a structurally stabilizing reserve asset. As global finance continues to evolve, and as digital monetary systems mature, BTC may emerge as a cornerstone of 21st-century sovereign reserve strategies. This research concludes that Bitcoin's role extends beyond speculation: it can be systematically modeled as a foundational component of fiscal strategy, aligning digital financial innovation with long-term debt sustainability and macroeconomic resilience. Additionally, the paper incorporates the Bd_t model to forecast BTC price evolution through 2035. Based on macroeconomic drivers assumed—capital inflows, issuance scarcity, and inflationary pressure — the model projects BTC prices of approximately $500,000 by 2035, assuming no speculative decoupling or major external shocks which may increase or decrease prices in the short term. The model, indeed, assumes a logarithmic relationship between the price level and the demand proxy $\boldsymbol{Bd}_t$, which captures the compounded effect of increasing capital allocation, macroeconomic liquidity, and Bitcoin's structural scarcity. This formulation acknowledges a fundamental property of monetary assets: price reacts non-linearly to changes in demand when supply is inelastic.

References

1. Krause, David, "A Roundtable Discussion on the Strategic Implications of a U.S. Bitcoin Reserve," (December 21, 2024). http://dx.doi.org/10.2139/ssrn.5067147
2. Krause, David, "Evaluating Bitcoin and Layer-1 Cryptocurrencies for a U.S. Strategic Reserve: Opportunities and Risks (December 05, 2024)." http://dx.doi.org/10.2139/ssrn.5045210
3. Cochrane, John H, "The value of government debt," Technical Report, National Bureau of Economic Research 2019. Available here.
4. Hall, George J., and Thomas J. Sargent. 2011. "Interest Rate Risk and Other Determinants of Post-WWII US Government Debt/GDP Dynamics." American Economic Journal: Macroeconomics 3 (3): 192–214.DOI: 10.1257/mac.3.3.192
5. Das, Piyali and Chetan Ghate, "Debt decomposition and the role of inflation: A security level analysis for India," Economic Modelling, 2022, p. 105855. https://doi.org/10.1016/j.econmod.2022.105855
6. Patel, Nikhil and Adrian Peralta-Alva (2024) "Public Debt Dynamics and the Impact of Fiscal Policy." IMF Working Paper WP/24/87, International Monetary Fund, Washington, D.C. ssrn-4815070.pdf.
7. Escolano J, (2010) "A practical guide to public debt dynamics, fscal sustainability, and cyclical adjustment of budgetary aggregates (No. 2010/002)." International Monetary Fund, Washington, DC. Available here.
8. [Genberg H, Sulstarova A (2008) Macroeconomic volatility, debt dynamics, and sovereign interest rate spreads. J Int Money Financ 27(1):26–39. https://doi.org/10.1016/j.jimonfin.2007.09.010
9. Samuelson PA (1939) "Interactions between the multiplier analysis and the principle of acceleration". Rev Econ Stat 21(2):75–78. http://dx.doi.org/10.2307/1927758
10. Hommes CH (1993) "Periodic, almost periodic and chaotic behaviour in hicks' non-linear trade cycle model." Econ Lett 41(4):391–397. https://doi.org/10.1016/0165-1765(93)90211-T
11. Hicks JR (1950) "A contribution to the theory of the trade cycle". The Clarendon Press, Oxford. Available here. [Hommes CH (1995) A reconsideration of hicks' non-linear trade cycle model. Struct Chang Econ Dyn 6(4):435–459. https://doi.org/10.1016/0954-349X(95)00032-I Kotsios S, Leventidis J (2004) "A feedback policy for a modifed Samuelson-Hicks model." Int J Syst Sci 35(6):331–341. Available here.
12. Puu T, Gardini L, Sushko I (2005) "A hicksian multiplier-accelerator model with foor determined by capital stock." J Econ Behav Organ 56(3):331–348. Available here.
13. Puu T (2007) "The hicksian trade cycle with foor and ceiling dependent on capital stock." J Econ Dyn Control 31(2):575–592. https://doi.org/10.1016/j.jedc.2005.12.004
14. Kostarakos I, Kotsios S (2017) Feedback policy rules for government spending: an algorithmic approach. J Econ Struct 6(1):5. https://rdcu.be/ekoGv
15. [Kostarakos I, Kotsios S (2018) Fiscal policy design in Greece in the aftermath of the crisis: an algorithmic approach. Comput Econ 51(4):893–911. https://doi.org/10.1007/s10614-017-9650-3
16. Spyrakis, V., Kotsios, S. "Public debt dynamics: the interaction with national income and fiscal policy. Economic Structures" 10, 8 (2021). https://doi.org/10.1186/s40008-021-00238-4
17. PlanB (2019). "Modeling Bitcoin Value with Scarcity Medium article
18. Raffelini, A. (2021). "The Model of Coexistence of Fiat and Cryptocurrency in an Economic Area: A Case Study of El Salvador: Monetary and Economic Implications". International Journal of Scientific and Research Publications (IJSRP), 11(10), 869. https://doi.org/10.29322/IJSRP.11.10.2021.p11869