Behavioural Finance

Lecture 04

Actual Finance Markets Behaviour

Recap

- Last week
  - Theoretical Development of Capital Assets Pricing Model
  - Distortion of *vN&M*'s Expected Utility Analysis
  - Why "Maximising Expected Return" is not rational
- This week
  - How the data destroyed CAPM

Overview

- CAPM assumes financial markets "efficient"
  - If so, prices follow a "random walk"
    - Deviations from trend follow Normal distribution
    - Change of huge change (+ or – 5 Standard deviations) vanishingly rare
  - Actual data shows huge changes extremely common
    - So markets not "efficient" in economists sense
      - Might still be "efficient" in common sense—fast trades, rapid assimilation of data
        - ***But key data might include what other traders do or believe***
        - **Feedback** causes extreme nonlinearities, booms and busts…

CAPM and Market "Efficiency"

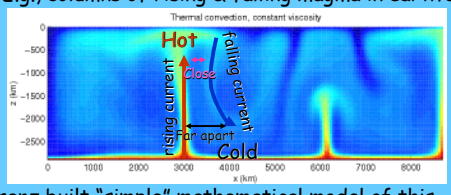
- CAPM became part of "Efficient Markets Hypothesis" (EMH)
  - Model in which prices set in equilibrium process
  - Explanation of why traders couldn't profit by exploiting mis-pricing in market
    - Share prices accurately reflect all available information
      - *No mis-pricing to exploit*
- Alternative view possible
  - Markets "chaotic"
    - Prices set in *disequilibrium* process
    - Information on mis-pricing exists
      - but (generally) too complicated to work it out…

Chaos or Efficiency?

- Systems with strong nonlinear feedbacks won't be "efficient" as economists use the word
  - meaning "values remain close to equilibrium"
- But will be impossible to predict
  - Similar to "traders can't exploit market mis-pricing" component of EMH
- Instead, nonlinear systems operate *far from equilibrium*
  - If stock market behaves this way, can be unpredictable even if prices far from equilibrium
    - "Mis-pricing" can exist
    - But be too difficult to exploit
  - An example… Lorenz's weather model

Lorenz's Butterfly

- Model of fluid flow caused by heat
- Convection in fluid
  - rising and falling columns of fluid
    - causing turbulence, storms
  - E.g., columns of rising & falling magma in earth's core



- Lorenz built "simple" mathematical model of this
  - Just 3 variables & 3 parameters…

Lorenz's Butterfly

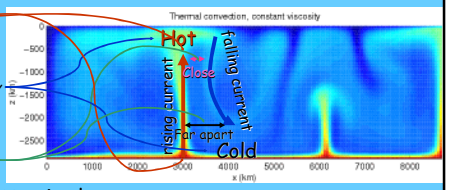
1. Intensity of convection (x)
2. Temperature gap between rising & falling current (y)
3. Deviation of Temperature profile from linear (z)

Rates of change:

$$\frac{dx}{dt} = a \times (y - x)$$

$$\frac{dy}{dt} = (b - z) \times x - y$$

$$\frac{dz}{dt} = x \times y - c \times z$$



- Looks pretty simple
  - Only 3 equations & 3 parameters
  - just a semi-quadratic (terms in x times y, etc.…)
- First step, work out equilibrium:

Lorenz's Butterfly

- To find equilibrium, set all 3 rates of change to zero:

$$\frac{dx}{dt} = a \times (y - x) = 0$$

$$\frac{dy}{dt} = (b - z) \times x - y = 0$$

$$\frac{dz}{dt} = x \times y - c \times z = 0$$

- Now solve for x, y, z values in each equation…
  1. 1st equation, **y=x** is solution
  2. Put x=y in 2nd equation:

$$(b - z) \times x - y = 0 \Rightarrow (b - z) \times y - y = 0$$

- Then solve: $(b - z) \times y = y \Rightarrow (b - z) = 1 \Rightarrow \quad z = b - 1$
- So z=(b-1). Now for 3rd equation $x \times y - c \times z = 0$
- Substitute x=y, z=(b-1) $y \times y - c \times (b - 1) = 0$

$$y^2 = c \times (b - 1)$$

  - Two solutions: $y = +\sqrt{c \times (b - 1)}; y = -\sqrt{c \times (b - 1)}$
- Same solutions for x: $x = \pm\sqrt{c \times (b - 1)}$
- ***AND*** x=y=z=0 also a solution:

Lorenz's Butterfly

- So there are ***3*** solutions:
  1. x=y=z=0

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

  2. z=b-1 combined with *positive* solution to $y^2 = c \times (b - 1)$

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} \sqrt{(b-1) \times c} \\ \sqrt{(b-1) \times c} \\ b - 1 \end{bmatrix}$$

- And
  3. z=b-1 combined with *negative* solution to $y^2 = c \times (b - 1)$

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} -\sqrt{(b-1) \times c} \\ -\sqrt{(b-1) \times c} \\ b - 1 \end{bmatrix}$$

- Bummer! Not one equilibrium but three!

