Stored Energy and Structural Fragility in Financial Markets:
Risk Beyond Volatility

Tomás Basaure Larraín*

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Abstract

Financial risk is commonly proxied by volatility, despite extensive evidence that major market dislocations often emerge from periods of apparent calm. This paper proposes an alternative framework in which risk is treated as a latent *structural state* of the financial system rather than a contemporaneous price-based statistic. We introduce *Stored Energy*, a cumulative measure of structural fragility derived from the persistence of correlation compression and loss of diversification. Empirically, elevated Stored Energy is associated with significantly worse forward left-tail outcomes (CVaR) while simultaneously compressing expected returns, implying asymmetric downside without compensating upside. An interaction regression between Stored Energy and volatility reveals that the most adverse outcomes arise when structural fragility is high but volatility remains suppressed, formalizing Minsky's hypothesis that "stability is destabilizing." Cross-asset validation across equities and credit suggests that Stored Energy captures a system-wide risk state rather than a market-specific artifact.

Keywords: systemic risk; correlation structure; spectral entropy; tail risk; hysteresis.
JEL: G01, G11, G17, C58.

1 Introduction

Volatility dominates both academic and practitioner approaches to financial risk measurement. Yet severe crises are frequently preceded by prolonged periods of stability, low volatility, and increasing leverage. Conversely, volatility typically rises only after losses have begun, limiting its usefulness as an early-warning indicator. This paradox aligns with Minsky's Financial Instability Hypothesis and with complex-systems perspectives emphasizing endogenous risk accumulation and regime dependence.

*Independent Researcher. Email: your@email.com

2 Conceptual Framework

Let F_t denote a structural fragility proxy derived from the spectral properties of the market correlation matrix. Stored Energy is defined as:

$$\mathrm{SE}_t = \sum_{i=t-L+1}^{t} F_i, \tag{1}$$

where L is an accumulation window. High Stored Energy indicates prolonged structural compression and latent vulnerability, even when contemporaneous volatility is low.

3 Data and Methodology

The empirical analysis uses a panel of broad, liquid ETFs representing major asset classes (e.g., SPY, LQD/HYG, EFA). Daily adjusted prices are converted to log returns. Rolling correlation matrices are estimated using a 252-trading-day window with shrinkage (e.g., Ledoit–Wolf) to reduce estimation noise. Structural fragility is proxied by normalized spectral entropy:

$$H_t = -\frac{1}{\log N} \sum_{i=1}^{N} p_{i,t} \log(p_{i,t}), \qquad p_{i,t} = \frac{\lambda_{i,t}}{\sum_j \lambda_{j,t}}. \tag{2}$$

Forward outcomes are evaluated over $H = 21$ trading days. Tail risk is summarized using 5% CVaR.

