Complex Dynamics in Action

Some reflections

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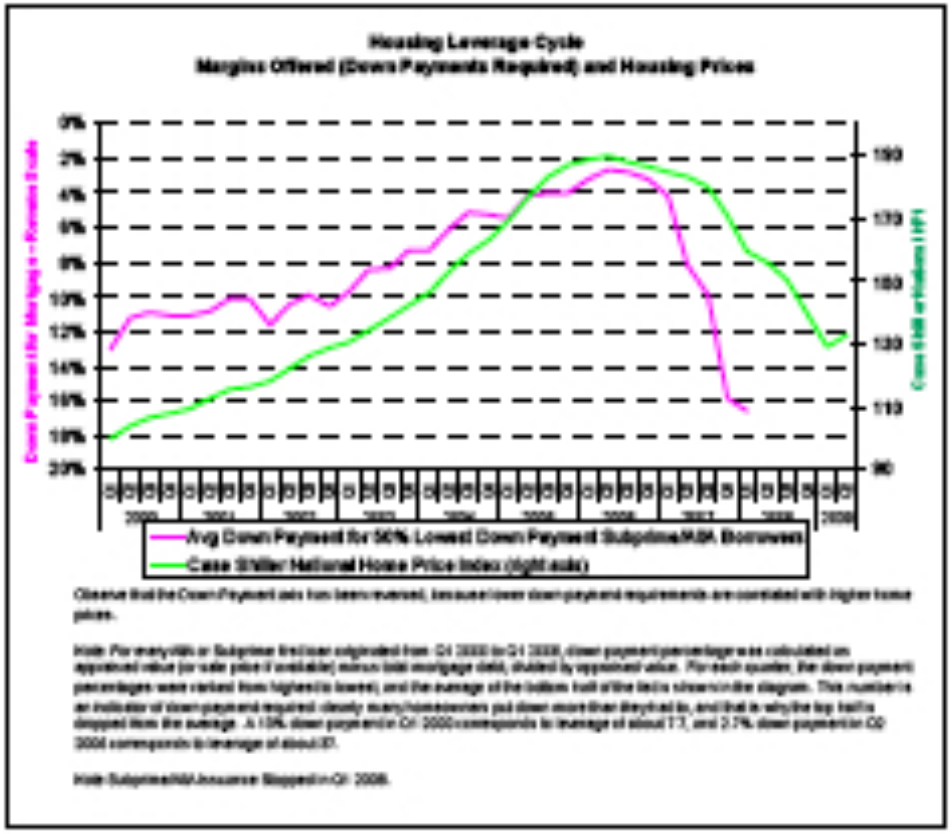
Presentation at the
Budapest Conference
6-8 september

Leverage Cycle (John Geneakoplos)

- Shakespeare. Merchant of Venice
- What do you remember Shylock's collateral, (a pound of flesh) or the rate of interest?
- The leverage effect on mortgages over time.