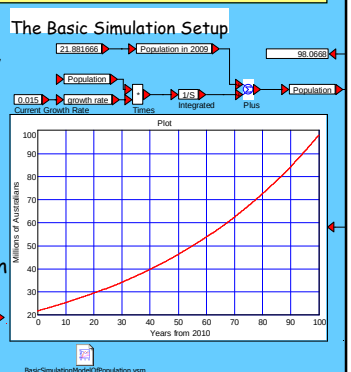
Lorenz's Butterfly

- How does system behave?
- Can show (with matrix mathematics) that
  - For some values of parameters
    - *All 3 equilibia are unstable!*
- So how to know how the system will behave?
  - Let's simulate it…
- Many programs exist to simulate dynamic models
  - More on these later, but the basic idea
    - Represent system as
      - Flowchart; or
      - Set of equations
    - Iterate from starting position
    - see what happens over time…

Lorenz_Any.vsm

Lorenz's Butterfly

- The basic idea is:
  - Take a variable (e.g., population)
  - Multiply its current value by its growth rate
  - Integrate this flow
    - "Add" the increments to population to current population
  - Add to initial population…
  - Estimate future population

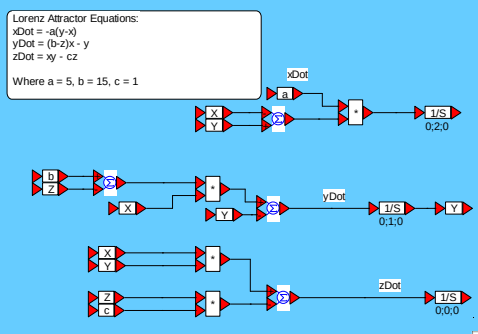


Free copy of Vissim for your use…

Vs.zip

Lorenz's Butterfly

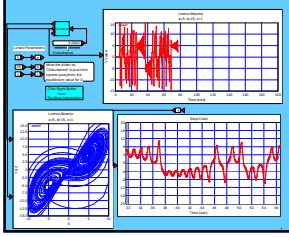
- Lorenz's model looks like this in Vissim:



- This is what happens when you simulate it:

Lorenz's Butterfly

- So the system is never in equilibrium; and
  - Follows complex cycles that are
    - Unpredictable
    - A-periodic (no set period as for sin, cosine etc.)
    - But have "hidden" structure behind the "chaos":
- Explains turbulent weather:



- Can it explain turbulent, unpredictable stock markets?

Stock Markets and Chaos?

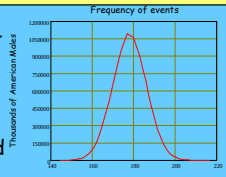
- Beniot Mandelbrot thought so…
  - (more on him and chaos soon…)
  - IF stock markets were "efficient" in CAPM sense
    - Prices "reflect all available information"
      - Accurately value future earnings of companies
        - (given what is known now)
  - THEN prices should follow "random walk with drift"
    - "Random walk" because of random arrival of news
      - News varies estimates of future earnings
    - "Drift" because prices tend upwards over time
  - Since news ("shocks" from non-economic systems) arrives at random, stock prices should move randomly
    - Basic pattern should be "Gaussian":

Random walking…

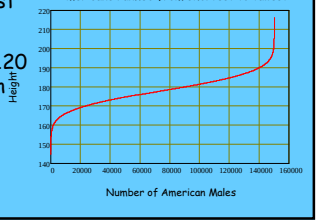
- "Gaussian" distributions result from random processes
  - Toss of a coin, roll of 2 dice, roulette wheel spin…
    - In the limit…
      - Do them often enough and…
    - Outcome will be fully described by
      - Average outcome
        - Toss ten coins, average 5 heads, 5 tails;
        - Roll of 2 dice, average 7
      - And standard deviation
        - 68% within +/- 1 standard deviations
        - 95% within +/- 2 standard deviations…

Random walking…

- E.g., height of American males…
  - Average 178cm
  - Standard deviation 8cm
  - Roughly 150 million of them
  - So height distribution should (& does) look like this:



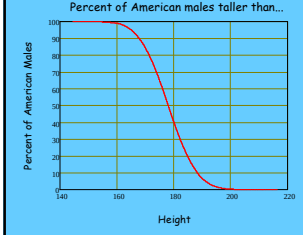
- Ranking them from shortest to tallest:

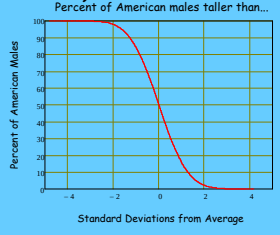


- Vast majority (more than 120 out of 150 million) between 170 & 190 cm tall

Random walking…

- Tiny insignificant fraction
  - Taller than 2 metres
    - (2.75 standard deviations above mean)
  - Shorter than 160cm
    - 2.25 standard deviations below)



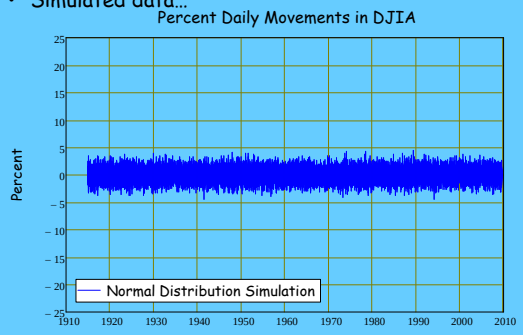


Random walking…

- If the stock market was following a random walk, then it would look the same:
  - Average daily movement
  - Standard deviation
    - 68% within +/- 1 standard deviations
    - 95% within +/- 2 standard deviations…
- Dow Jones from 1914-2009
  - Average daily movement 0.027%
  - Standard deviation 1.136%
  - 24,437 trading days (till August 15 2009)
- So the market "***should***" look like this…

