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# The limits to quantitative risk modelling

For if he knows, then it is certain this will be, and  
if this is certain, then chance does not exist.

But chance does exist,  
so there is no foreknowledge of things  
that happen by chance

Cicero *De Divinatione*

It is impossible to achieve demonstrably true knowledge  
about our universe or ourselves.

Nor is logic decisive. ***No kind of reasoning can ever give  
rise to a new idea.***

*Hume*

**SIAS July 2009  
Con Keating**



## Decisions – Newcomb's Paradox

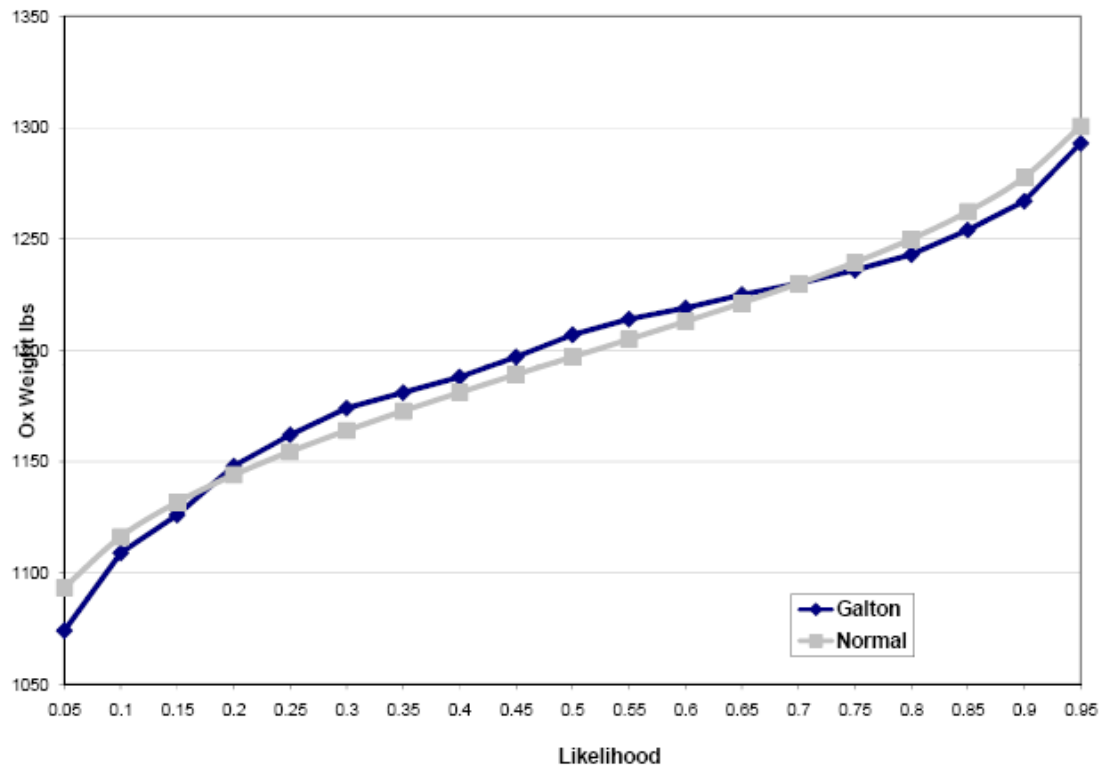
- Consider the following: Two boxes – One opaque, One transparent
- You can see there is £1,000 in the transparent box
- In the opaque there is either £1,000,000 or nothing.
- You must decide whether to take one or both boxes.
- There is a being with strong predictive powers and he has already determined the content of the box and in this follows these rules
- if he predicted that you would take only the opaque box, he put £1,000,000 in it.
- If he predicted you would take both, he put nothing in the opaque.
- What do you do??



