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DOES STOCK PRICE HAVE MEMORY? INSIGHTS FROM CHAOS THEORY

Exploring Market Efficiency and Chaos in Financial Markets

21 March 2024

WHAT WE'LL DISCUSS

- Understanding Complex Market Behaviors
- Advanced Financial Analysis Techniques:

  -- Hurst Exponents to assess market efficiency and memory

  -- Statistical tests to evaluate the randomness and efficiency of market movements
- Trading Strategies based on Hurst Exponents

  -- Persistence (trend following)

  -- Anti-persistence (mean-reversion)
- Critical Thinking in Finance

Introduction to Efficient Market Hypothesis

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- **EMH Defined**: Financial markets are efficient and reflect all available information.
- Suggests that price movements are essentially random and follow a "random walk," without predictable patterns or memory.
- **Implication**: Impossible to "beat the market" consistently on a risk-adjusted basis.
- **Criticisms:**
  - Market anomalies. Flash Crash
  - Psychological factor, herding behaviour affects market movement.
  - Insider trading
- Fama, E.F. (1970). "Efficient Capital Markets: A Review of Theory and Empirical Work." The Journal of Finance, 25(2), 383-417.

MARKET INEFFICIENCIES AND ANOMALIES

MARKET INEFFICIENCIES: NOT ALL MARKETS ARE PERFECT; SOMETIMES, PRICES DON'T REFLECT ALL AVAILABLE INFORMATION.

Example: "Consider the 'January Effect,' where stocks, especially small caps, tend to outperform at the beginning of the year. This suggests that investors can predict and potentially exploit this pattern, challenging the notion of market efficiency."

Behavioral Factors: Investor behavior, like overreaction or herd mentality, can create predictable price movements.

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Common Anomalies

MOMENTUM

Stocks that go up/down tend to keep going up/down in the short term.

MEAN REVERSION

Stocks with extreme movements tend to return to their average price.

CALENDAR EFFECTS

Stock patterns based on time, like higher returns in January.

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Market Inefficiencies and Anomalies

Photo generated by AI

- **Complex Systems**: Systems with many interconnected parts that behave unpredictably: **The whole is more than the sum of its parts**
  => Nonlinear Dynamic Relationships
- **Sensitivity to Initial Conditions**: Small changes can lead to vastly different outcomes, known as the butterfly effect.
- **Chaos Theory**: A subfield in math-physics, explores how subtle variations in a dynamic system's initial conditions can lead to significant and unpredictable changes in the system's future state.
- **Emergent Behaviour:**
- **Examples**: *weather, pendulum, brain/neural networks, Market*,...

Complex Systems, Chaos Theory

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MARKET AS A COMPLEX ADAPTIVE SYSTEM

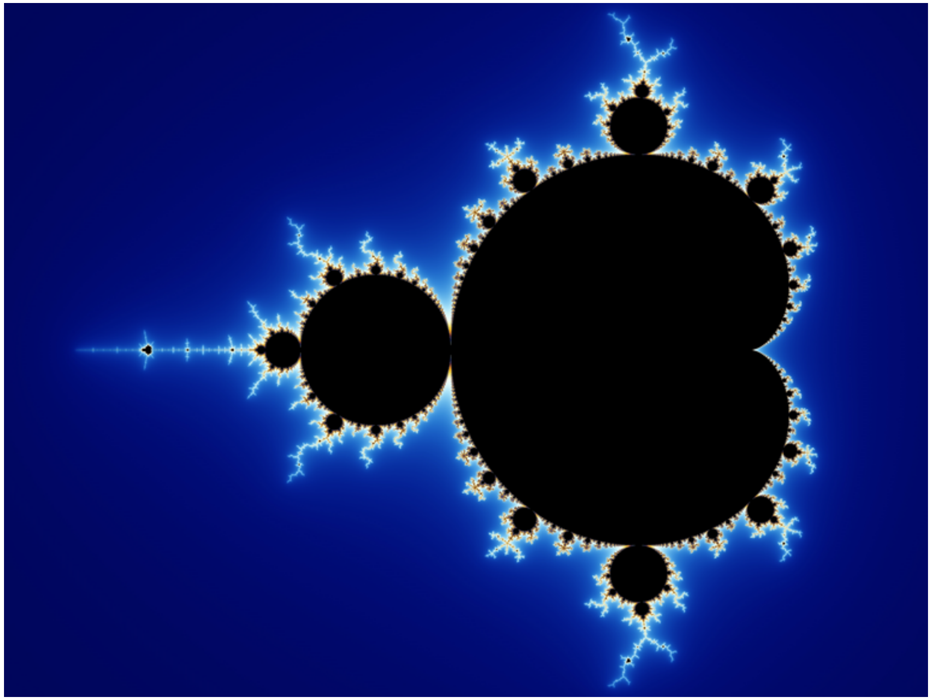
- **Adaptive Agents:** individual traders, institutions, and algorithms,... responding to new information and adjusting their strategies accordingly.
- **Feedback Loops**
- **Emergent Behaviour:** not predictable from individual elements alone
- **Adaptation and Evolution**: evolve over time, with strategies, regulations, and technologies continuously adapting, leading to an ever-changing landscape.