Random walking…

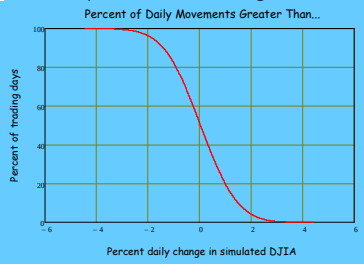
- Simulated data…



- When sorted from smallest to biggest, this looks like…

Random walking down Wall Street…

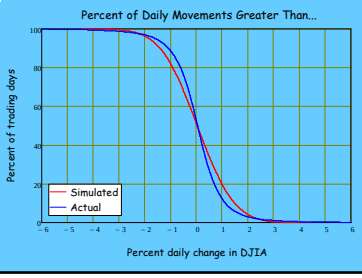
- Same pattern as for height of Americans…



- Does the actual data look like this?
  - At first glance, not too different…

An actual walk down Wall Street…

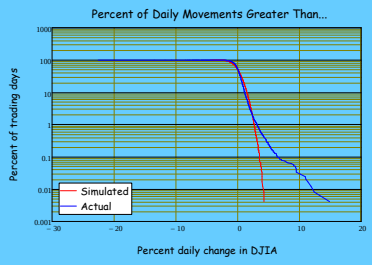
- Similar pattern it seems, but…
  - Many more events near average movement
  - "Tail" (large negative or positive movements) clearly longer



- How much longer?
- Let's look at same data
  - Without limits to horizontal axis
  - With log of percent scale

An actual walk down Wall Street…

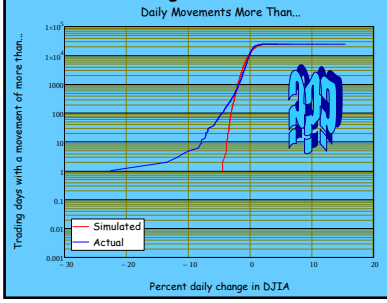
- Whoops…



- Actual data has daily movements as large as -22%;
- Many more positive events too—as large as +15%

An actual walk down Wall Street…

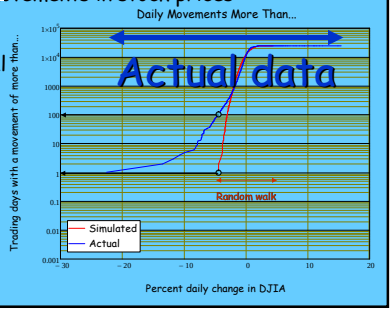
- Many more large negative movements than positive in actual data
- Let's re-rank data from smallest to biggest movement and see what we get…



- What's going on???
- Simulated data now looks ***nothing like*** actual data!
- What on earth does this mean???

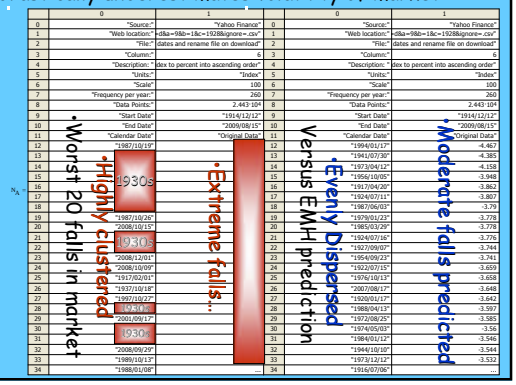
An actual walk down Wall Street…

- Both data series have the same number of points
  - 24,436 trading days from 1914-2009
  - "Random walk" simulation predicts much narrower range of daily movements in stock prices
- So "random walk" plot has to be shorter than actual data plot…
- Random model predicts only 1 movement of -4.46% or worse
- There were 100 days with 4.46% fall or more in actual data!



An actual walk down Wall Street…

- EMH drastically underestimates volatility of market:



Random or Fractal Walk Down Wall Street?…

- EMH/CAPM argued returns can't be predicted
  - Random walk/Martingale/Sub-martingale
  - Distribution of returns should be "Gaussian"
- Non-EMH theories (Fractal Markets, etc.) argue distribution should be non-random
  - Basic characteristics of fractal distributions
    - "Fat tails"—many more extreme events than random distribution
    - Extreme events of any magnitude possible vs vanishingly unlikely for random
  - Random: Odds of 5% fall of DJIA? *Less than 2 in a million*… (biggest fall in simulated data 4.467%)
    - How many years needed to see **one** 5% fall?

Random or Fractal Walk Down Wall Street?…

- Power law distribution very different to Gaussian:
  - Number of size X events ≈ X raised to some power

$$N(X) = X^{-\alpha} = \frac{1}{X^{\alpha}}$$

- **Result of statistical relation: a "straight line" between size of event and event frequency when graphed on log-log plot:**

$$\log\{N(X)\} = \log(X^{-\alpha}) = -\alpha \log(X)$$

  - **"Log of number of events of size X = -α times log(X)"**
  - **Rule applies to huge range of phenomena**
  - **Does it apply to stock market?**

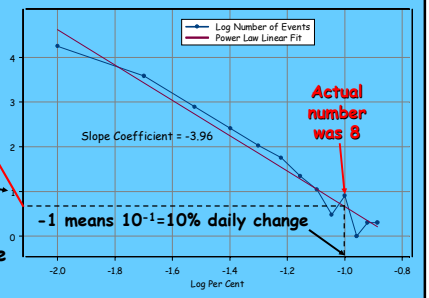
Random or Fractal Walk Down Wall Street?…