Laws of large numbers

The average will always be better than most individual

False



Some individual forecast will always outperform the average

Not Necessarily – think of 3,3,3,8,8 (av. 5) and an outcome of 6

Whenever most forecasts perform substantially worse than average, then some will always perform substantially better

False

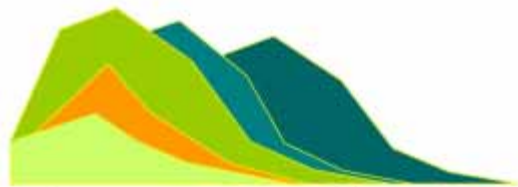


# Axioms and Rumsfeld

Artzner et al. – Axioms for Coherent measures of risk  
**Sub-additivity ??**

Known Knowns -- Standard probability theory  
Known Unknowns – Stress Testing  
Unknown Unknowns – Knightian Uncertainty

By 'uncertain' knowledge, let me explain, I do not mean merely to distinguish what is known for certain from what is only probable. The game of roulette is not subject, in this sense, to uncertainty...The sense in which I am using the term is that in which the prospect of a European war is uncertain, or the price of copper and the rate of interest twenty years hence...About these matters there is no scientific basis on which to form any calculable probability whatever. We simply do not know." (J.M. [Keynes](#), 1937)



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## Keynes

“(1) We assume that the present is a much more serviceable guide to the future than a candid examination of past experience would show it to have been hitherto. In other words we largely ignore the prospect of future changes about the actual character of which we know nothing.

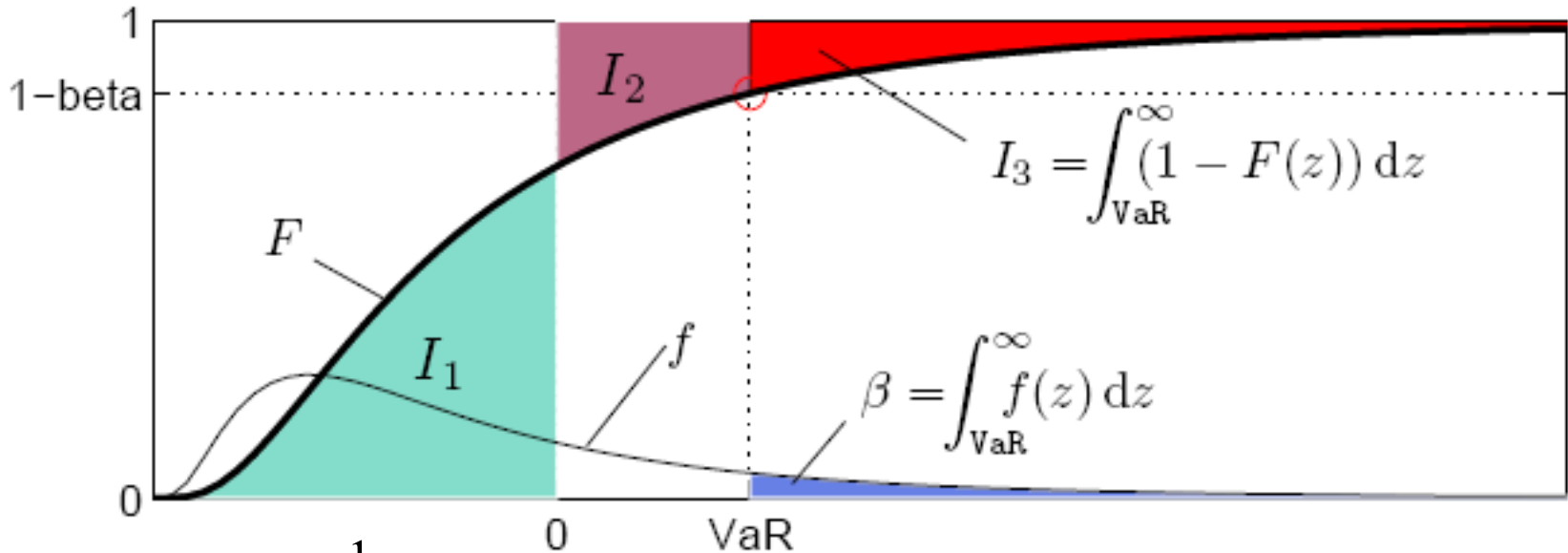
(2) We assume that the *existing* state of opinion as expressed in prices and the character of existing output is based on a *correct* summing up of future prospects, so that we can accept it as such unless and until something new and relevant comes into the picture.

