An Introduction to Chaotic Market
Stock Market Crash 1987 and The Application of Chaos Theory into Finance

- The assumptions on rationality, order and optimization appear to be inadequate to explain large market volatility, especially during the stock market crash in 1987.

- This has prompted the needs of using chaos theory and nonlinear dynamic models to explain some of the irrational stock price movements.
Complexity Theory

• A complex system can be explained by complexity theory. Chaos theory is one of the topics classified under complexity theory.


• In financial market, a well-defined and effective algorithms and heuristics approach can provide a fundamental empirical features of price dynamics in financial transactions, decompose global portfolio risks into a definable and controllable way and set future risks into a certain ranges.
Chaos Theory

• Chaos theory is a subset of nonlinear dynamics. Nonlinear dynamics refers to the concept that a certain system is governed by nonlinear parameters.

• Chaos theory arose when researchers discovered that a completely deterministic system can produce a time path nearly indistinguishable from a random time series. Even though the process is exactly governed by a set of deterministic equations, the time path may not be predictable.
The Lorenzian Waterwheel
– An Example of Chaotic System
What is Chaos Theory?

• A chaotic system is a typical deterministic of nonlinear systems.

• It is a time evolution with sensitive dependence on initial conditions.

• It rejects the concept of discontinuity. What appears to be discontinuity is not an abrupt break with the past but the logical consequence of preceding events.

• The significant of a chaos time series is that prediction accuracy falls off with the increasing passage of time.
Characteristic of nonlinear dynamic systems

• Long-term correlations and trends (feedback effects);

• Erratic (critical levels) markets under certain conditions and at certain times;

• A time series of returns that, at smaller increments of time, will still look the same and will have similar statistical characteristics (fractal structure);

• Less reliable forecasts, the further out in time we look (sensitive dependence on initial conditions).
Figure 1: Lorenz’s 1961 printouts
Figure 3: Bifurcation Diagram
What is Fractal?

(Mandelbrot, 1972; Gleick, 1987; Peters, 1994)

• A fractal is a shape made of parts similar to the whole in some way (self-similar feature).

• They may be different between each other but they have the same underlying pattern.

• For example, branches for a tree. Each branch and the following branches are different, but they have the same qualities similar to the structure of the whole tree.
Fractal Market Hypothesis (FMH) (Proposed by Peter, 1994)

- to explain the impact of liquidity and investment horizons on investors’ behavior.
- to give a model of investor behavior and market price movements that fits market observations.
Five assumptions for FMH

• When there are a lot of investors with different investment horizons, the market will be stable due to the large liquidity in the market.
• Information has a different impact on different investment horizons.
• The liquidity, determined by the balance between supply and demand, can affect the stability of a market. Many investors with many different investment horizons provide the market liquidity.
• Prices are made up of a combination of short-term technical trading and long-term fundamental valuation.
• If a security has no correlation with economic cycle, then there will be no long-term trend.
Local Randomness and Global Determinism (Peter, 1994)

- In the context of fractal at any particular of time, randomness and determinism, chaos and order coexist.
- E.g. the pine tree has global structure and local randomness.
- Stock market shows local randomness and global determinism. Each market cycle may have different characteristic but it has same global characteristics.
- Global characteristics are referred to each bull and bear market consists of rising and falling pries, during rising and falling business cycles. However, the causes or circumstances around each cycle are not the same – local randomness.
- In Malaysia, Ooi, Zamri and Ruhani (2002 & 3) showed that KLSE has long-term memory in returns (global determinism).
Butterfly Effect

• The “butterfly effect” first was described by Edward Lorenz in the early 1960s.
• The butterfly effect states that a butterfly flapping its wings in the Brazilian rain forest may spawn a hurricane in the Atlantic Ocean a few months later.
• The butterfly effect suggests that assuming away as insignificant any variable or interdependence of variables in a model could result in a model that may not resemble reality.
Noah Effect & Joseph Effect

• Mandelbrot (1968) points out two characteristics of stock price behavior, namely the “Noah effect” and “Joseph effect”.

• The “Noah effect”
  – the observed instances of large discontinuous jumps in stock prices, periods of tumultuous change.
  – It contradicts to the requirement of the normal probability distribution. He refers the problem as having “fat tails” or extreme tails in the normal distribution.

• The “Joseph effect”
  – the apparent tendency toward long-term trends and non-periodic cycles.
  – It challenges the validity of the independent and identically distributed (IID) assumption regarding the independence of error terms from the random walk model.
  – It also challenges the validity of the EMH.
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<th>Chaos Theory</th>
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<td>Chaotic systems are unpredictable over most time scales.</td>
<td>To explain the reason why even though the market is not efficient and investors are not acting in a rational manner, traders are still not able to outperform market consistently.</td>
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<td>Chaotic systems are feedback systems where outputs from a previous period are the inputs for the next period.</td>
<td>Market statistics, price and volume are factored into the decision-making process for the next day’s trading activity.</td>
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<td>The relationships between variables are nonlinear.</td>
<td>The relationship between cause and effect are not proportional (e.g. overreaction and under reaction).</td>
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<td>A chaotic system is sensitive to its initial conditions.</td>
<td>Same methodology but with different time series of data can produce different results and conclusions.</td>
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<td>Characteristic of chaotic system from the “Noah” and “Joseph” effects</td>
<td>Market can be in booms, crashes or periods of stability at any point of time.</td>
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<td>Small inputs can be compounded and have great influence over time.</td>
<td>The effect of small events, a single trade or investment strategy can be compounded and have large consequences over time.</td>
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<td>Prediction in chaotic system may be possible over the short run before the butterfly effect dominates the system.</td>
<td>To apply in option or future trading. Some technical analysis may be able to provide some predictive power over a short-term period.</td>
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<td><strong>A chaotic system shows leptokurtotic distribution</strong></td>
<td>The fatter tails imply that the probability of high volatility of stock prices is higher than a normal distribution.</td>
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<td>Fractal market hypothesis and coherent market hypothesis attempt to explain the behavior in a chaotic system.</td>
<td>These models may pose threat to the existing Efficient Market Hypothesis (EMH).</td>
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