- Power law fit Dow Jones:

$$\log\{N(X)\} = -3.96 \cdot \log(X)$$

$$N(X) = X^{-3.96}$$

Power Law Plot Log Number Events versus Per Cent Daily Change



Power law predicts 6 10% daily movements per century

1 means 10^{1}=10 events per century

Actual number was 8

-1 means 10^{-1}=10% daily change

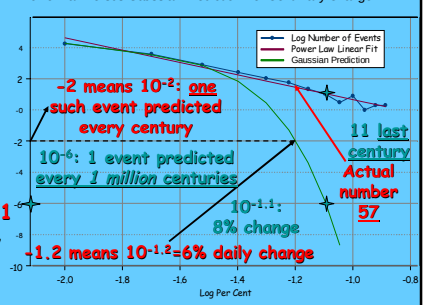
- **Does this tell us anything the EMH doesn't?**

Random or Fractal Walk Down Wall Street?…

- **"Random walk" prediction OK for small movements**
  - **+/-3% 780 reality v 718 random prob.**
- **Hopeless for large**
  - **+/-6%: 57 v 1**
  - **+/- 8%: 11 v 1 in a million chance per century!…**

- ***You betcha!***

Power Law versus Gaussian Prediction Per Cent Daily Change



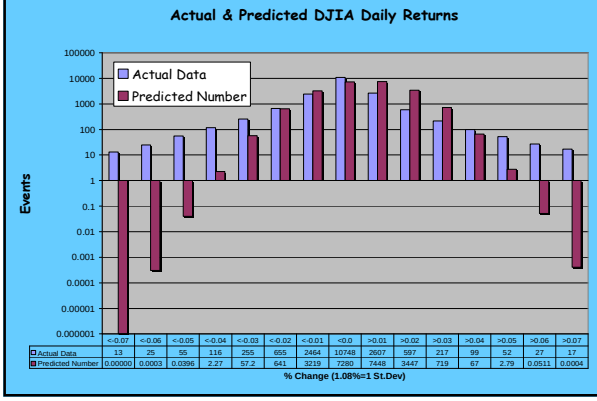
Random or Fractal Walk Down Wall Street?…

- Belief system is
  - in equilibrium
  - changes due to random shocks
- Results in prediction that huge events vanishingly rare
- Actual data manifestly different:

Magnitude +/-	Events	Gaussian	Ratio Actual/Random
1%	17813	18648	0.96
2%	3818	3447	1.11
3%	780	719	1.09
4%	257	67	3.83
5%	106	2.79	38
6%	57	0.0511	1,114
7%	22	0.000411	53,464
8%	11	0.00000144	7,613,560
9%	3	0.0000000022	1,363,030,944
10%	8	0.00000000000	Gaussian prediction is zero to 20+ decimal places
11%	1	0.00000000000	
12%	2	0.00000000000	
13%	2	0.00000000000	

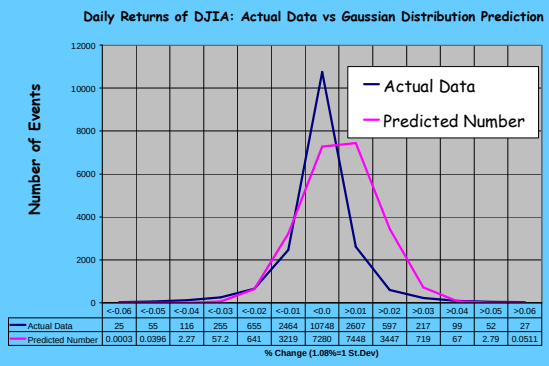
- Daily movements in stock exchange
  - Any size crash feasible
  - Likelihood far higher than predicted by random/equilibrium model
  - ***"Crashes" not aberrations but normal behaviour***

Random or Fractal Walk Down Wall Street?…



	<-0.07	<-0.06	<-0.05	<-0.04	<-0.03	<-0.02	<-0.01	<0.0	>0.01	>0.02	>0.03	>0.04	>0.05	>0.06	>0.07
Actual Data	13	25	55	116	255	655	2464	10748	2607	597	217	99	52	27	17
Predicted Number	0.00000	0.0003	0.0396	2.27	57.2	641	3219	7280	7448	3447	719	67	2.79	0.0511	0.0004

Random or Fractal Walk Down Wall Street?…



	<-0.06	<-0.05	<-0.04	<-0.03	<-0.02	<-0.01	<0.0	>0.01	>0.02	>0.03	>0.04	>0.05	>0.06
Actual Data	25	55	116	255	655	2464	10748	2607	597	217	99	52	27
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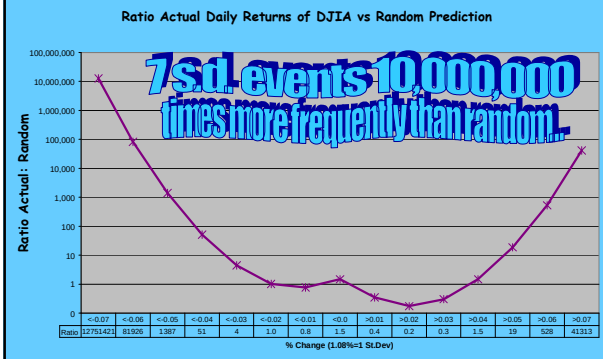
Random or Fractal Walk Down Wall Street?…



	<-0.07	<-0.06	<-0.05	<-0.04	<-0.03	<-0.02	<-0.01	<0.0	>0.01	>0.02	>0.03	>0.04	>0.05	>0.06	>0.07
Ratio	12751421	81926	1387	51	4	1.0	0.8	1.5	0.4	0.2	0.3	1.5	19	528	41313

Random or Fractal Walk Down Wall Street?…

- Data clearly not random
- More sophisticated analyses (future lecture) confirm this
  - Underlying process behind stock market therefore
    - Partly deterministic
    - Highly nonlinear
      - Interacting "Bulls" & "Bears"
      - Underlying economic-financial feedbacks
- Economics needs
  - a theory of endogenous money…
  - A theory of nonlinear, nonequilibrium finance…
  - Why do most economists still cling to the EMH?