(3) Knowing that our own individual judgement is worthless, we endeavour to fall back on the judgement of the rest of the world which is perhaps better informed. That is, we endeavour to conform to the behaviour of the majority or the average. The psychology of a society of individuals each of whom is endeavouring to copy the others leads to what we may strictly term a *conventional* judgement”.



# VaR and Shortfall

## The conventional



$$\text{ES} = \text{VaR} + \frac{1}{\beta} I_3$$

$$\text{VaR}_{1-\beta} = F^{-1}(1-\beta)$$

But beware the discrete, and do remember that a sample arises from within the true distribution

Beware also of mixing expectations – credit risk [  $E(X)$  ] but most risk measures are second moment based [  $\text{SQRT}(E(X)^2)$  ]



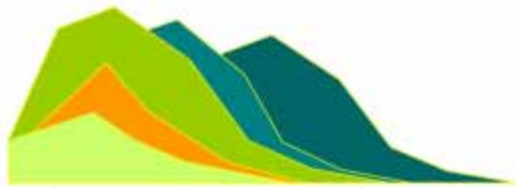
## Value at What?

- There is no time dimension to VaR.
- So this is not a dynamical measure.
- As such as a risk measure it is incomplete.
- This is actually an exercise in comparative statics.
- As are most of the Greeks in option pricing.
- Or duration and convexity in bond evaluation.
- Keynes / Hicks model equilibria are the results of dynamical systems which have ceased movement.
- Let's consider comparative dynamics rather than statics



## Comparative Statics vs Dynamics

- Comparative statics show us how the equilibrium changes, wrt to a particular set of circumstances, when a particular parameter changes
- However the displaced equilibrium will not be that to which the disturbed system converges
- Rather, the very process of convergence, of adjustment to the displacement, will itself further change the equilibrium.
- Whether or not the ultimate equilibrium will be close to the one predicted by the comparative statics or even whether the ultimate effects of the displacements will be in the predicted direction is not a question that lends itself to a general answer.
- The answer depends on the effects of the parameter shift on the adjustment path of the system – on the comparative dynamics rather than on comparative statics.



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Time

- Time – Motion – Dynamics
- Time – Irreversibility – Thermodynamics
- Time – History – Sociology (Biology)
  
- *And “To reach a coherent view of the world of which we are part, we must find some way to pass from one description to another.” I. Prigogine*
  
- The future depends on what we do now, the past does not
- But this does not mean that the past is independent of the present
- Our actual problem is that only a minute collection of the minutest details of the present state of the world can be reasonably taken under our control.



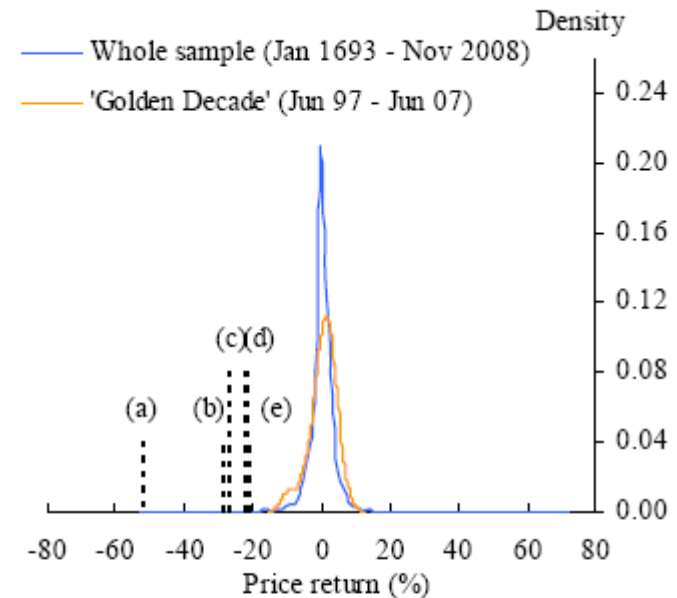
## VaR & Ruin Probabilities

$$P_{\text{ruin}} \leq \frac{1}{\beta^2}, \quad \text{where } \beta = \frac{C + \lambda N}{\sigma\sqrt{N}}.$$