Leverage and house prices



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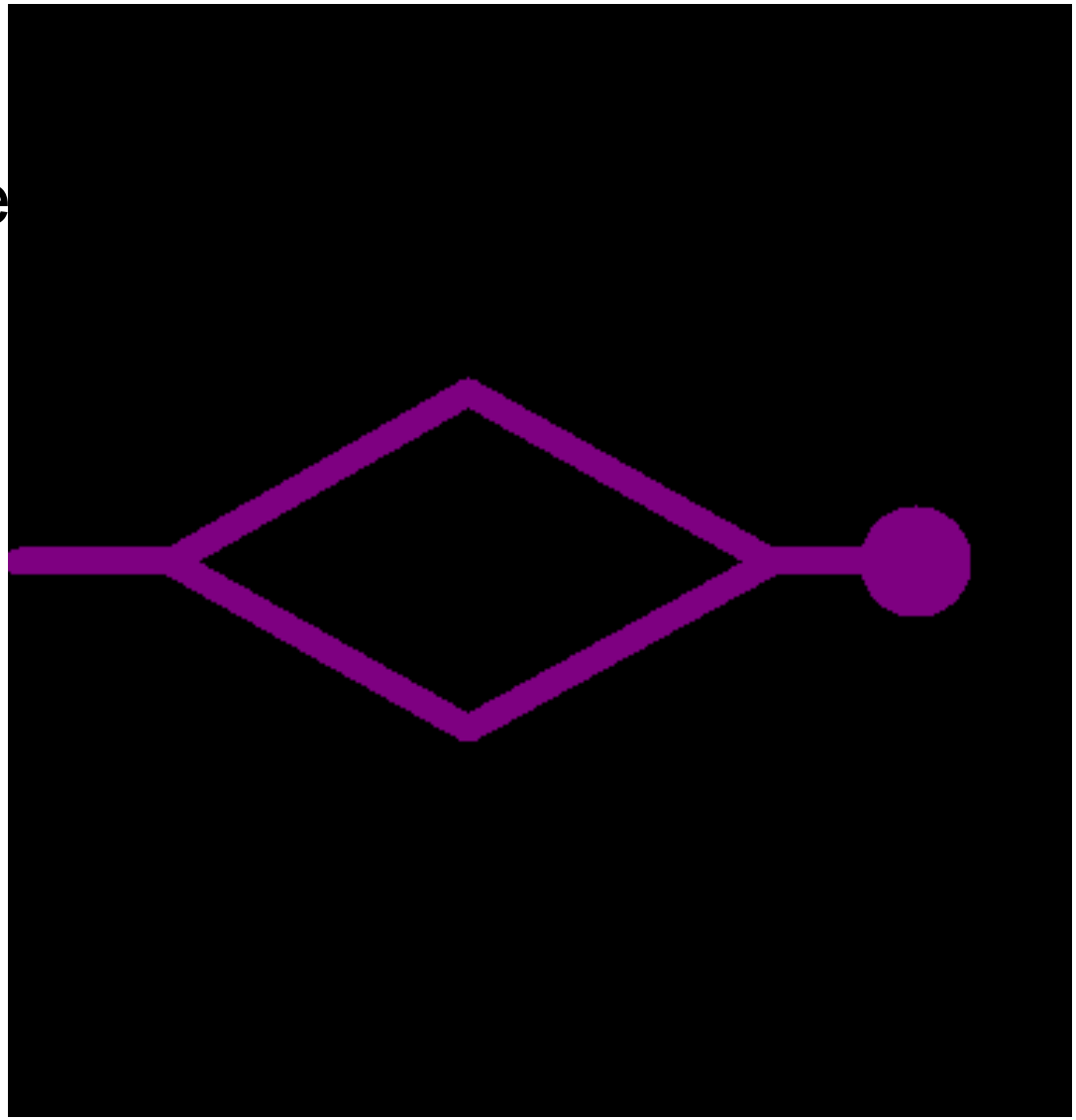
Ants learn to find the route to food

- Ants communicate with each other
- either through a pheromone trail
- or by tandem recruiting.



