Structural Admissibility of Asset Price Trajectories: A Theoretical Price-Only Effective Action Framework

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Abstract

Modern financial markets exhibit regime shifts, instability, and path-dependent behavior that challenge prediction-centric modeling approaches. While extensive literature exists on forecasting and stochastic diffusion, comparatively little attention has been given to formal criteria for determining when observed price dynamics remain structurally admissible under evolving conditions. This paper introduces a theoretical price-only effective action framework for diagnosing the structural admissibility of asset price trajectories. Formulated entirely in discrete time using observable price series, the framework decomposes price dynamics into three orthogonal integrity dimensions: Material (geometric coherence), Energetic (volatility stability), and Temporal (directional persistence). These dimensions act as phenomenological constraint fields that condition admissible trajectories without generating or predicting price movements. An "effective action" is defined as the cumulative aggregation of integrity-conditioned contributions along a realized price path. High action values correspond to structural incoherence and repeated constraint violations, while low action values indicate compatibility with recent market structure. We propose a dissipation-conditioned energetic term with a scale-matching attenuation constant, estimated through stability criteria rather than performance optimization. The framework is presented not as a predictive tool, but as a structural diagnostic for "disciplined abstention"—identifying when market conditions preclude structural coherence. We conclude by outlining a set of falsifiable hypotheses to guide future empirical validation.

1 Introduction

Modern financial markets are characterized by complex dynamics, regime shifts, and intermittent instability that challenge traditional modeling approaches. While a wide range of statistical, equilibrium-based, and behavioral frameworks have been developed to describe asset price behavior, many remain fundamentally oriented toward *prediction* rather than *admissibility* of action. This emphasis creates structural blind spots during

1

periods of regime transition and market dislocation—precisely when disciplined decision-making is most critical. This perspective aligns with prior observations that market behavior is adaptive and non-stationary, though existing frameworks remain primarily predictive in orientation (Lo, 2004).

1.1 Motivation

Prediction-centric models fail under regime shifts. A substantial portion of financial modeling focuses on predicting future price movements or expected returns. While such models may perform adequately within stable regimes, they tend to degrade sharply during structural breakdowns. Empirically, large drawdowns often occur not due to incorrect forecasts *within* a regime, but due to continued participation during periods when the regime itself has become incoherent. This suggests a gap in the literature: markets require clear criteria for determining when prediction itself is no longer actionable.

Risk governance and abstention are under-theorized. While risk management is widely studied, *abstention*—the decision not to act—is typically treated as a byproduct of position sizing rather than an explicit outcome of a formal framework. Yet, empirically, disciplined abstention during unstable regimes is a dominant contributor to capital preservation. There exists no widely accepted formalism for determining when abstention is structurally warranted based solely on price dynamics.

1.2 Contribution

This paper proposes a theoretical alternative. Rather than forecasting prices, we introduce a *price-only effective action framework*, defined as a discrete-time functional on observed price paths. The framework makes four primary contributions:

1. **A Price-Only Effective Action Formulation:** We introduce a phenomenological Lagrangian defined exclusively on observable price dynamics, requiring no volume, order flow, or fundamental inputs.

2. **Decomposition into Three Integrity Dimensions:** The action is decomposed into conceptually distinct components:

   - *Material Integrity:* Structural coherence of price geometry.
   - *Energetic Integrity:* Availability and stability of usable volatility.
   - *Temporal Integrity:* Directional coherence and persistence across time.

3. **Admissibility over Optimality:** Rather than seeking optimal trajectories, the framework defines *admissible* behavior—price paths that remain consistent with prevailing structural constraints. This naturally yields periods of "inadmissibility" (abstention) without requiring predictive accuracy.

4. **Falsifiable Theoretical Basis:** We propose a set of hypotheses and protocols for future empirical validation, designed to test the framework's stability independent of any trading application.

1.3 Postulate and Scope

The central postulate of this work is that market behavior imposes evolving constraints on admissible trajectories, and that these constraints can be inferred empirically from price alone. The framework operates in discrete time and is agnostic to asset class. The objective is structural assessment: evaluating the compatibility of a price path with its recent statistical context.

2 Background and Related Work

This section situates the proposed framework within existing financial, statistical, and physical modeling traditions. Rather than providing an exhaustive survey, we highlight key conceptual approaches relevant to the formulation of a price-based effective action.