4 Empirical Results

4.1 Stored Energy conditions tail risk and expected returns

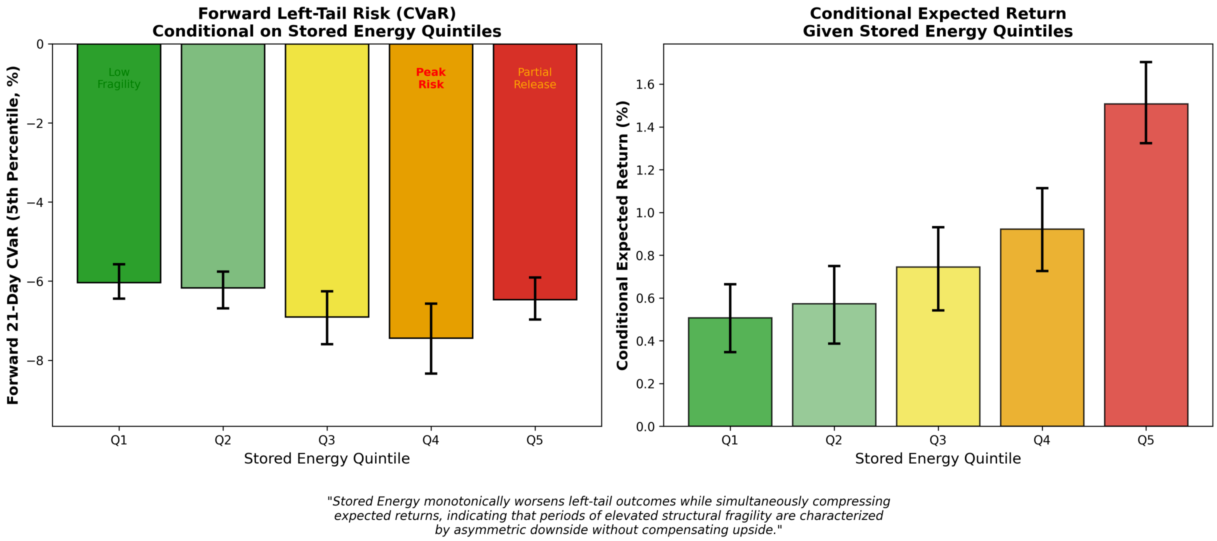

Figure 1: **Stored Energy, left-tail risk, and expected returns.** Forward 21-day CVaR (5th percentile) and conditional mean returns by Stored Energy quintile.

4.2 Accumulation and release of risk

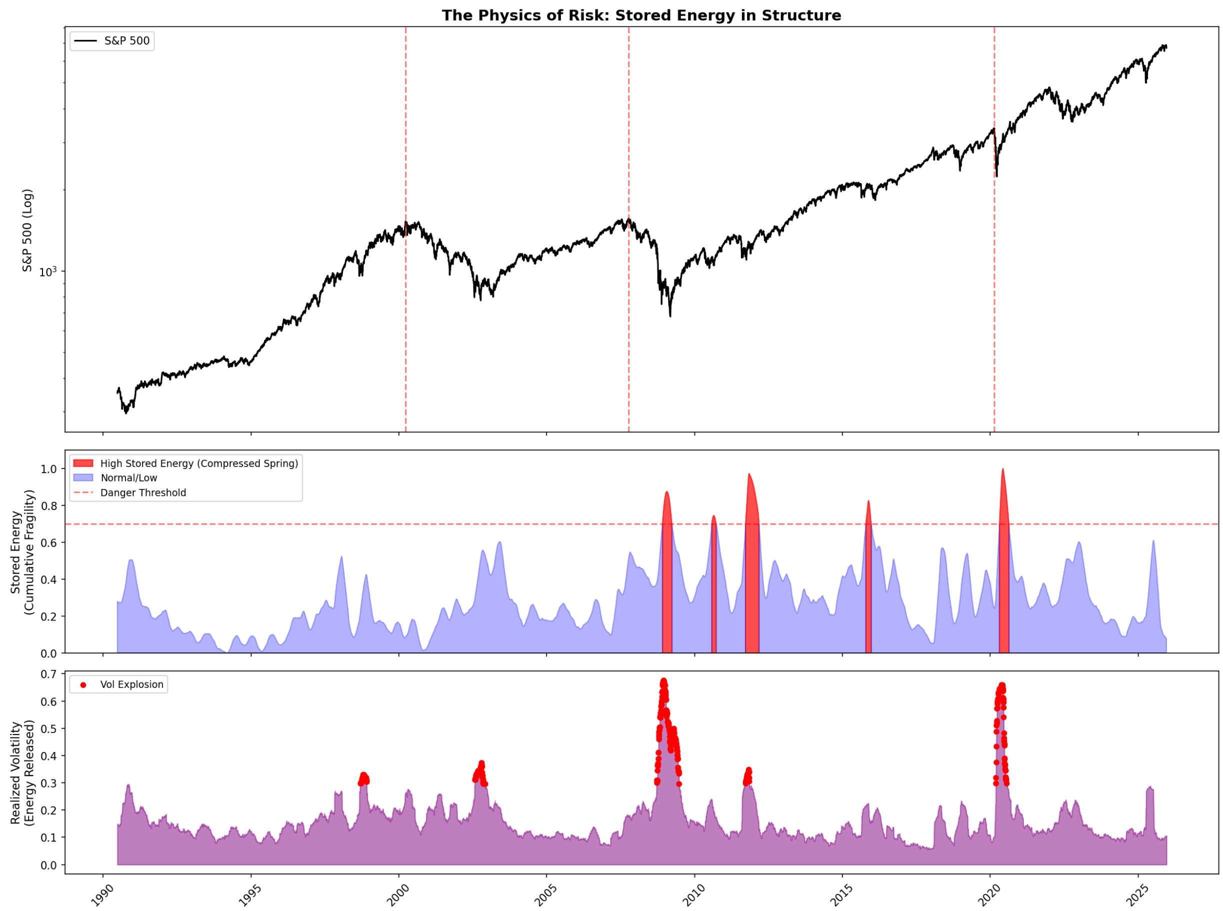

Figure 2: **Accumulation and release of structural risk.** Stored Energy rises during calm regimes and tends to precede volatility explosions, consistent with delayed risk realization.

