Yuan Ze University

Energy Anchoring in Cryptocurrency Markets

Evidence from Natural Experiments

Christopher Ongko (1133958) Empirical Finance

Spring 2025 Term Report Proposal May 28, 2025

Evolution Since Proposal

What Changed Our Perspective

Original Vision:

Energy costs create a universal price floor for Bitcoin, similar to gold mining costs supporting gold prices.

The Reality We Discovered:

The relationship exists but depends critically on mining concentration. When China hosted 70% of global mining, energy costs anchored prices. After the ban dispersed mining globally, this anchor weakened by half.

Key Additions Since Proposal:

- *Discovered structural break at China ban (June 21, 2021)*
- *Added Ethereum merge as counterfactual experiment*
- *Refined CEIR with country-weighted electricity prices*
- *Tested regulation indices (found null effects)*

This evolution from simple model to regime-dependent theory strengthens our contribution

Literature Review & Variables

Building on Robust Evidence

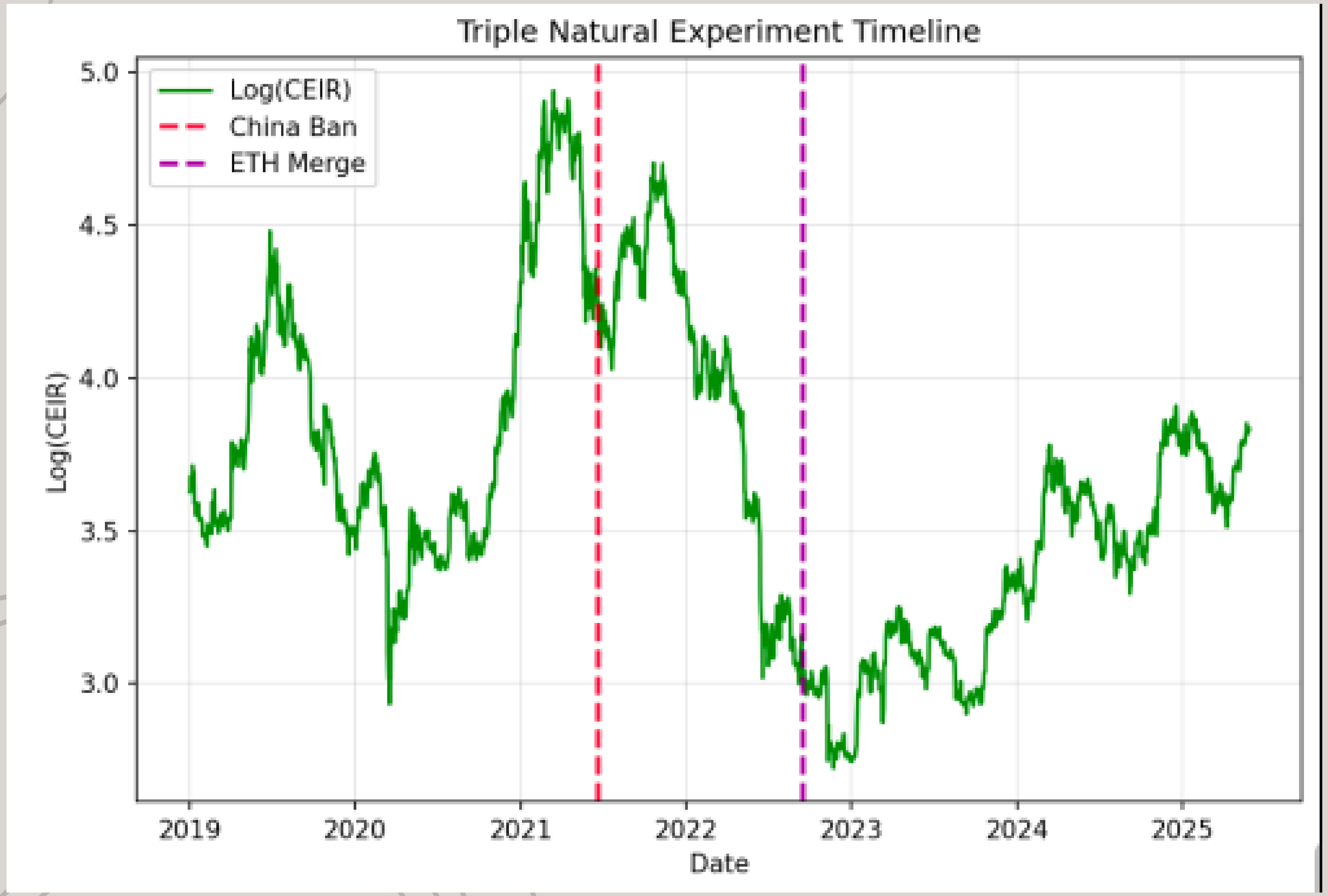
Variable	Ahmed (2022)	Feinstein & Werbach (2021)	Our Study
CEIR	Not tested	Not tested	**✓ Novel contribution**
Google Trends	**"Robust"**	-	**✓ Include**
VIX/EPU	**"Robust"**	-	**✓ Include**
Regulation	Not tested	"Null across 17 events"	**✗ Exclude**
S&P500	**"Fragile"**	-	**✗ Exclude**
Gold	**"Fragile"**	-	**✗ Exclude**