2.1 Classical Asset Pricing Frameworks

Modern asset pricing theory is dominated by equilibrium-based and no-arbitrage frameworks. Canonical models describe asset prices as stochastic processes driven by information arrival, risk premia, and rational expectations. In continuous-time settings, prices are often modeled as diffusions, with returns approximated by Gaussian or conditionally heteroskedastic processes. However, they rely on assumptions that become fragile under empirical conditions commonly observed in real markets. In particular, many models presuppose stationarity or weakly time-varying parameters, well-defined equilibria, and continuous participation.

Empirical evidence suggests that these assumptions break down during periods of regime transition, volatility clustering, and structural dislocation. While extensions incorporating stochastic volatility, regime switching, or jump processes partially address these issues, they remain fundamentally predictive in orientation: the objective is still to forecast returns or distributions under assumed structural stability. The question of admissibility—whether a given market state supports disciplined action at all—is typically left implicit.

2.2 Econophysics and Information-Theoretic Approaches

A parallel literature, often grouped under the umbrella of econophysics, has explored the application of tools from statistical mechanics and information theory to financial markets. These approaches emphasize empirical regularities in price fluctuations and frequently model markets as complex interacting systems rather than equilibrated optimizers (Mantegna and Stanley, 2000; Bouchaud and Potters, 2003).

Information-theoretic formulations introduce quantities such as entropy, mutual information, and scaling exponents to characterize uncertainty, dispersion, and dependence in price dynamics (Cover and Thomas, 2006). Within this tradition, several works employ path-integral or action-like representations to describe ensembles of possible price

trajectories, drawing formal analogies to stochastic processes in physics (Bouchaud and Potters, 2003).

Importantly, these formulations are generally interpretive rather than normative. The action, where introduced, functions as a compact representation of statistical structure or likelihood over paths, not as a governing physical law or behavioral principle. As such, these approaches do not posit that markets minimize an action functional, nor do they impose variational optimality conditions on realized price paths.

Despite their empirical insights, econophysics models typically remain disconnected from evaluative or constraint-based frameworks. They focus on distributional properties of returns rather than on determining whether observed dynamics remain structurally compatible with their recent history. Consequently, they do not directly yield criteria for regime stability, abstention, or admissibility under evolving market conditions.

The present work builds on the descriptive strengths of this literature while departing from its objectives. Rather than encoding statistical regularities alone, we introduce an effective action formulation designed explicitly to evaluate structural compatibility and constraint satisfaction in realized price trajectories.

2.3 Non-Equilibrium and Constraint-Based Perspectives

Outside of finance, non-equilibrium systems are frequently analyzed using effective descriptions that emphasize constraints rather than optimality. In such systems, macroscopic behavior is shaped by evolving boundary conditions, dissipation, and structural limits, rather than by equilibrium solutions or global extrema. Effective action and effective potential formulations arise in this context as phenomenological tools: they aggregate complex micro-scale dynamics into tractable functionals defined on observable trajectories (Prigogine, 1977; Graham and Tél, 1984).

Crucially, these formulations do not require that the underlying system obey a variational principle in a literal sense. Instead, the action serves as an evaluative construct, encoding how compatibility, stability, or transport efficiency degrades as constraints are violated. Such approaches are common in the study of dissipative dynamical systems, where effective functionals are introduced to characterize admissible behavior even in the absence of equilibrium or conserved quantities (Graham and Tél, 1984; Lanczos, 1970).

These perspectives motivate a reframing of market analysis away from return prediction and toward constraint evaluation. Asset markets, like many non-equilibrium systems, exhibit path dependence, hysteresis, and regime-dependent behavior that resist equilibrium characterization. The framework introduced in this paper adopts this stance. Rather than importing physical laws into finance, it borrows the formal strategy of effective description: constructing empirically grounded functionals that evaluate coherence, stability, and constraint satisfaction directly from observed price dynamics (Prigogine, 1977).

In this sense, the effective action formulation proposed here is not a claim about market optimality or physical lawfulness. It is a diagnostic framework designed to assess whether realized price trajectories remain compatible with the structural constraints implied by their recent evolution.

3 Price Dynamics as a Constrained Process

This section formalizes the treatment of asset prices as constrained dynamical processes. The objective is not to generate price dynamics, but to evaluate whether observed or hypothetical price trajectories remain structurally compatible with recent market behavior.