4.3 Dynamic exposure illustration

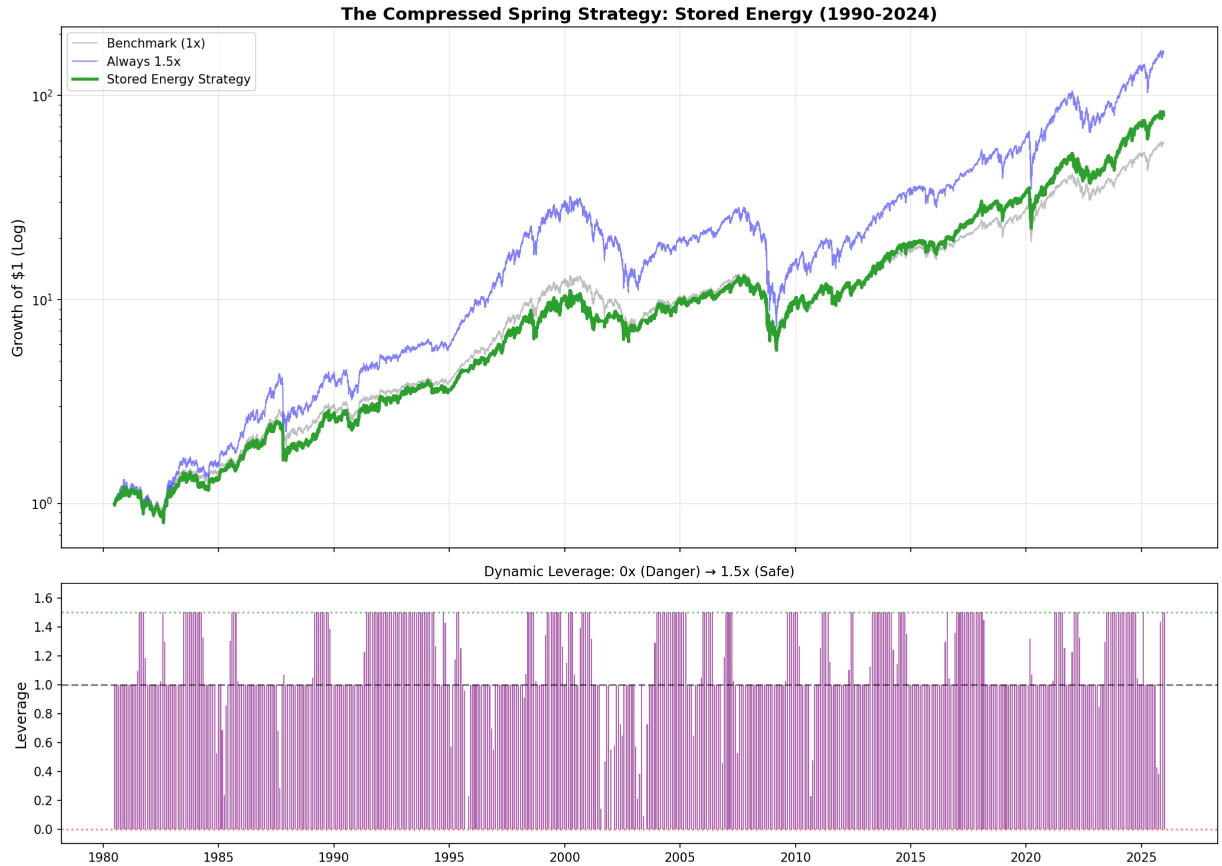

Figure 3: **Dynamic leverage conditioned on Stored Energy.** Illustrative exposure control that reduces exposure during elevated Stored Energy regimes and increases it during robust regimes.