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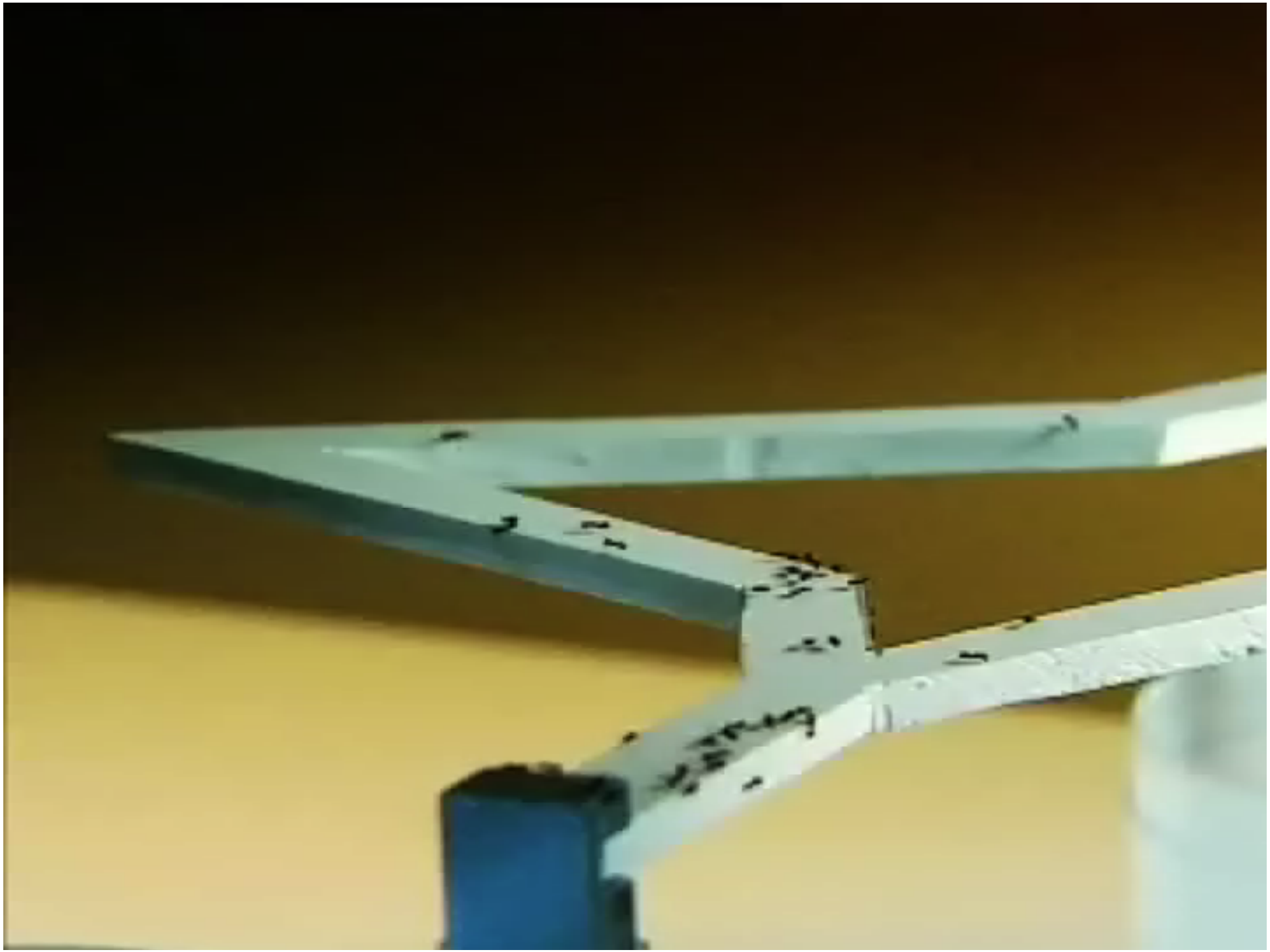


How should we model this learning behaviour?

- Think of the number of ants taking a path at time t as k_t and suppose that one ant meets another and is recruited to the path of the other with probability $(1-\delta)$ and changes it path with probability ε.