3.1 Price as the Sole Observable

The framework is constructed exclusively from price data. Let P_t denote the observed asset price at discrete time t. We define the log-price process:

$$X_t = \log P_t \tag{1}$$

and the associated log-returns:

$$r_t = X_t - X_{t-1} \tag{2}$$

All quantities introduced in this paper are functions of $\{X_t\}$ or $\{r_t\}$ over finite rolling windows. No additional observables—such as volume, order flow, fundamentals, or exogenous signals—are employed. This ensures that all measures are universally observable across markets and asset classes, and that the formulation remains invariant to market microstructure differences.

3.2 Integrity as an External Field

We introduce the concept of integrity as an external conditioning field acting on price dynamics. Integrity characterizes structural properties that constrain which price trajectories remain admissible under prevailing conditions. We decompose integrity into three orthogonal dimensions:

Material Integrity (Structural Order): Quantifies the geometric and statistical coherence of price structure. It reflects the extent to which price evolution remains consistent with its recent spatial organization, including trend continuity and bounded excursions.

Energetic Integrity (Usable Volatility): Measures the availability and stability of volatility that can support meaningful price movement. It distinguishes between volatility that contributes to coherent evolution and volatility that is excessive, unstable, or self-canceling.

Temporal Integrity (Directional Coherence): Represents the persistence and alignment of directional movement across time. It reflects whether price evolution exhibits sustained directional coherence or is dominated by rapid reversals and noise.

Crucially, integrity does not prescribe actions, signals, or optimal behavior. It conditions the set of admissible trajectories; it does not generate dynamics.

3.3 Observer-Relative Integrity

Integrity measures are defined relative to an explicit reference frame. In this framework, the reference frame is provided by an **analytical observer** that evaluates structural properties of price trajectories. Please see the Figure 1 depiction below.

Crucially, the observer is not a market participant. It does not generate buy/sell decisions, impose objectives, or maximize utility. Instead, the observer functions as a *statistical reference baseline*—a set of rolling geometric and statistical properties against which the current price path is measured. The simplest observer is self-referential: integrity is evaluated relative to the asset's own recent price history. Within this reference frame:

- **Material Integrity** evaluates geometric compatibility relative to the reference structure.

- **Energetic Integrity** evaluates the stability of price excitation relative to reference variability.

- **Temporal Integrity** evaluates directional coherence relative to reference drift.

Figure 1: The Observer-Relative Evaluation Frame
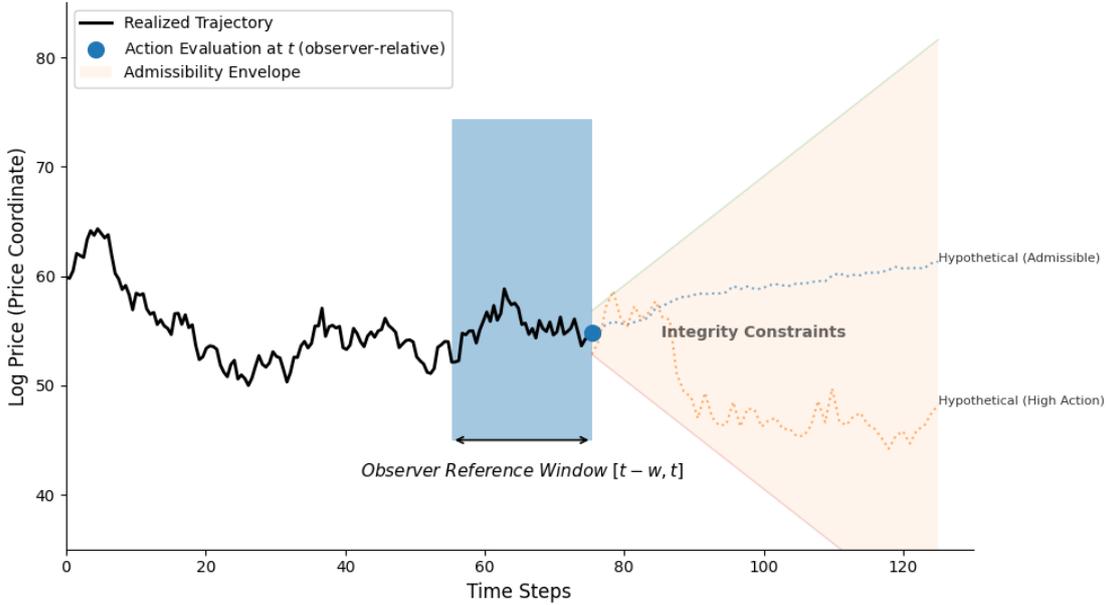
3.4 Admissible Observer Measurements

To evaluate integrity in a manner that is empirically testable, we restrict the observer to a class of admissible measurements. An admissible measurement must be computed exclusively from observable price series, be descriptive rather than prescriptive, and be capable of evaluation relative to appropriate null or surrogate models.