Key Literature Finding:

"We find almost entirely null results... no systemic evidence that regulatory measures cause traders to flee" - Feinstein & Werbach (2021)

Our Contribution: Test production cost theory with cumulative measures + natural experiments

Data Architecture & Timeline



The timeline showing CEIR evolution with China Ban and ETH Merge markers

Data Construction Process:

We built CEIR from multiple validated sources:

- *Price Data: CoinGecko API (2,340 daily observations)*
- *Energy Consumption: Cambridge Centre estimates (40-175 TWh/year range)*
- *Mining Geography: Monthly country-level hash rate distribution*
- *Electricity Prices: Country-specific rates with pre/post ban adjustment for China*

Why Start in 2019?

The 2017-18 bubble saw Bitcoin crash from $20k to $4k, creating non-representative mining dynamics. By 2019, we observe a mature, competitive mining market.

Re-Introducing CEIR

Introducing CEIR (Cumulative Energy Investment Ratio)
Definition:

CEIR = Market Cap / Cumulative Energy Cost

Intuitive Interpretation:

- *CEIR = 40 means Bitcoin is worth 40x the total electricity ever consumed*
- *High CEIR → Bitcoin expensive relative to energy invested*
- *Low CEIR → Bitcoin cheap relative to energy invested*

Construction Steps:

1. *Calculate daily mining energy (TWh) from hash rate and efficiency*
2. *Weight electricity prices by country mining shares*
3. *Compute cumulative cost since 2018 baseline*
4. *Divide market cap by cumulative cost*

This cumulative approach captures the total "sunk" energy investment, unlike flow measures that only consider current costs

Note: *We implemented country-weighted electricity prices where data was available. For countries/periods with missing data, we used regional averages to ensure complete coverage.*

Econometric Strategy

Three Complementary Approaches

1. Predictive Regression:

$$\text{30-day Forward Returns} = \alpha + \beta \cdot \log(\text{CEIR}) + \gamma \cdot \text{Controls} + \varepsilon$$

Tests whether CEIR predicts future price movements

2. Structural Break Analysis:

The Chow test examines whether β changed at China ban:

- *Pre-ban: Estimate* β_1 *using 902 observations*
- *Post-ban: Estimate* β_2 *using 1,408 observations*
- *Test: Are* β_1 *and* β_2 *statistically different?*
- *Result:* $F = 22.954$ ($p < 0.0001$) *- massive evidence of change*