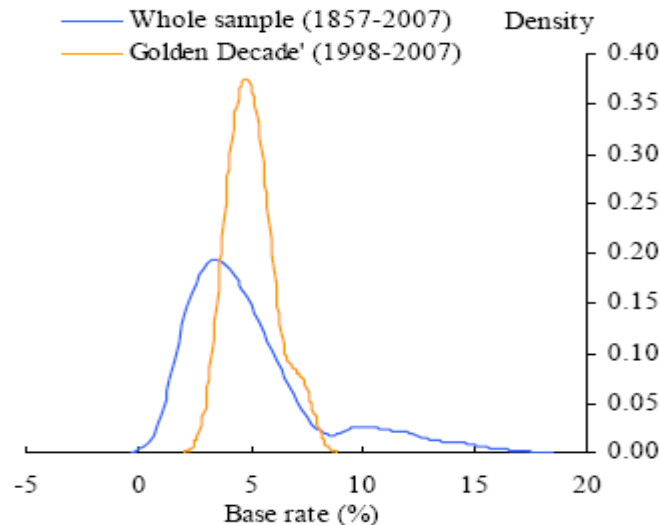
- Value at Risk is simply an application of insurance ruin theory
- It dates from 1963 and William Baumol rather than the 1990s
- If we wish to regulate the probability of ruin, there are variables other than capital (C) we may utilise.
- The loading factor ( $\lambda$ ) but this is product regulation
- The number of risks (N) but this has competition implications
- The variability of individual risks ( $\sigma$ ), again product regulation
- The regulator favours institutional over product regulation.
- The regulator also favours principles over prescriptive rules
- The first and most obvious problem

- Representativeness

### FTSE All-Share Index



### UK Base rate



Sources: Global Financial Data and Bank calculations.

- (a) September 1720 (South Sea Bubble)
- (b) October 1720 (South Sea Bubble)
- (c) October 1987 (Black Monday - portfolio insurance)
- (d) July 1940 (WWII - merchant ships attacked)
- (e) March 1974 (Price/wage controls, unions, etc.)



## Crisis

- In application these financial models are stationary
- This is the mathematics of gambling
- All outcomes can be specified and probabilities assigned
- Risk is the subset of uncertainty for which we can specify all events and assign probabilities.
- This is a compact set, closed and bounded
- Arrow Debreu – is just a fixed point theorem on this set.
- There are simply far too few markets in existence for A-D
- Rational Expectations – just another fixed point theorem
- With initial boundary conditions, General Equilibrium follows
  
- Revert to time and co-ordination



## Keynesian Beauty Parades

- Choose the face which will be chosen prettiest by most
- This is about guessing other people's guesses
- And they of course are guessing your guess
- And there is no logically sufficient reason to stop at any point
- This is endogenous and in-eradicable.
- Activity designed to anticipate the future or reduce uncertainty cannot be completely successful
- There is a distinction in uncertainty here
- This is unique uncertainty, time dependent uncertainty
  
- Let's take this further



## Beauty Parades continued

- Introduce an agency that collects and disseminates guesses before they are entered.
- Now everyone knows for sure what the other guesses are
- So the pay-off isn't worth winning
- But someone may make a guess that differs, so I'll guess something different because that increase my pay-off
- And as the realisation that some will follow that strategy permeates, all will follow it – the game continues again with end
- We have created an institution to cope with uncertainty that is also responsible for its perpetuation
- In eliminating one layer uncertainty, we are creating another