Early Pioneers

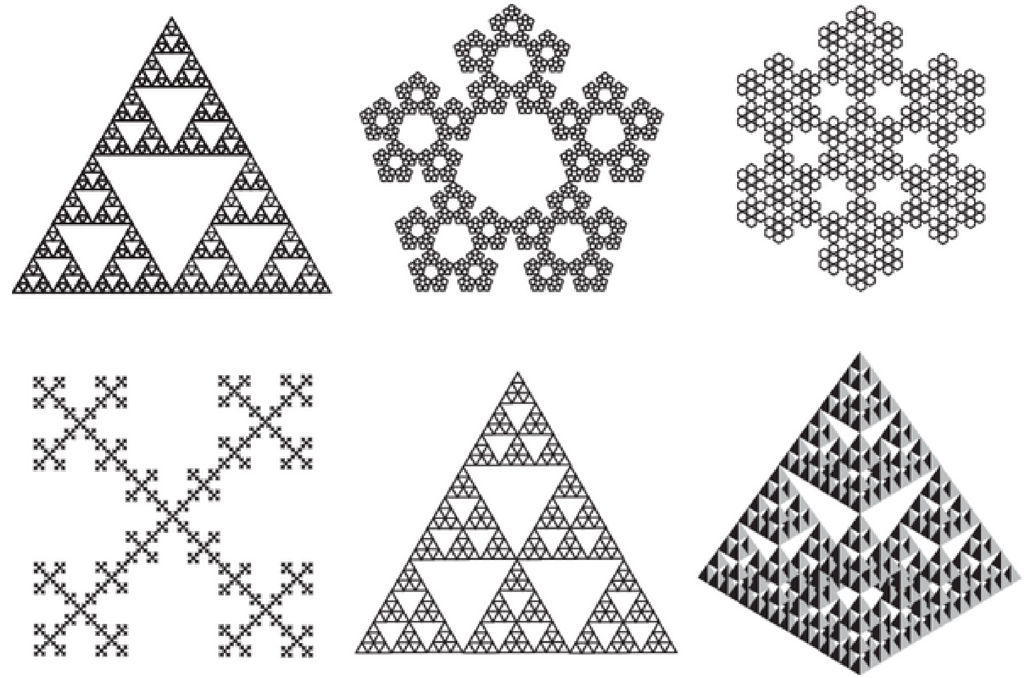
Norman Packard

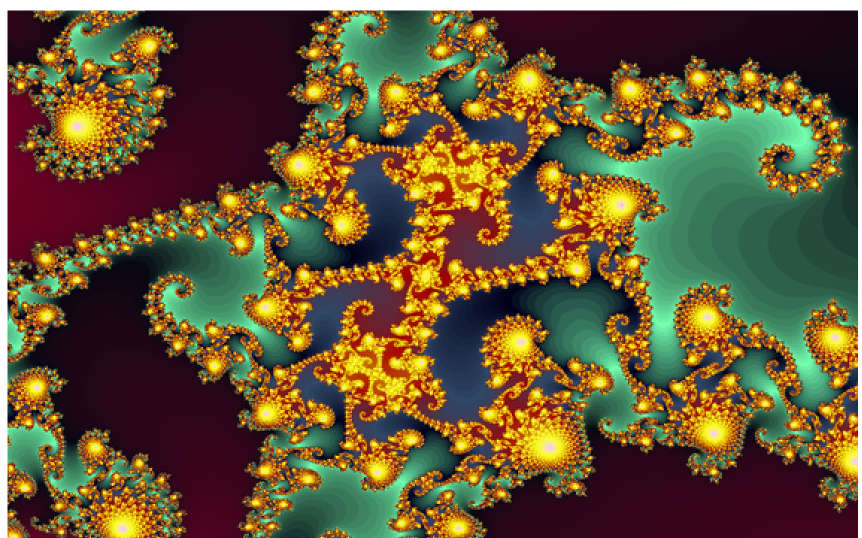
Doyne Farmer

- Renowned physicists who explored the boundaries of chaos theory and complex systems at Los Alamos and Santa Fe
- Founded the Prediction Company with a vision to decode market behavior through advanced mathematical models.
- Not just for academic fulfillment but to gain financial independence, aiming to become millionaires and fund their research without the constraints of traditional grant systems.
- achieved an impressive track record, consistently outperforming the market and managing over $1 billion in assets before being acquired by UBS in 2006.