CAPM: The original belief

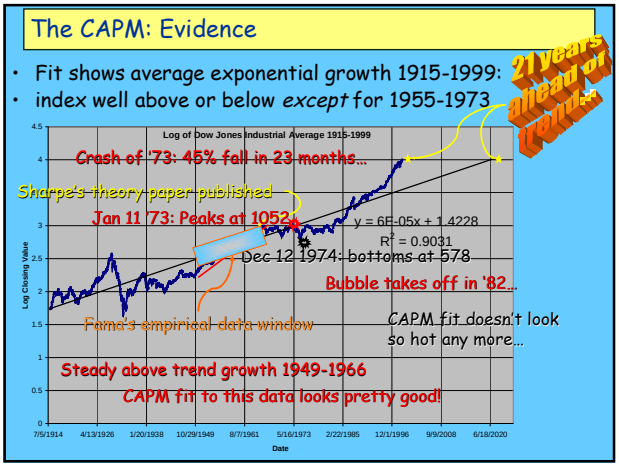
- CAPM fitted belief in equilibrium behaviour of finance markets, but required extreme assumptions of:
- "a common pure rate of interest, with all investors able to borrow or lend funds on equal terms. Second, we assume homogeneity of investor expectations: investors are assumed to agree on the prospects of various investments the expected values, standard deviations and correlation coefficients…
- Justified on basis of methodology and agreement with *theory*:
  - "Needless to say, these are highly restrictive and undoubtedly unrealistic assumptions. However, since the proper test of a theory is not the realism of its assumptions but the acceptability of its implications, and *since these assumptions imply equilibrium conditions which form a major part of classical financial* ***doctrine***, it is far from clear that this formulation should be rejected-especially in view of the dearth of alternative models leading to similar results." (Sharpe 1964: 433-434)
- Fama (1969) applied "the proper test" and hit paydirt…

Fama 1969: Data supports the theory

- "For the purposes of most investors the efficient markets model seems a good first (and second) approximation to reality. In short, the evidence in support of the efficient markets model is extensive, and (somewhat uniquely in economics) contradictory evidence is sparse." (Fama 1969: 436)
- Fama's paper reviewed analyses of stock market data up till 1966…
  - Table 1, 1957-66; Ball & Brown 1946-66; Jensen 1955-64;
  - Remember longer term look at the DJIA data?…

The CAPM: Evidence

- Fit shows average exponential growth 1915-1999:
- index well above or below *except* for 1955-1973



The Capital Assets Pricing Model

- Remember Sharpe's assumptions?:
  - *"a common pure rate of interest, with all investors able to borrow or lend funds on equal terms…*
  - *homogeneity of investor expectations: investors are assumed to agree on the prospects of various investments.*
- And his defence of them?
  - *"Needless to say, these are highly restrictive and undoubtedly unrealistic assumptions.* **However**, since **the proper test of a theory is not the realism of its assumptions but the acceptability of its implications…"**
- How valid is this defence?

The "Instrumental" Defence

- Appeal to Milton Friedman's "Methodology of Positive Economics":
  - "Realism" of assumptions irrelevant:
    - "the more significant the theory, the more unrealistic the assumptions… a hypothesis is important if it 'explains' much by little" (Friedman 1953: pp. 14-15)
- Sharpe invokes Friedman's "Instrumental" Defence:
  - OK to assume investors agree on future prospects of all shares, etc., even if not true…
    - So long as resulting model fits the data???
      - (See History of Economic Thought Methodology lecture), but in summary)
        - Instrumental defence false…

The "Instrumental" Defence

- Logical consistency of assumptions can be challenged, not just realism
  - "Proof by contradiction" also
    - can't assume "square root of 2 is rational";
    - likewise can't assume "all investors identical" to "aggregate"
  - Sciences ***do*** attempt to build theories which are essentially descriptions of reality
  - Musgrave (1981) argues Friedman's "significant theory, unrealistic assumptions" position invalid
    - Classifies assumptions into 3 classes
      - Negligibility assumptions
      - Domain Assumptions
      - Heuristic Assumptions

Within Economics: Instrumentalism

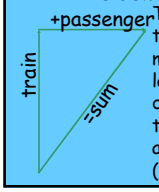
- Negligibility Assumptions
  - Assert that some factor is of little or no importance in a given situation
    - e.g., Galileo's experiment to prove that weight does not affect speed at which objects fall
      - dropped two different size lead balls from Leaning Tower of Pisa
      - "assumed" (correctly) air resistance "negligible" at that altitude for dense objects, therefore ignored air resistance
- Domain assumptions
  - Assert that theory is relevant if some assumed condition applies, irrelevant if condition does not apply

Within Economics: Instrumentalism

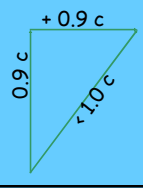
- e.g., Newton's theory of planetary motion "assumed" there was only one planet
  - if true, planet follows elliptical orbit around sun.
  - if false & planets relatively massive, motion unpredictable. Poincare (1899) showed
    - there was no formula to describe paths
    - paths were in fact "chaotic"
    - planets in multi-planet systems therefore collide
    - present planets evolved from collisions
    - "evolutionary" explanation for present-day
      - roughly elliptical orbits
      - absence of collisions between planets

Classes of assumptions

- Heuristic
  - assumption known to be false, but used as stepping stone to more valid theory
  - e.g., in developing theory of relativity, Einstein assumes that distance covered by person walking across a train carriage equals trigonometric sum of
    - forward movement of train
    - sideways movement of passenger



Then says: "We shall see later that this result … cannot be maintained; in other words, the law that we have just written down does not hold in reality. For the time being, however, we shall assume its correctness." (Einstein 1916)



Just where are markets efficient?