## Time Dependent Uncertainty

- There is in-eradicable uncertainty here
- This is not about measurable versus unmeasurable uncertainty or subjective versus objective interpretations of probability
- This is purely time dependent uncertainty versus Newtonian uncertainty
- Purely time dependent uncertainty is completely inconsistent with static equilibrium
- The individual always has an incentive to eliminate uncertainty but the collective can only transform it
- So we should be looking to dis-equilibrium economics
- Though complete stability and predictability is inconsistent with time,
- But their total absence is incompatible with action
- And that will take us back to conventions
- And new risk management tools



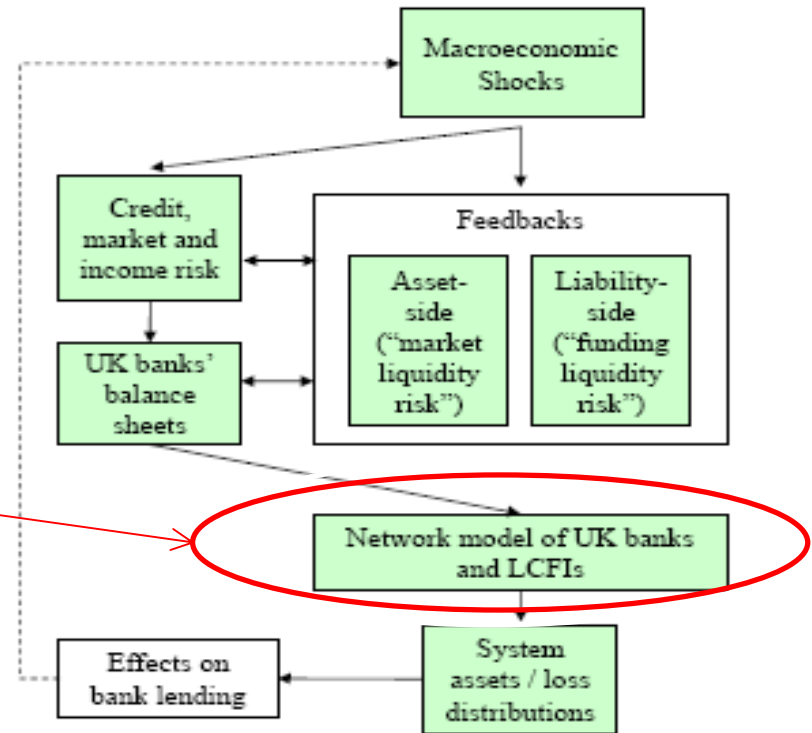
# BoE - Ramsi

A complex stress testing model

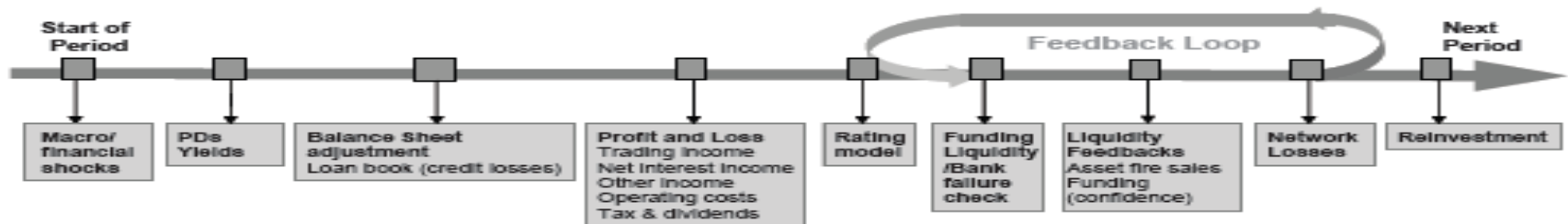
Network

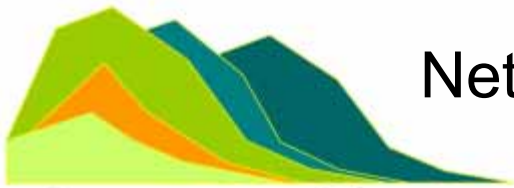
With some risk dynamics

# Model Architecture



# Time-line of events within a quarter





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# Network Topology

## Real world networks :

1. power-law degree distribution
2. clustering
3. small degree of separation: *small world phenomenon*