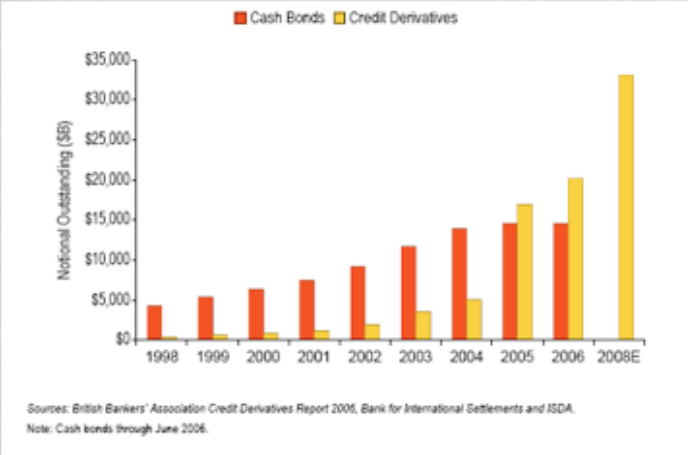
The recruiting process

The dynamic evolution of the process is then given by

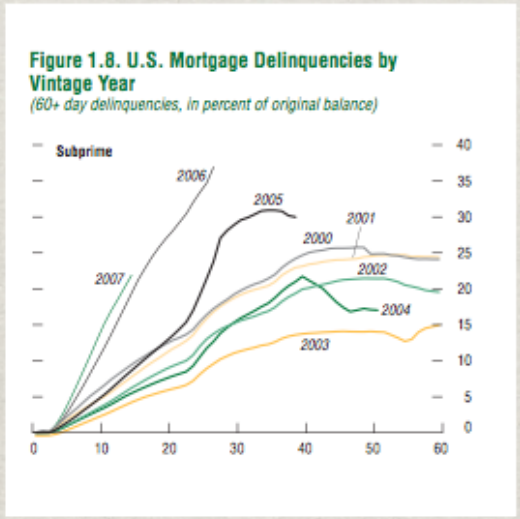
$$(1)\quad k \;\begin{cases} \nearrow\ k+1 \text{ with probability } p_1 = P(k,k+1) = \left(1-\frac{k}{N}\right)\left(\epsilon + (1-\delta)\frac{k}{N-1}\right) \\ \searrow\ k-1 \text{ with probability } p_2 = P(k,k-1) = \frac{k}{N}\left(\epsilon + (1-\delta)\frac{N-k}{N-1}\right). \end{cases}$$

Historical motivation

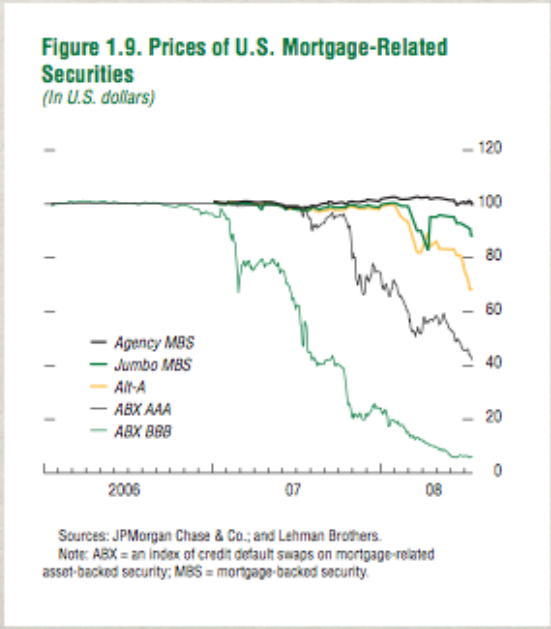
1. trading complex credit derivative products without really understanding what they're worth



2. ... in the face of bad news accumulating ...



3. Crash!!!



Why so sharp?

Figures from Global Financial Stability Report Oct. 2008

THE MODEL: RULE EPIDEMICS

- The rule:
  buy an ABS without checking whether it is "toxic" or not
- Strategy: follow the rule ($z_i=1$, i=1,...,N labels agents)
  don't, i.e. check before buying ($z_i=0$)
  Idea: checking is costly, if majority follows the rule, then I better follow it too
- Prob{ABS is toxic when checked} = p (bad news: p larger than expected)
- Agents connected in a network (OTC market):
  i trades with j drawn at random among his neighbors
- Payoffs: pay a price p_0 to seller
  resell at $p_2 < p_0$ if buyer checks & ABS toxic
  resell at $p_1 > p_0$ else
  checking costs $-\chi_i$ (drawn from pdf $\Phi(\chi)$)