3.4.1 Material Integrity Measurements

Measurements focus on path structure rather than magnitude. Representative measurements include normalized path roughness (total variation normalized by range), multiscale structural consistency, and excursion topology (drawdown depths and recovery lengths). Material Integrity is expressed as the degree to which observed price geometry deviates from structurally uncorrelated alternatives (surrogates).

3.4.2 Energetic Integrity Measurements

Measurements are derived from realized price variability. Admissible measurements include price excitation (e.g., RMS log-returns), excitation stability (temporal variance of the excitation), and distributional entropy of normalized returns. These are combined through a dissipation-conditioned formulation described in Section 4.3.

3.4.3 Temporal Integrity Measurements

Measurements characterize directional coherence. Admissible measurements include run-length statistics relative to Markovian null models, scaling coherence (via detrended fluctuation analysis), and cross-scale directional consistency.

3.4.4 Aggregate Integrity Representation

Each integrity dimension yields a normalized score derived from its deviation relative to surrogate distributions. These scores are combined into an aggregate integrity measure through monotonic composition. Crucially, no fixed thresholds or action rules are introduced.

4 Effective Action Formulation

This section introduces an effective action formulation for asset price dynamics in discrete time. The effective action aggregates integrity-related contributions along an observed price path, producing a scalar measure of compatibility between realized dynamics and the constraints implied by recent market behavior.

4.1 Discrete-Time Market Lagrangian

We define a discrete-time phenomenological Lagrangian L_t evaluated at each time step t. This functional is not derived from physical conservation laws but is constructed to penalize structural incoherence. It is defined as:

$$L_t = \Phi_M(t) + \Phi_E(t) + \Phi_T(t) + C(t) - R(t) \tag{3}$$

Where:

- $\Phi_M(t)$ – **Material contribution:** Captures geometric coherence and structural order.

- $\Phi_E(t)$ – **Energetic contribution:** Captures the stability of usable volatility.

- $\Phi_T(t)$ – **Temporal contribution:** Captures directional coherence and persistence across time.

- $C(t)$ – **Constraint penalty:** A phenomenological term representing penalties for hard violations of admissibility conditions.

- $R(t)$ – **Regularization term:** Represents stabilizing contributions, ensuring the action remains bounded during normal regime recovery.

4.2 Action Over a Trajectory

Given a finite price trajectory observed over a time horizon $[t_0, t_1]$, we define the effective action as the cumulative sum of the Lagrangian along the trajectory:

$$A = \sum_{t=t_0}^{t_1} L_t \tag{4}$$

High action corresponds to trajectories exhibiting structural incoherence or instability. Low action corresponds to trajectories that remain compatible with recent structural, energetic, and directional conditions. No assumption is made that observed price paths minimize the action, nor that lower action implies preferred or optimal behavior. The action serves solely as a diagnostic measure of admissibility.

4.3 Dissipation-Conditioned Energetic Term

The energetic contribution $\Phi_E(t)$ is formulated to reflect how structurally compatible price variability is attenuated by market disorder. We propose the following ansatz for the energetic term:

$$\Phi_E(t) = E(t) \exp(-\gamma S(t)) \tag{5}$$

Where:

- $E(t)$ is **Price Excitation**, a measure of realized variability intensity (e.g., RMS log-returns).

- $S(t)$ is a measure of **Disorder**, derived from price dispersion or entropy.

- γ is a **Dissipation Slope** estimated empirically.

We utilize an exponential decay form to model the hypothesis that as disorder (S) increases, the "useful" portion of volatility (E) decays continuously rather than discontinuously. This form is chosen for its standard properties in attenuation modeling and its ability to be linearized for small $S(t)$.