Chart 3: Global Financial Network: 2005

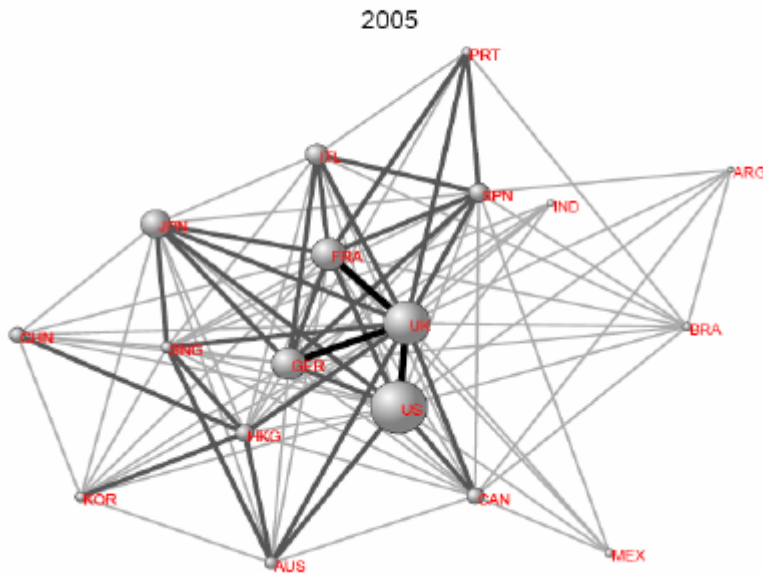


Chart 1: Global Financial Network: 1985

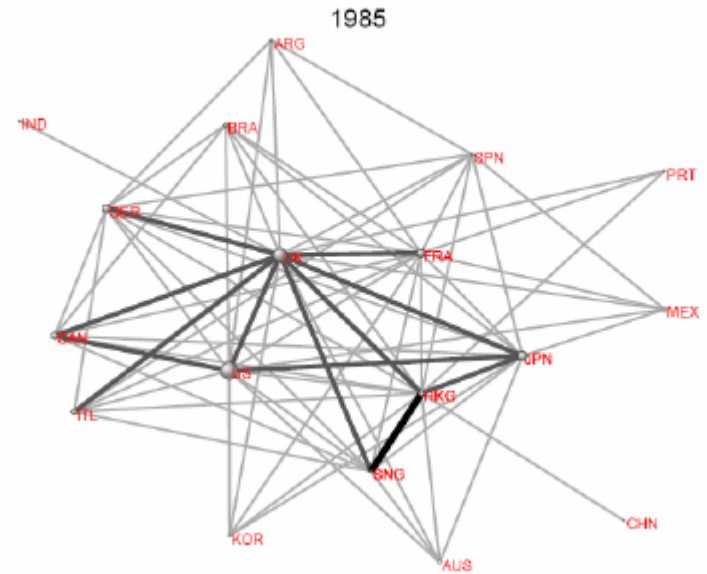
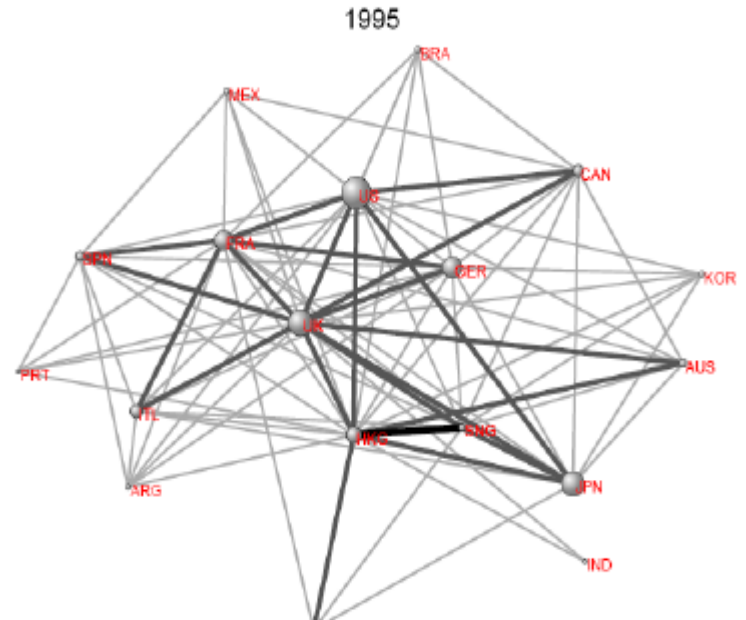