- The Efficient Markets Hypothesis: assume
  - All investors have identical *accurate* expectations of future
  - All investors have equal access to limitless credit
- Negligible, Domain or Heuristic assumptions?
- Negligible? No: if drop them, then according to Sharpe "*The theory is in a shambles*" (see last lecture)
- Heuristic? No, EMH was "end of the line" for Sharpe's logic: no subsequent theory developed which
  - replaced risk with uncertainty, or
  - took account of differing inaccurate assumptions, different access to credit, etc.
- Basis of eventual empirical failure of CAPM

The CAPM: Evidence

- Sharpe's qualms ignored & CAPM takes over economic theory of finance
- Initial evidence seemed to favour CAPM
  - Essential ideas:
    - Price of shares accurately reflects future earnings
      - With some error/volatility
    - Shares with higher returns more strongly correlated to economic cycle
      - Higher return necessarily paired with higher volatility
    - Investors simply chose risk/return trade-off that suited their preferences
  - Initial research found expected (positive) relation between return and degree of volatility
  - But were these results a fluke?

The CAPM: Evidence

- Sharpe's CAPM paper published 1964
- Initial CAPM empirical research on period 1950-1960's
  - As noted in last lecture
    - Dow Jones advance steadily from 1949-1965
      - July 19 1949 DJIA cracks 175
      - Feb 9 1966 DJIA sits on verge of 1000 (995.15)
        - 467% increase over 17 years
  - Continued for 2 years after Sharpe's paper
    - Then period of near stagnant stock prices
    - Fama's enthusiastic empirical paper on CAPM used data from 1950-1966:

The CAPM: Evidence According to Fama 1969

- Evidence supports the CAPM
  - "This paper reviews the theoretical and empirical literature on the efficient markets model… We shall conclude that, with but a few exceptions, the efficient markets model stands up well." (383)
- Assumptions unrealistic but that doesn't matter:
  - "the results of tests based on this assumption depend to some extent on its validity as well as on the efficiency of the market. But some such assumption is the unavoidable price one must pay to give the theory of efficient markets empirical content." (384)

The CAPM: Evidence According to Fama 1969

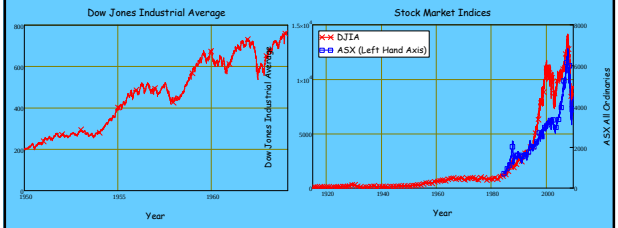
- CAPM good guide to market behaviour
  - "For the purposes of most investors the efficient markets model seems a good first (and second) approximation to reality." (416)
- Results conclusive
  - "In short, the evidence in support of the efficient markets model is extensive, and (somewhat uniquely in economics) contradictory evidence is sparse." (416)
- Just one anomaly admitted to
  - Large movements one day often followed by large movements the next—"volatility clustering"…

The CAPM: Evidence According to Fama 1969

- "one departure from the pure independence assumption of the random walk model has been noted …
- large daily price changes tend to be followed by large daily changes.
- The signs of the successor changes are apparently random, however, which indicates that the phenomenon represents a denial of the random walk model but not of the market efficiency hypothesis…
- But since the evidence indicates that the price changes on days following the initial large change are random in sign,
  - the initial large change at least represents an unbiased adjustment to the ultimate price effects of the information, and this is sufficient for the expected return efficient markets model." (396)

The CAPM: Evidence 50-66 and 1914-2009

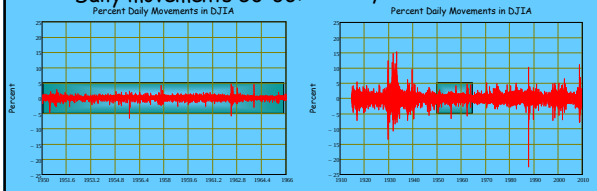
- But was this "evidence" just a fluke?
  - Result from considering too narrow a range of data?
  - Dow Jones 1950-1966:
  - Dow Jones 1914-2009:



- A rather different pattern!

The CAPM: Evidence 50-66 and 1914-2009

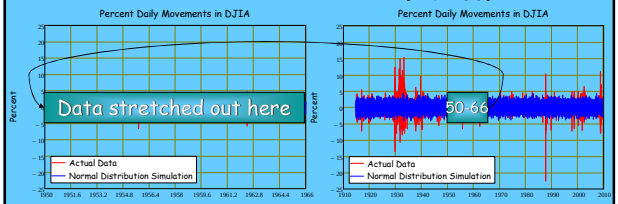
- What about volatility?
  - Daily movements 50-66:
  - Daily movements 14-09:



- 50-66 data much less volatile…

The CAPM: Evidence 50-66 and 1914-2009

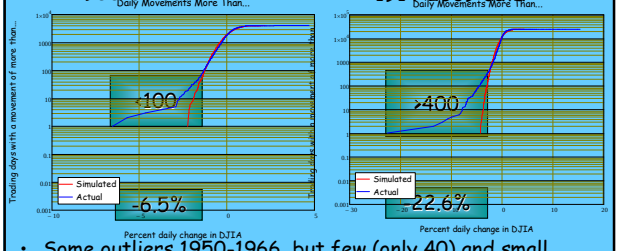
- Superimposing "EMH" simulated data to actual
  - 1950-66
  - 1914-2009