Mandelbrot Set





FRACTAL MARKET HYPOTHESIS

Proposed by Mandelbrot -- a pioneer in fractal and chaos study

Markets exhibit fractal characteristics, meaning market movements are self-similar across different time scales.
This contradicts the linear models traditionally used in financial analysis (e.g. Capital Asset Pricing Model (CAPM))

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Challenge to EMH

FMH implies that understanding the fractal structure of markets could lead to better predictions of market movements, even if not with perfect accuracy.	Fractal Dimension: A statistical measure that quantifies the complexity of fractal patterns by describing how detail in a pattern changes with the scale at which it is measured.
Market analysis can't be confined to fixed timeframes or traditional geometric shapes.	Traders may use fractal-based tools like the Mandelbrot Set or Elliott Wave Theory to identify repeating patterns and potential trend reversals.

HURST EXPONENT: A KEY TO UNDERSTANDING MARKET MEMORY

A statistical measure used to identify the nature of a time series: detecting trends, mean reversion, or random walk behavior.

Values range from 0 to 1:

+ $H<0.5$ indicates mean reversion,
+ $H=0.5$ suggests a random walk,
+ $H>0.5$ points to a persistent trend.

- H.E. Hurst (1951): Originated the concept while analyzing the Nile River's flooding patterns to optimize dam storage capacities.
- Mandelbrot and Wallis (1969): Extended Hurst's work, establishing its relevance to fractals and financial markets, illustrating that market prices exhibit memory and long-term dependencies.
- Formula for Hurst Exponent:

$$H = \frac{\log_{10}(R/S)}{\log_{10}(n)}$$

- Where R/S is the rescaled range and n is the length of the time series.

1. **Calculate the Mean-Adjusted Series:**

   $$Y_t = X_t - \mu$$

   Where μ is the mean of the series.

2. **Create the Cumulative Deviate Series:**

   $$Z_t = \sum_{i=1}^{t} Y_i$$

3. **Calculate the Range (R) for Each Segment:**

   $$R(n) = \max(Z_{1:n}) - \min(Z_{1:n})$$

4. **Calculate the Standard Deviation (S) for Each Segment:**

   $$S(n) = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (X_i - \bar{X})^2}$$

5. **Compute the Rescaled Range (R/S):**

   $$R/S(n) = \frac{R(n)}{S(n)}$$

6. **Determine the Hurst Exponent (H):**
   - Plot $\log(R/S(n))$ against $\log(n)$ for various segment sizes n.
   - The slope of the line in this log-log plot, obtained through linear regression, is an estimate of the Hurst exponent H.

IMPLICATIONS IN FINANCIAL MARKETS

- Demonstrates that financial markets are not purely random and that past price changes can influence future price behavior.
- Provides insights into the market's tendency towards mean reversion or trending, aiding in the development of trading strategies.
- **Applications for Traders:** Traders can use the Hurst Exponent to assess the market's phase and adjust their strategies for trend following or mean-reversion.

FUTURE DIRECTIONS & Q&A

1. Predictability & Hurst Exponents:
    - Examine the link between Hurst exponents and market predictability using LSTM models.
2. Fractal Market Hypothesis Today:
    - Assess FMH's relevance amidst high-frequency trading and AI's influence on market volatility.
3. Real-Time Application & Market Impact:
    - Debate the practical use of the Hurst exponent in trading systems and its effects on market dynamics.

Open Questions:

- Is the Hurst exponent more effective for short-term trading or long-term strategies?
- How might widespread adoption of Hurst exponent analysis influence market efficiency and stability?

REFERENCES

- **Mandelbrot, B. B. (1983).** The Fractal Geometry of Nature. WH Freeman and Company. - A seminal work introducing fractals.
- **Hurst, H.E. (1951). "**Long-term storage capacity of reservoirs." Transactions of the American Society of Civil Engineers. - Introduces the Hurst exponent.
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