Chart 2: Global Financial Network: 1995





## Information in Finance

- With perfect information institutions don't matter, nor does history or the distribution of wealth.
- Imperfect knowledge of price, quality and effort has no effect
- Given the production technology, initial endowment and preferences all future is determined.
- The Arrow-Debreu world is one of perfect information – beliefs cannot be endogenous and cannot change
- And that precludes investing in information discovery
- Imperfect information has major consequences, even if small.
- It limits markedly the domain of the law of supply and demand, the law of diminishing returns, the law of the single price and the efficient markets hypothesis.
- In general though it never pays to invest in just a little information discovery.



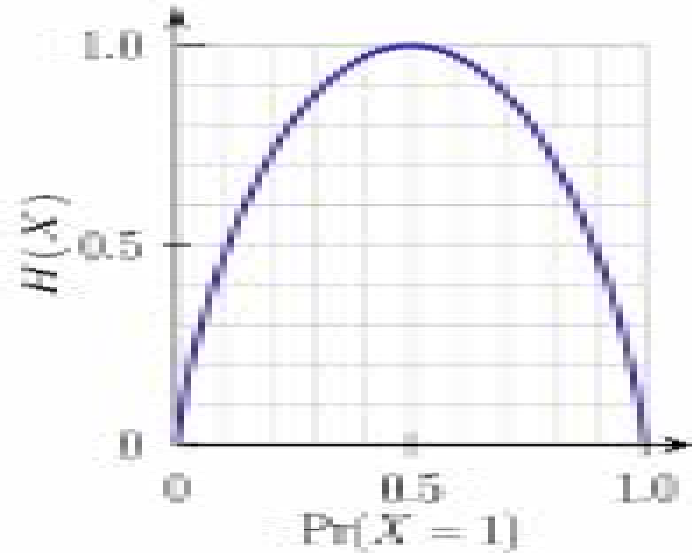
Entropy

$$H = \sum_{i=1}^n p_i \log_2 \left( \frac{1}{p_i} \right)$$

Information has a direction in time

informative wrt information packing within a distribution

Extends to within group and among group decompositions



Successful prediction involves new instances of familiar phenomena and the occurrence of new phenomena. – This is item novelty versus type novelty

Not just quantitatively more wrt old ground, but qualitatively new in broaching new ground – not just predictions but **surprising** predictions



## Models

- There are questions with all financial theories as to whether they function as cameras, recording empirical regularities or as engines influencing performance.
- Most important for these latter theories are the prescriptive actions they generate to reinforce themselves. Or as the German sociologist Max Weber expressed it: “*To seal the ideological bondage*”
- Better is to use models to parse data into information and noise
- No assumption of a true model is needed
- The objective becomes to extract the useful and learnable information with a model class suggested
- By defining learnable information, we can also compare any two models



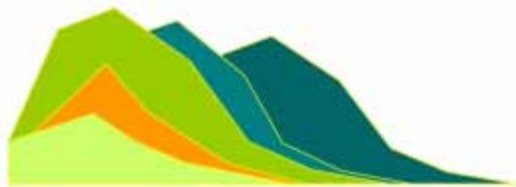
## Trust and Transparency

- In the naïve efficient market inefficiencies and failures must be due to informational disparities
- To which more transparency is a universal solution
- “Transparency certainly destroys secrecy;
- But it may not limit the deception and deliberate misinformation that undermine relations of trust.
- If we want to restore trust we need to reduce *deception* and *lies* rather than *secrecy*.
- Some sorts of secrecy indeed support deception, others do not.
- Transparency and openness may not be the unconditional goods that they are fashionably supposed to be.
- By the same token, secrecy and lack of transparency may not be the enemies of trust.”