  (reduce # params. by rescaling: $p_1-p_2=1$, $c=p_0-p_2$)

	check & toxic	no check
$z_i=0$	$-\chi_i$	$1-c-\chi_i$
$z_i=1$	$-c$	$1-c$

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Analysis

- Expected payoffs:

$$\begin{aligned} u_i(z_i = 1) &= E_j\left[-p(1-z_j)c + [1-p(1-z_j)](1-c)\right] \\ &= 1 - p(1-\bar{z}_i) - c \end{aligned}$$

$$u_i(z_i = 0) = (1-p)(1-c) - \chi_i \qquad \bar{z}_i = \frac{1}{|N_i|}\sum_{j \in N_i} z_j$$

- Best response:

$$\begin{aligned} z_i^* &= \theta\left(u_1(1) - u_i(0)\right) \\ &= \theta\left(p(\bar{z}_i - c) + \chi_i\right) \end{aligned}$$

- Nash equilibria?

Mean field analysis

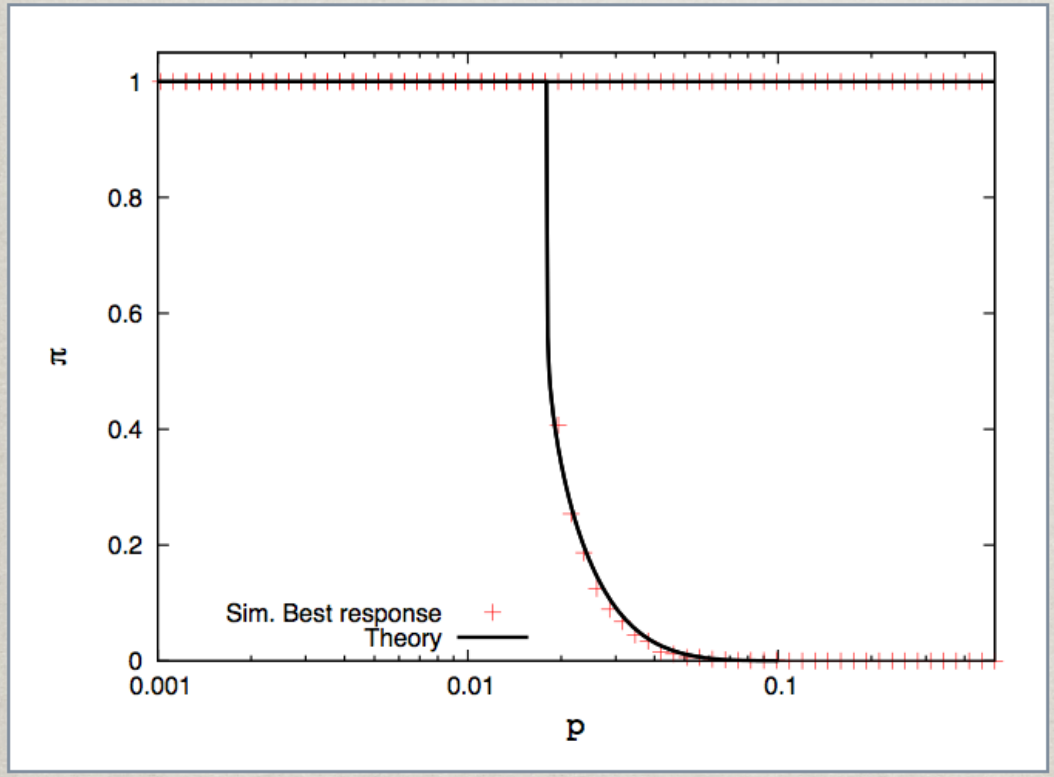
- Regular random graph ($|N_i|=k$ for all i)

$$\pi(\chi) \equiv P\{z_i^* = 1 | \chi_i = \chi\} = \sum_{\ell > (c-\chi/p)k} \binom{k}{\ell} \bar{\pi}^\ell (1-\bar{\pi})^{k-\ell} \qquad \bar{\pi} = E_\chi[\pi(\chi)]$$