Linearized Interpretation (Low-Disorder Limit)   For sufficiently small values of disorder $S(t)$, the dissipation-conditioned formulation admits a first-order Taylor approximation:

$$\Phi_E(t) \approx E(t)(1 - \gamma S(t)) = E(t) - \gamma E(t)S(t) \tag{6}$$

This linearized form reveals the structural logic of the term: it acts as a net volatility score, where the "gross" excitation $E(t)$ is penalized by a disorder-weighted drag term $\gamma E(t)S(t)$. This is formally analogous to effective capacity measures in information theory or free-energy decompositions (of the form $F = U - TS$), though no thermodynamic literalism is assumed.

5   Admissibility Criterion

5.1   Definition

A price trajectory over a finite horizon is said to be admissible if its associated effective action remains bounded and compatible with prevailing integrity constraints, without sustained divergence indicative of structural incoherence. This criterion is purely evaluative: it does not prescribe controls, does not assume agents, and does not require equilibrium structure.

Formally, the criterion is aligned with the general mathematical idea that a dynamical system evolving under constraints may or may not admit trajectories that remain inside a constraint set over time. In the control and dynamical-systems literature, this is studied under viability theory (existence of trajectories that remain in an admissible set) and forward invariance (conditions under which trajectories cannot leave a set once inside).

In this paper, the "constraint set" is not imposed exogenously; it is inferred empirically from price-only integrity structure (material, energetic, ethereal). The admissibility criterion therefore provides a structural test: whether observed dynamics remain consistent with the constraints implied by their own recent geometric and statistical organization.

5.2   Implications

Several implications follow directly from this definition:

Existence (or non-existence) of admissible trajectories.

Integrity constraints may eliminate admissible trajectories over a given horizon, indicating structural incompatibility rather than guidance or preference. This is consistent with the viability-theoretic perspective in constrained dynamical systems, where tightening constraints can collapse the viability kernel—the set of states from which evolution can remain admissible over time (Aubin et al., 2011). In the present framework, such collapse is inferred empirically from price-derived integrity measures rather than imposed a priori.

Bounded structural influence under constraint violation.

Because admissibility is conditioned on integrity compatibility, periods of instability or disorder naturally limit their own structural influence through sustained constraint violation. This mirrors forward-invariance interpretations in non-smooth and non-equilibrium dynamics, where the central question is not how a system evolves optimally, but whether trajectories can remain compatible with a constraint set once boundary violations occur (Filippov, 1988; Aubin et al., 2011). No external thresholds or corrective mechanisms are required.

Intrinsic explainability via decomposition.

The effective action provides a transparent decomposition of structural compatibility, as constraint failure can be localized to specific integrity contributions or penalty terms. This parallels explainability advantages in constraint-based system analysis, where incompatibility is attributable to explicit violations of admissibility conditions rather than to opaque predictive errors. In this sense, structural incoherence is diagnosed through observable breakdown modes rather than inferred latent causes.

6 Empirical Hypotheses and Experiment Design

The empirical analysis is structured around a set of testable hypotheses that assess the internal consistency, discriminative power, and stability of the effective action formulation.

6.1 Hypotheses

H1: Realized price paths exhibit lower effective action than randomized alternatives. For a given asset and time window, the effective action computed along the realized price trajectory is expected to be systematically lower than that computed along suitably randomized or surrogate trajectories. This tests whether observed price dynamics encode nontrivial structural constraints.

H2: Lower energetic integrity is associated with increased subsequent instability. Periods characterized by reduced energetic integrity are expected to be followed by higher realized instability. This evaluates whether the energetic component captures meaningful degradation in structural capacity without relying on directional prediction.

H3: The dissipation parameter γ is stable within regime classes. The dissipation slope γ is expected to exhibit relative stability within statistically similar regime classes, testing whether it reflects an intrinsic structural scaling property rather than an outcome-tuned parameter.

6.2 Experiment Design

The design emphasizes structural discrimination and stability. It relies on:

- **Price-only inputs:** Computed exclusively from historical price series.

- **Cross-asset evaluation:** Conducted across equities, cryptocurrencies, and indices.

- **Rolling-window analysis:** To capture regime dependence.

- **Observer-relative baselines:** Comparisons relative to self-referential rolling statistics.

- **Surrogate trajectory construction:** Randomized paths to serve as null models.