## Rational Decision Problems

- Agents possessed of free will must, if rational, be substantially predictable exactly because of that rationality
- Sargent's "communism"
- In some situations the acts chosen will not be predictable
- Under-determination due to insufficient information-DSGE
- And also over-determination - Prisoner's Dilemma
- Belief formations matter..
- When determination fails after rationality has had its say, rationality's predictive power is exhausted.
  
- Fortunately, however, that does not mean that our human resources of issue resolution are at the end of their tether.



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## Knightian Uncertainty

In conformity with the Savage model of decision-making, modern asset pricing theory assumes that agents' beliefs about the likelihoods of future states of the world may be represented by a probability measure. As a result, no meaningful distinction is allowed between risk, where probabilities are available to guide choice, and uncertainty, where information is too imprecise to be summarized adequately by probabilities. In contrast, Knight and Keynes emphasized the distinction between risk and uncertainty and argued that uncertainty is more common in economic decision-making. Moreover, the Savage model is contradicted by evidence, such as the Ellsberg Paradox, that people prefer to act on known rather than unknown or vague probabilities. This paper provides a formal model of asset price determination in which Knightian uncertainty plays a role. Specifically, we extend the Lucas (1978) general equilibrium pure exchange economy by suitably generalizing the representation of beliefs along the lines suggested by Gilboa and Schmeidler. Two principal results are the proof of existence of equilibrium and the characterization of equilibrium prices by an "Euler inequality." A noteworthy feature of the model is that uncertainty may lead to equilibria that are indeterminate, that is, there may exist a continuum of equilibria for given fundamentals. That leaves the determination of a particular equilibrium price process to "animal spirits" and sizable volatility may result. Finally, it is argued that empirical investigation of our model is potentially fruitful.

Epstein & Wang

"Intertemporal Asset Pricing under Knightian Uncertainty"

Econometrica 1994



## Innovation and the Real World

- Is characterised not by equilibrium, but by innovation and diversity
- In diversity there is economic resilience
- Principles based regulation admits innovation
- Successful innovation is exaptive, rather than adaptive,
- and usually co-constructive
- Accompanied by Schumpeter's "waves of creative destruction"
- We eliminate from the algebra some events
- But we introduce new risk, and **new uncertainty**
- And as the rewards will rapidly all accrue to the consumer
- We need to act quickly and jump on band-wagons



## The Real World

- These are open not closed systems
- Non-equilibrium dynamics
- Self organisation and Non-linearities
- Chaos and Power Laws
- Path dependency – history matters
- Entropy and Thermodynamics indicative but not enough
  
- Is a mixed game - partly against nature and partly against others
- Risk is now endogenous and that brings hysteresis
- Distributions would result that may be far from normal and can be multimodal
- We can foresee some events for which we cannot assign probabilities as we do not know their relative frequency.
- We are now dealing with uncertainty



## Newcomb examined

- Principle of Maximising Conditional Expected Utility (PMCEU)
- Do that which makes the most desirable most likely- given the likelihood of the predictor is close to 1, take just the opaque box.
- But the predictor has already made the allocation – so my act cannot change anything – I will get the contents of the opaque regardless of my decision – so take both
- Another one box argument – to get £1,001,000 the agent must take both and for that to be true the predictor must have been wrong and also to get £0 the predictor has to have been wrong.
- This can go on and on...



## The Future

- Co-ordination Effects
- Learning Effects
- Self-Reinforcing Expectations
- Large Set-up or Fixed Costs

leading to...

- Multiple equilibria
- Path dependence
- Lock-in
- Possible inefficiency
- The theory of value is not satisfactory without a description of the adjustment processes that are applicable to the economy and of the way individuals adjust to disequilibrium



An ending quotation

**Because things are the way they are, things will not stay the way they are.**

*Bertolt Brecht (1898 - 1956)*

**Life can only be understood backwards; but it must be lived forwards.**

*Soren Kierkegaard (1813 - 1855)*

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