- Taking expectation over $\chi_i \Rightarrow$ self-consistent equation

$$\begin{aligned} \bar{\pi} &= E\left[\chi_i > p(c - \bar{z}_i)\right] \\ &= \sum_{\ell=0}^{k} \binom{k}{\ell} \bar{\pi}^\ell (1-\bar{\pi})^{k-\ell} P\{\chi > p(c-\ell/k)\} \\ &= F(\bar{\pi}) \end{aligned}$$

Coexistence



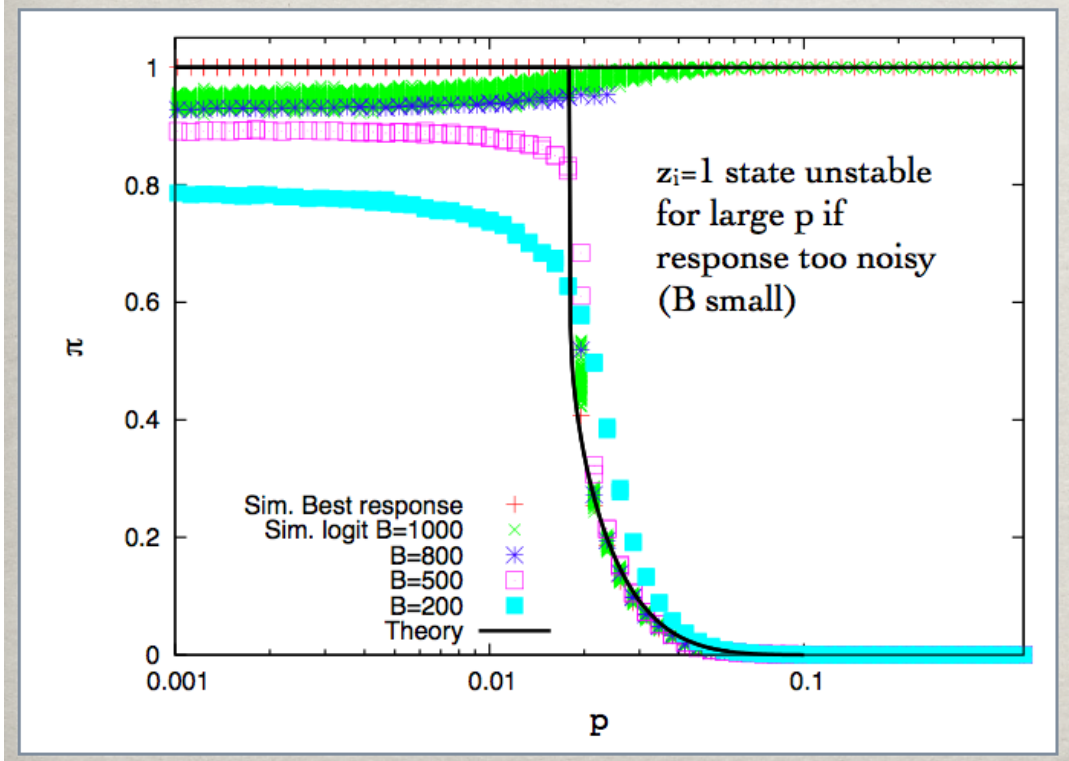
$z_i = 1$ for all agents is always an equilibrium