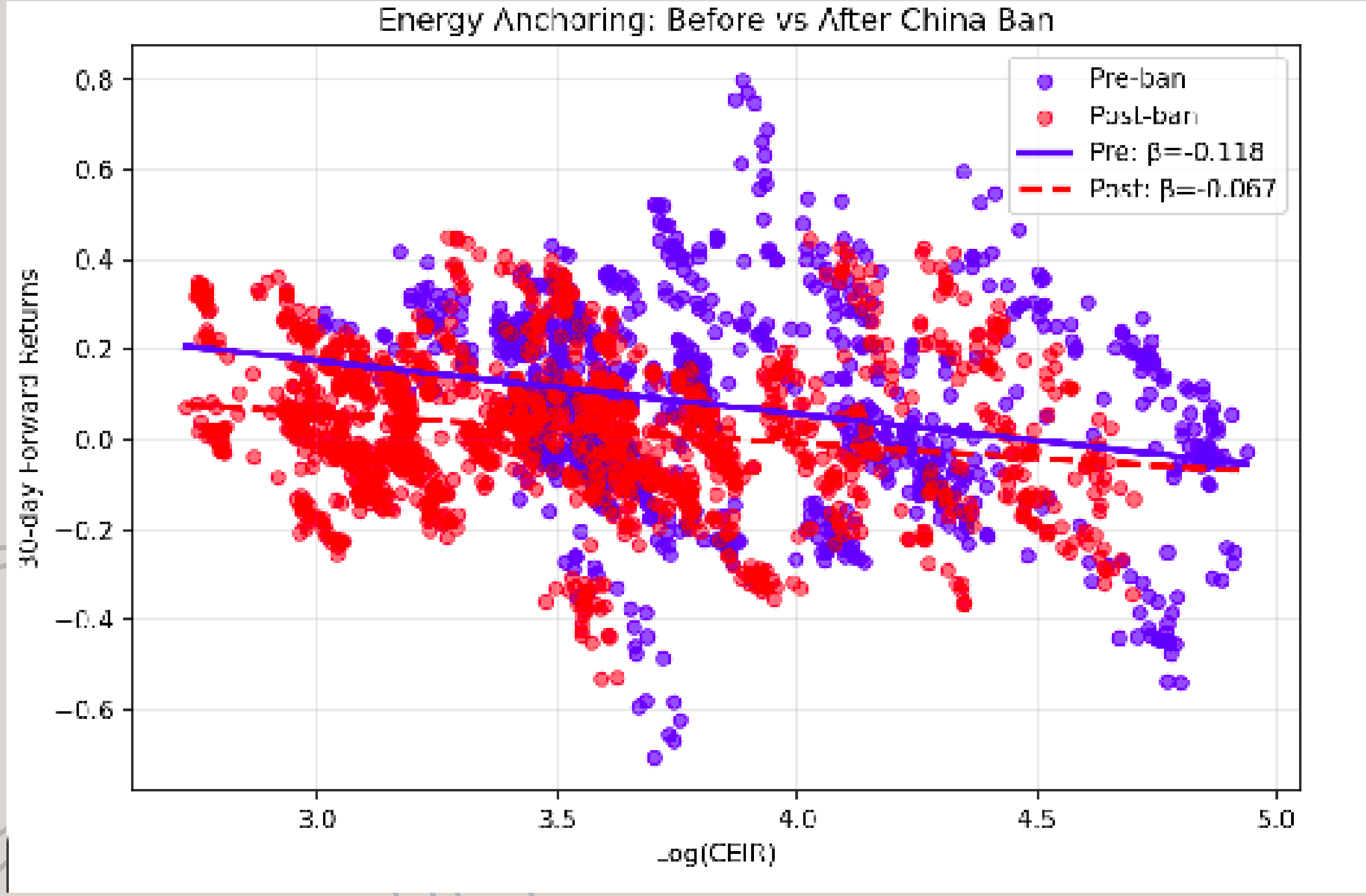
3. Difference-in-Differences Validation:

Using Ethereum's proof-of-stake transition:

$$\text{Volatility} = \alpha + \beta_1(\text{ETH}) + \beta_2(\text{Post}) + \beta_3(\text{ETH}\times\text{Post}) + \varepsilon$$

Treatment: ETH loses energy costs entirely
Control: BTC maintains energy costs
Outcome: Relative volatility change

Main Finding – The Structural Break



Pre-China Ban (2019-2021):

- CEIR coefficient: *-0.1312 (p = 0.043)*
- Interpretation: *1 SD decrease in CEIR → 6.0% higher returns*
- R^2 = *0.064 (meaningful for crypto)*

Post-China Ban (2021-2025):