6.3 Gamma Measurement Protocol

The dissipation slope γ is estimated as a measurement problem, not an optimization task. It follows principles of scale matching (aligning energetic magnitude with attenuation), local stability assessment (evaluated over rolling windows), and cross-asset consistency checks.

7 Structural Observations and Analysis Framework

This section outlines the observable structural signatures implied by the effective action formulation. These signatures are not predictions of future behavior, but empirical patterns expected to arise when price trajectories evolve under integrity-based constraints.

7.1 Observable Action Signatures

- **Bounded action accumulation:** Periods of structural coherence correspond to smooth, slowly varying accumulation of effective action. In such regimes, marginal contributions remain bounded, indicating sustained compatibility between observed price dynamics and prevailing integrity constraints. This behavior is consistent with constrained-system interpretations in which trajectories remain within a viable region of state space (Aubin et al., 2011).

- **Action excursions:** Regime transitions manifest as sharp increases in marginal action. These excursions reflect transient incompatibilities as price dynamics depart from previously stable structural conditions. Importantly, such increases need not coincide with extreme price movements; they arise from constraint mismatch rather than magnitude alone.

- **Sustained high-action intervals:** Extended periods of elevated action indicate persistent structural incompatibility. From a constrained-dynamics perspective, this corresponds to trajectories evolving outside the viability kernel, where admissibility cannot be maintained without structural reorganization or constraint relaxation (Aubin et al., 2011).

- **Recovery-associated action decay:** Returns to structural coherence coincide with declining marginal action, reflecting re-entry into compatible regions of price behavior. This decay mirrors recovery dynamics in non-equilibrium systems, where dissipation and constraint realignment restore admissibility over time (Filippov, 1988).

7.2 Integrity-Specific Structural Failure Modes

Different integrity dimensions fail in distinct and empirically observable ways. These failure modes provide diagnostic clarity rather than categorical signals.

- **Material Integrity Failure:** Material failure is characterized by geometric breakdowns in price structure, including dispersion widening, destabilization of local extrema, or loss of spatial coherence. Such failures indicate erosion of the structural constraints that previously supported orderly evolution.

- **Energetic Integrity Failure:** Energetic failure manifests as attenuation of usable price excitation under rising disorder. Although raw variability may increase, the dissipation-conditioned formulation reveals a declining capacity for coherent evolution. This behavior is consistent with non-equilibrium systems in which disorder progressively suppresses effective transport or signal propagation (Filippov, 1988).

- **Temporal Integrity Failure:** Temporal failure appears as loss of directional persistence, frequent sign reversals, or incoherent oscillation across time scales. These patterns reflect breakdowns in constraint continuity rather than randomness per se.

7.3 Falsification Criteria

The framework is explicitly falsifiable. Evidence against the formulation includes:

- Effective action statistics indistinguishable from randomized or surrogate price paths

- Collapse of integrity measures into redundant or non-informative quantities

- Erratic or regime-inconsistent estimates of the dissipation slope γ

- Failure of integrity-conditioned action to distinguish coherent from incoherent structural regimes

These criteria align with falsification principles used in constrained dynamical systems, where the validity of an effective description is judged by its ability to delimit admissible behavior rather than to optimize outcomes (Aubin et al., 2011).

8 Discussion and Limitations

8.1 Interpretation and Scope

The effective action formulation provides a structural lens for evaluating asset price dynamics as constrained processes. It does not assert that markets minimize action, nor that observed price trajectories are optimal. The effective action is an evaluative construct, utilized to diagnose compatibility between realized dynamics and inferred constraints.

8.2 Limitations

- **Price-only observability:** Excludes volume and order flow, potentially limiting sensitivity to microstructural effects.

- **Non-generative nature:** Not suitable for simulation or forecasting in isolation.

- **Regime dependence:** Structural interpretation depends on the choice of temporal scale.

- **No normative interpretation:** Admissibility is a structural property, not a normative judgment.

8.3 Concluding Perspective

This work proposes a structural framework for interpreting asset price dynamics through the lens of constrained admissibility. Whether the effective action formulation captures meaningful structure in asset prices is ultimately an empirical question. The purpose of this paper is to pose that question precisely and to provide the analytical tools required to answer it. These hypotheses are empirically evaluated in the companion paper, *Empirical Validation of Structural Admissibility in Asset Price Trajectories* [**?**].

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