- Fit looks OK for 50-66
  - Only a few "anomalies"—near 5 standard deviations
    - Can be filtered out as "outliers"
- Not so for 14-09 data—terrible fit by random model
  - Far too many "+5 sigma" events

The CAPM: Evidence 50-66 and 1914-2009

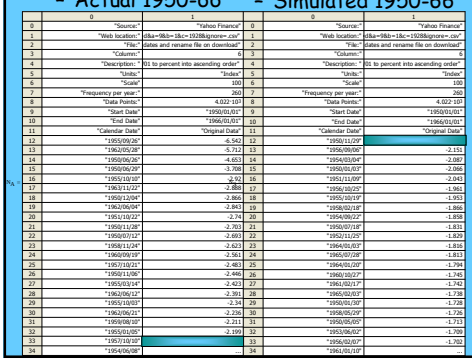
- Daily movement indicator looks OK for 50-66 too:
  - 1950-66 data:
  - 1914-2009 data:



- Some outliers 1950-1966, but few (only 40) and small (less than 6% daily movements)
- 400 outliers 14-09, and some huge (more than 10%)

The CAPM: Evidence 50-66 and 1914-2009

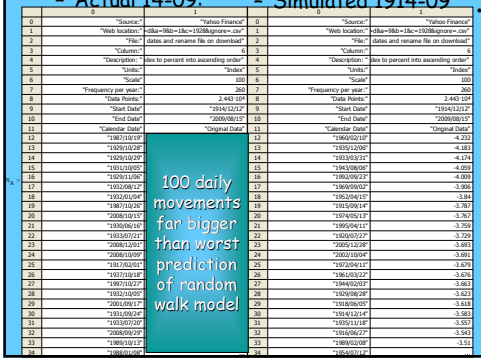
- Large movements data looks OK vs simulated data:
  - Actual 1950-66
  - Simulated 1950-66



- Actual more volatile, but only 20 outside simulated range
- But 1914-2009 data?

The CAPM: Evidence 50-66 and 1914-2009

- Far more large movements in data than simulation:
  - Actual 14-09:
  - Simulated 1914-09



100 daily movements far bigger than worst prediction of random walk model

- No overlap between biggest 100 movements and simulated data

The CAPM: Evidence 50-66 and 1914-2009

- So early "success" of CAPM a statistical aberration
  - Period used
    - Too short
      - Just 16 years data when 60 years available
    - Too stable
      - 50-66 period of low debt, high financial resilience, low speculation
      - Versus 14-09 period including 4 major market crashes: 29, 87, 2000, 2008
- Fama forced to admit empirical defeat of CAPM in 2004:
  - *(But should have been rejected on scientific methodology grounds in the first place!)*

The CAPM: Evidence According to Fama 2004

- "The attraction of the CAPM is that it offers powerful and intuitively pleasing predictions about how to measure risk and the relation between expected return and risk.
- **Unfortunately, the empirical record of the model is poor—poor enough to invalidate the way it is used in applications.**
- *The CAPM's empirical problems may reflect theoretical failings, the result of many simplifying assumptions…*
- In the end, we argue that whether the model's problems reflect weaknesses in the theory or in its empirical implementation, *the failure of the CAPM in empirical tests implies that most applications of the model are invalid.*" (Fama & French 2004: 25)

The CAPM: Evidence According to F&F 2004

- Clearly admits assumptions dangerously unrealistic:
  - "The first assumption is *complete agreement* given market clearing asset prices at *t-1,* investors agree on the joint distribution of asset returns from *t-1* to *t.*
  - ***And this distribution is the true one***—that is, it is the distribution from which the returns we use to test the model are drawn. The second assumption is that there is *borrowing and lending at a risk free rate,* which is the same for all investors and does not depend on the amount borrowed or lent." (26)
    - Bold emphasis: ***model assumes all investors know the future***
- Assumptions, which once "didn't matter" (see Sharpe earlier) are now crucial…

The CAPM: Evidence According to F&F 2004

- "The assumption that short selling is unrestricted is as unrealistic as unrestricted risk-free borrowing and lending…
- But when there is no short selling of risky assets and no risk-free asset, the algebra of portfolio efficiency says that portfolios made up of efficient portfolios are not typically efficient.
- **This means that the market portfolio**, which is a portfolio of the efficient portfolios chosen by investors, **is not typically efficient. And the CAPM relation between expected return and market beta is lost.**" (32)
  - Still some hope that, despite lack of realism, data might save the model…

The CAPM: Evidence According to F&F 2004

  - "The efficiency of the market portfolio is based on many unrealistic assumptions, including complete agreement and either unrestricted risk-free borrowing and lending or unrestricted short selling of risky assets. But all interesting models involve unrealistic simplifications, which is why they must be tested against data." (32)
- Unfortunately, no such luck…
  - 40 years of data strongly contradict all versions of CAPM
    - Returns not related to betas
    - Other variables (book to market ratios etc.) matter
    - Linear regressions on data differ strongly from risk free rate (intercept) & beta (slope) calculations from CAPM