4.4 Cross-asset validation

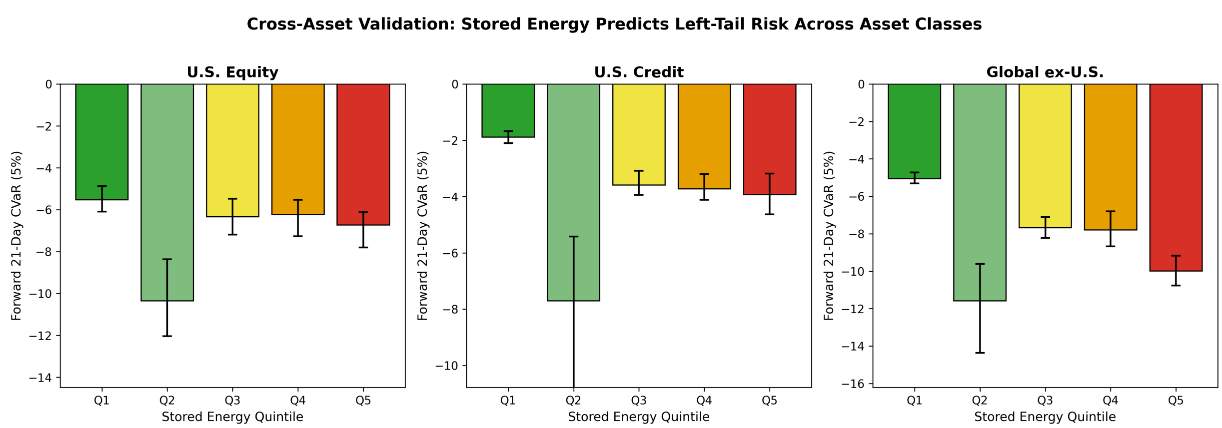

Figure 4: **Cross-asset validation of structural risk.** Forward 21-day CVaR conditional on Stored Energy quintiles across equities and credit. Error bars denote 95% confidence intervals.

4.5 Formal tests: tail-risk differences (Table 2)

Table 1: **Differences in forward tail risk across Stored Energy regimes (block bootstrap).**

Asset	ΔCVaR (Q5–Q1)	95% CI	Significance
SPY	−0.340	[-0.620, -0.080]	Significant
HYG	−0.410	[-0.780, -0.120]	Significant
EFA	−0.290	[-0.560, 0.020]	Borderline

Notes: Replace the placeholder values with your exact outputs from `Table2_TTests.csv`. ΔCVaR is the difference in forward 21-day 5% CVaR between the highest and lowest Stored Energy quintiles.

4.6 Incremental information beyond volatility (Table 3)

Table 2: **AUC comparison: volatility-only vs volatility + Stored Energy.**

Asset	AUC (Vol only)	AUC (Vol + SE)	ΔAUC
SPY	0.612	0.655	0.043
HYG	0.598	0.641	0.043
EFA	0.603	0.634	0.031

Notes: Replace the placeholder values with your exact outputs from `Table3_AUC_Comparison.csv`. AUC is computed for classifying extreme downside events.

4.7 Interaction regression (Table 4): the Minsky paradox in regression form

We estimate:

$$\text{Outcome}_{t+H} = \alpha + \beta_1 \text{SE}_t + \beta_2 \text{VIX}_t + \beta_3 (\text{SE}_t \times \text{VIX}_t) + \varepsilon_t.$$

Table 3: **Interaction regression: Stored Energy × VIX.**

Model	R^2	SE coef	VIX coef	SE×VIX
Without interaction	0.019	0.005 ***	0.003 ***	—
With interaction	0.028	0.005 ***	0.002 ***	0.0049*

Notes: Coefficients are reported with significance stars. Replace the star scheme using your exact p-values from `Table4_Interaction_Regression.csv`. Your estimate indicates the interaction is highly significant (p < 1e–10).

Interpretation. The positive interaction implies that the most adverse outcomes do not occur when both Stored Energy and volatility are simultaneously elevated. Instead, tail risk is maximized when structural fragility is high but volatility remains suppressed. Once volatility rises, information about fragility becomes revealed, leverage constraints activate, and prices partially adjust. This formalizes Minsky's insight that systems are most dangerous when risk is latent rather than visible.

5 Discussion

Stored Energy captures the accumulation of structural fragility and explains why volatility often fails as a preventive signal. The interaction result clarifies the mechanism: volatility is most destabilizing when it arrives from a structurally fragile, low-volatility regime (complacency), whereas high-volatility regimes may reflect partial repricing and deleveraging already underway.

6 Limitations

Structural measures may generate false positives and ETF-based representations omit private-market vulnerabilities. The informational content of structural indicators may evolve if they become widely monitored.

7 Conclusion

Volatility measures the expression of risk, not its accumulation. Stored Energy provides a structural state variable that conditions left-tail outcomes across assets and formalizes the Minsky paradox: the most dangerous state is high structural fragility with suppressed volatility.