- CEIR coefficient: *-0.0623 (p = 0.114)*
- Interpretation:
- *1 SD decrease in CEIR → 3.0% higher returns*
- R^2 = *0.039 (relationship weakened)*

The 52% decline in predictive power coincides precisely with the mining exodus from China

Scaling Effects & Robustness

The Relationship Holds Across Time Horizons

Horizon	Pre-Ban β	Post-Ban β	% Reduction
30 days	-0.131	-0.062	52%
60 days	-0.299	-0.149	50%
90 days	-0.440	-0.224	49%

Robustness Battery:

To address endogeneity concerns, we residualized CEIR by removing price momentum:

- Regress log(CEIR) on lagged returns (1, 7, 30 days)
- Use residuals in main specification
- Result: **β** = -0.142** (p = 0.028) pre-ban - even stronger!

Additional tests confirm robustness:

- Alternative samples (2020 start, 2021 only)
- Full control specifications (adds EPU, trading volume)
- Placebo break dates (no other significant breaks found)

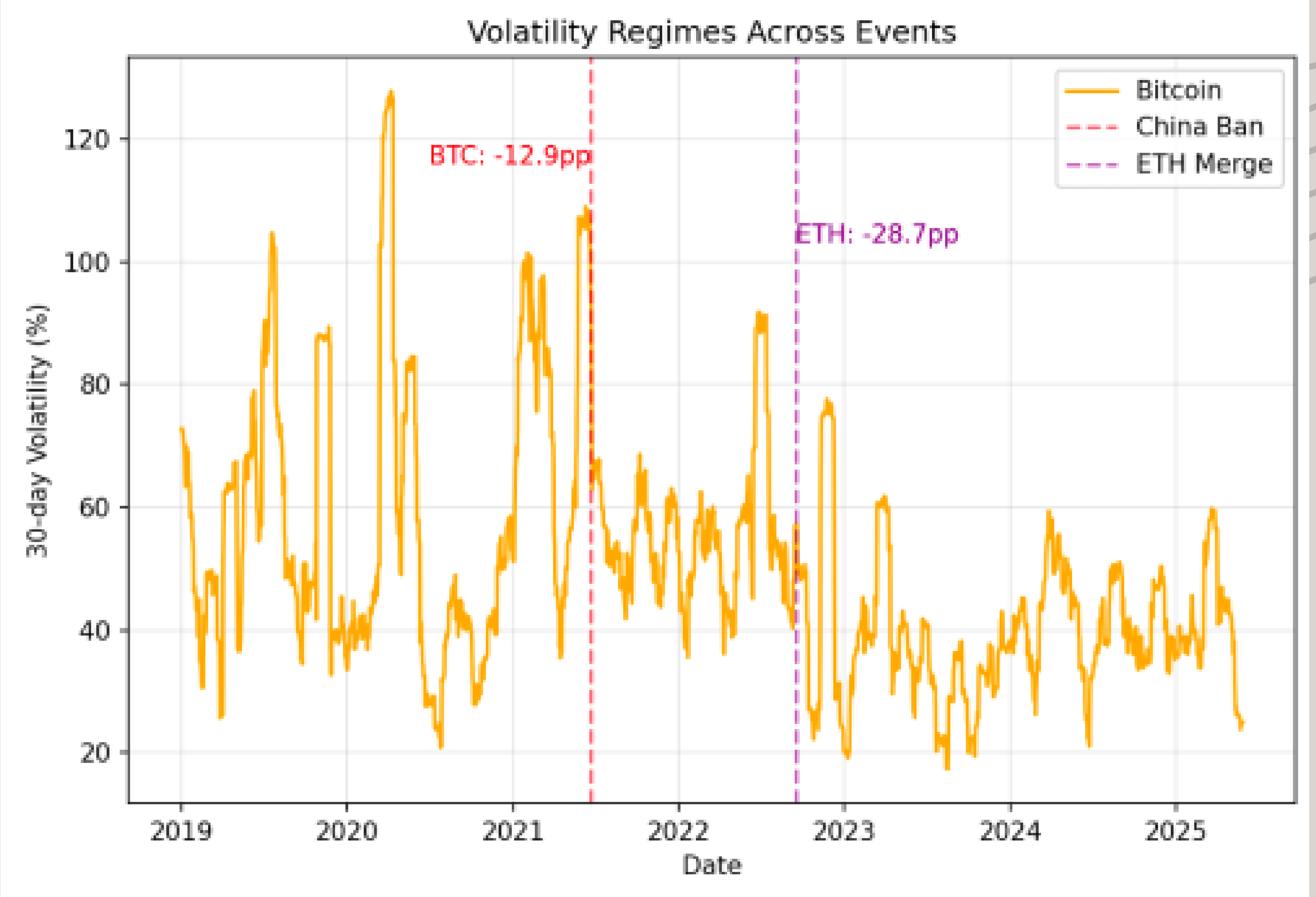
The Ethereum Natural Experiment

The Experiment: On September 15, 2022, Ethereum eliminated mining entirely:

- Energy use: 80 TWh/year → 0.01 TWh/year (-99.98%)
- No more production costs to anchor value
- Perfect counterfactual for our theory

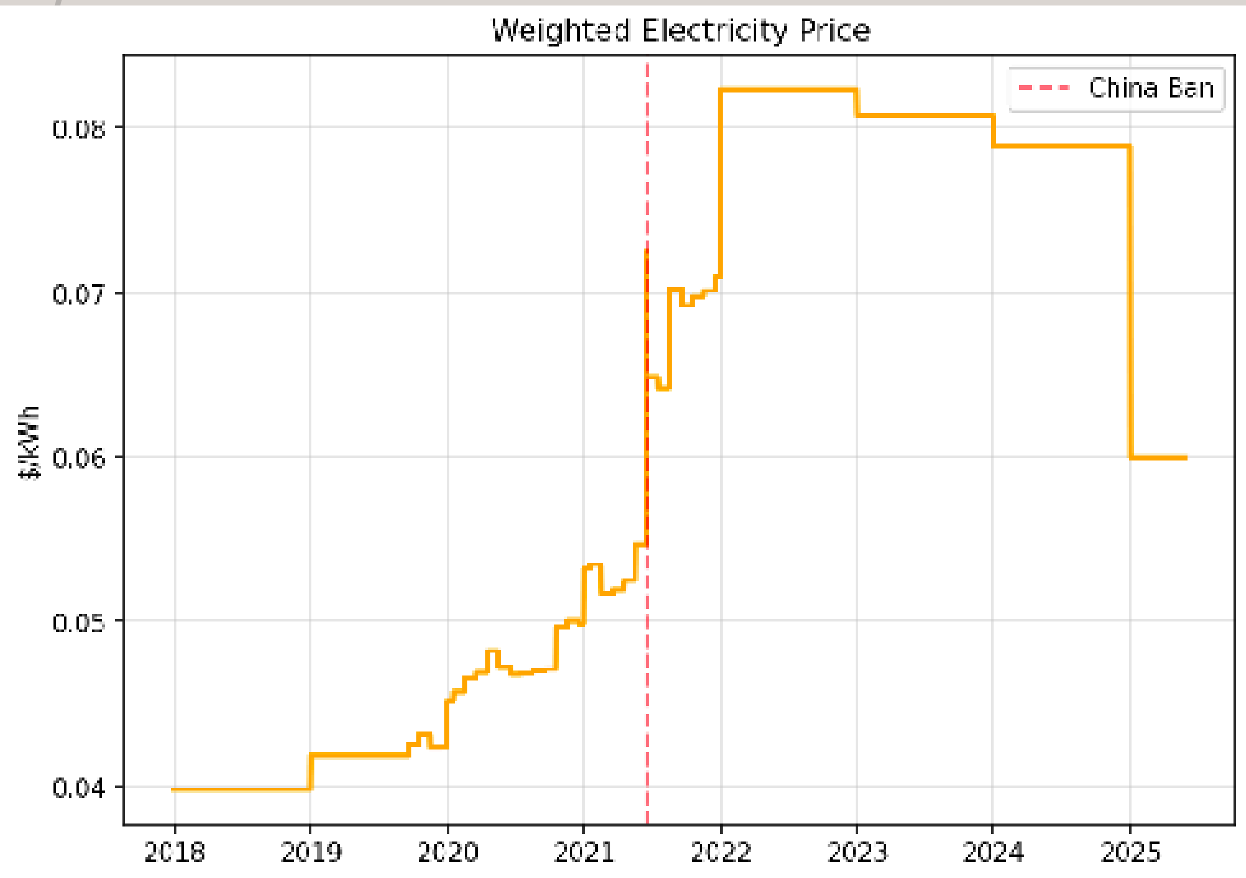
Difference-in-Differences Results:

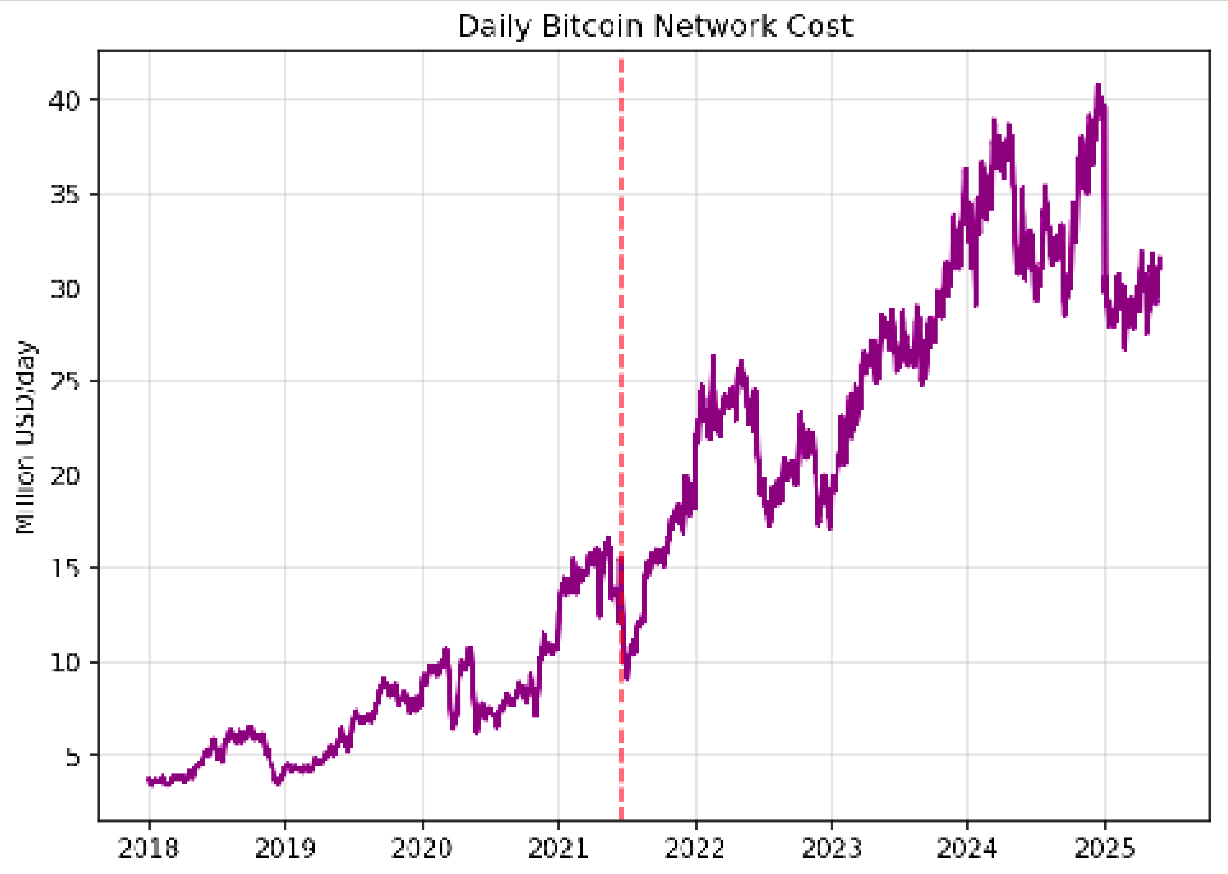
	Pre-Merge	Post-Merge	Change
Ethereum	94.4%	65.7%	-28.7pp
Bitcoin	63.1%	50.2%	-12.9pp
Differential			-15.8pp



Ethereum became 15.8 percentage points MORE volatile relative to Bitcoin after losing energy anchoring - exactly what our theory predicts.