The CAPM: Evidence According to F&F 2004

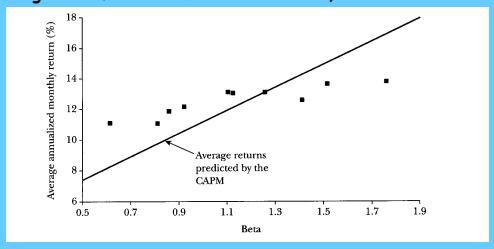
- Tests of the CAPM are based on three implications…
  - "First, expected returns on all assets are linearly related to their betas, and no other variable has marginal explanatory power.
  - Second, the beta premium is positive, meaning that the expected return on the market portfolio exceeds the expected return on assets whose returns are uncorrelated with the market return.
  - Third, … assets uncorrelated with the market have expected returns equal to the risk-free interest rate, and the beta premium is the expected market return minus the risk-free rate." (32)

The CAPM: Evidence According to F&F 2004

- "There is a positive relation between beta and average return, but it is too "flat." … the Sharpe-Lintner model predicts that
  - the intercept is the risk free rate and
  - the coefficient on beta is the expected market return in excess of the risk-free rate, *E(RM) - R.*
  - The regressions consistently find that the intercept is greater than the average risk-free rate…, and the coefficient on beta is less than the average excess market return" (32)

The CAPM: Evidence According to F&F 2004

- **Average Annualized Monthly Return versus Beta for Value Weight Portfolios Formed on Prior Beta, 1928-2003**



- "the predicted return on the portfolio with the lowest beta is 8.3 percent per year; the actual return is 11.1 percent. The predicted return on the portfolio with the highest beta is 16.8 percent per year; the actual is 13.7 percent." (33)

The CAPM: Evidence According to F&F 2004

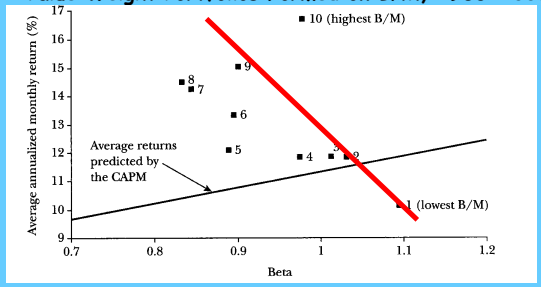
- The hypothesis that market betas completely explain expected returns …
  - Starting in the late 1970s… evidence mounts that much of the variation in expected return is unrelated to market beta…" (34)
  - Fama and French (1992) update and synthesize the evidence on the empirical failures of the CAPM…
  - they confirm that size, earnings-price, debt equity and book-to-market ratios add to the explanation of expected stock returns provided by market beta." (36)
  - Best example of failure of CAPM as guide to building investment portfolios:
    - *Book to Market (B/M) ratios provide far better guide than Beta…*

The CAPM: Evidence According to F&F 2004

- "Average returns on the B/M portfolios increase almost monotonically, from 10.1 percent per year for the lowest B/M group to an impressive 16.7 percent for the highest.
- But the positive relation between beta and average return predicted by the CAPM is notably absent…
  - **the portfolio with the lowest book-to-market ratio has the highest beta but the lowest average return.**
- The estimated beta for the portfolio with the highest book-to-market ratio and the highest average return is only 0.98. With an average annualized value of the riskfree interest rate, *Rf, of* 5.8 percent and an average annualized market premium, *Rm - Rf, of* 11.3 percent,
  - the Sharpe-Lintner CAPM predicts an average return *of* 11.8 percent for the lowest B/M portfolio and 11.2 percent for the highest, far from the observed values, 10.1 and 16.7 percent."

The CAPM: Evidence According to F&F 2004

- **Average Annualized Monthly Return versus Beta for Value Weight Portfolios Formed on B/M, 1963-2003**



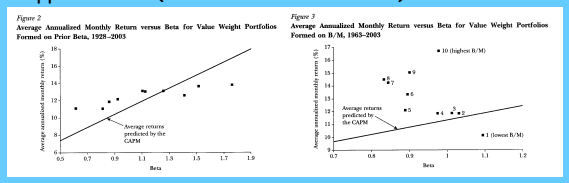
- Simple regression gives opposite relationship to CAPM: *return rises as beta falls!* High returns with low volatility

The CAPM: Evidence According to F&F 2004

- End result: CAPM should not be used.
  - "The … CAPM … has never been an empirical success… The problems are serious enough to invalidate most applications of the CAPM.
  - For example, finance textbooks often recommend using the … CAPM risk-return relation to estimate the cost of equity capital… [But] CAPM estimates of the cost of equity for high beta stocks are too high … and estimates for low beta stocks are too low…
  - The CAPM … is nevertheless a theoretical tour de force. We continue to teach the CAPM as an introduction to the fundamental concepts of portfolio theory and asset pricing…
  - But we also warn students that despite its seductive simplicity, the CAPM's empirical problems probably invalidate its use in applications." (F&F 2004: 46-47)

Fama & French 2004: Data kills the theory

- "The attraction of the CAPM is that it offers powerful and intuitively pleasing predictions about how to measure risk and the relation between expected return and risk.
- Unfortunately, the empirical record of the model is poor—poor enough to invalidate the way it is used in applications." (Fama & French 2004: 25)



- So "founding fathers" of CAPM have abandoned their child…
  - Why do economists still teach it?

Random or Fractal Walk Down Wall Street?…

- Many don't know that developers of CAPM have abandoned it
- Most don't know that any alternative exists, so teach what they know
- But alternatives do exist
  - "Fractal/Coherent/Inefficient" Markets in finance
  - In Economics?
    - Key aspect of CAPM:
      - How investments are financed doesn't affect value of firm (determined solely by net present value of investments…)
      - As a result, finance doesn't affect economics
  - So since CAPM is false, finance does affect economics…