Why Geography Matters





Concentrated Mining Era (Pre-Ban):

- 70% of hash rate in China
- Uniform electricity costs (~$0.05/kWh)
- Miners face similar economics
- Creates focal point for value

Dispersed Mining Era (Post-Ban):

- Hash rate across 10+ countries
- Varied costs ($0.03-0.12/kWh)
- No coordination point
- Anchor loses salience

The Behavioral Story:

Energy anchoring works through coordination. When miners share similar costs, the market can coordinate expectations around cumulative energy investment. Geographic dispersion breaks this coordination mechanism.

China: $0.05/kWh → Global: $0.03-0.12/kWh

Implications & Contributions

What This Means

For Academics:

- *First evidence of regime-dependent fundamental anchoring in crypto*
- *Cumulative costs matter more than flow costs*
- *Natural experiments can reveal hidden market mechanisms*

For Practitioners:

- *CEIR provided trading signals pre-2021 (buy when CEIR < MA - 1.5σ)*
- *Post-ban: Traditional indicators may work better*
- *Mining geography affects price formation*

For Policymakers:

- *Mining bans don't just redistribute hash rate*
- *They can fundamentally alter price formation mechanisms*
- *May increase market volatility*

Key Innovation:

We show that "fundamentals" in crypto aren't fixed - they depend on market structure

Conclusions & Next Steps

The Big Picture

What We Found: Energy creates a valuation anchor for Bitcoin, but only under specific conditions. The China mining ban revealed this by breaking the mechanism, while Ethereum's transition confirmed it by eliminating energy entirely.

Statistical Highlights:

- Structural break: $F = 22.954$ ($p < 0.0001$)
- Effect reduction: 52% post-China ban
- Ethereum differential: -15.8pp volatility

Where This Goes:

1. Immediate: Submit to Journal of Empirical Finance
2. Extensions: Test other PoW cryptocurrencies
3. Theory: Develop formal model of energy anchoring

Final Thought:"In searching for Bitcoin's fundamental value, we discovered something more interesting - fundamentals that appear and disappear with market structure"

References & Dataset

Core Literature:

Nakamoto, S. (2008). Bitcoin: A peer-to-peer electronic cash system. White paper.Hayes, A. (2017). Cryptocurrency value formation: An empirical study leading to a cost of production model for valuing bitcoin. Telematics and Informatics, 34(7), 1308-1321.Kapengut, E., & Mizrach, B. (2023). An event study of the Ethereum transition to proof-of-stake. Commodities, 2(2), 96-110.Liu, B., Prodromou, T., Suardi, S., & Xu, C. (2025). Ethereum's Merge: Market liquidity, efficiency and volatility in the proof of stake era. Finance Research Letters, 61, 104985.Borri, N., Shakhnov, K., & Veronesi, P. (2023). On the robust drivers of cryptocurrency liquidity: the case of Bitcoin. Financial Innovation, 9(1), 1-31.

Theoretical Foundations:

Fama, E. F. (1970). Efficient capital markets: A review of theory and empirical work. Journal of Finance, 25(2), 383-417.Schilling, L., & Uhlig, H. (2019). Some simple bitcoin economics. Journal of Monetary Economics, 106, 16-26.

Energy & Environmental Studies:

Krause, M. J., & Tolaymat, T. (2018). Quantification of energy and carbon costs for mining cryptocurrencies. Resources, Conservation & Recycling, 137, 232-243.Guidi, G., Dominici, F., Steinsultz, N. et al. (2025). The environmental burden of the United States' bitcoin mining boom. Nature Communications, 16, 2970.

Market Behavior:

Cheah, E. T., & Fry, J. (2015). Speculative bubbles in Bitcoin markets? Economics Letters, 130, 32-36.

Dataset

https://docs.google.com/spreadsheets/d/1Xpn2Vf63RcA2jg9T7si92Kw94mdb21t5qZCVpmPUqq8/edit?usp=sharing