If p is small enough it is the only equilibrium

Exponential distribution of χ_i with $E[\chi_i]=0.01$
k=11 neighbors, c=0.9

Noisy best response

Logit: $P\{z_i = 1\} \propto e^{B[u_i(1) - u_i(0)]}$



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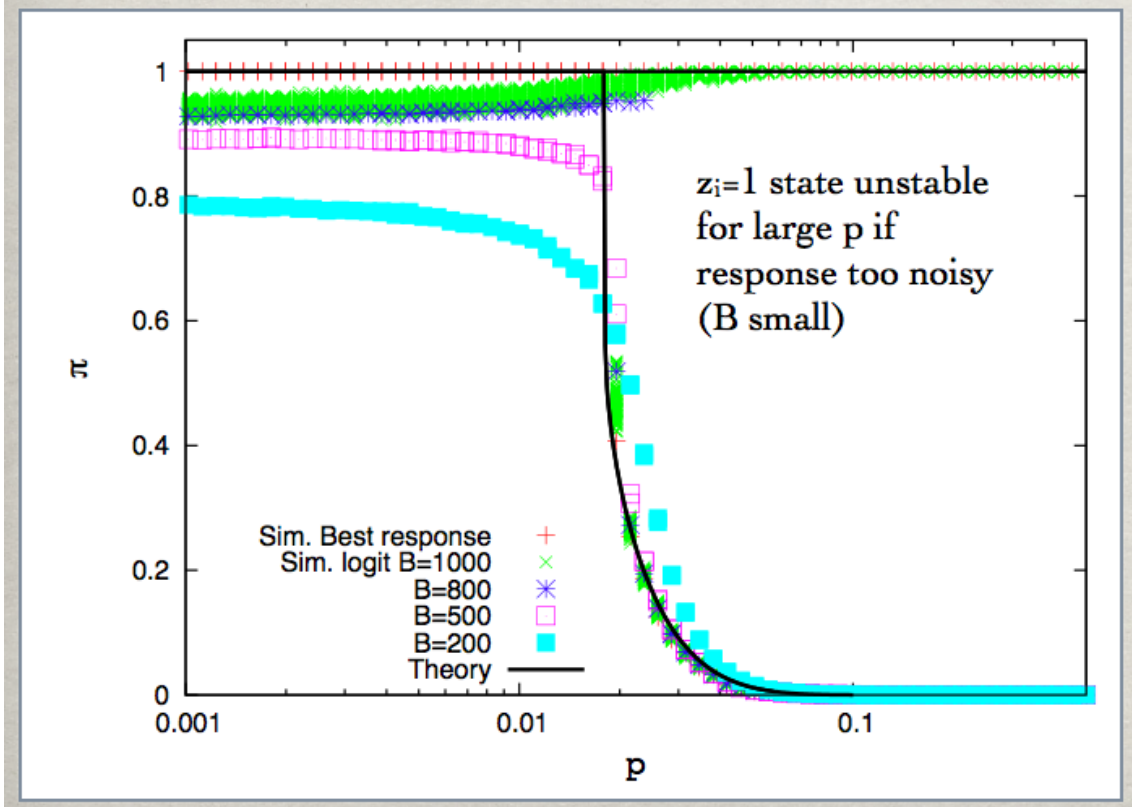
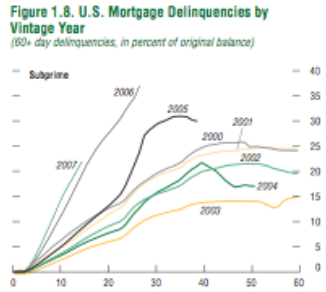
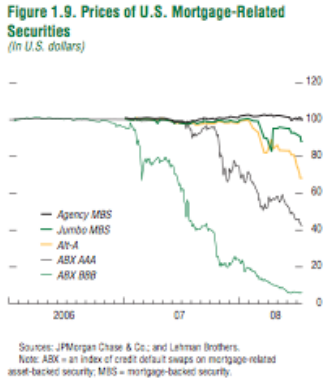


Back to ABS story:



increasing p ...



... sharp transition!

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Systemic Risk and the Role of the financial network

- The network of interactions in the economy is extremely important.
- As Haldane has pointed out the evolution of structure of the financial network, (self organisation) and of the links between countries or financial institution can play a major role in undermining the stability of the system.
- Increased connectivity is not enough to guarantee stability, other features are important.

Chart 1: Global Financial Network: 1985

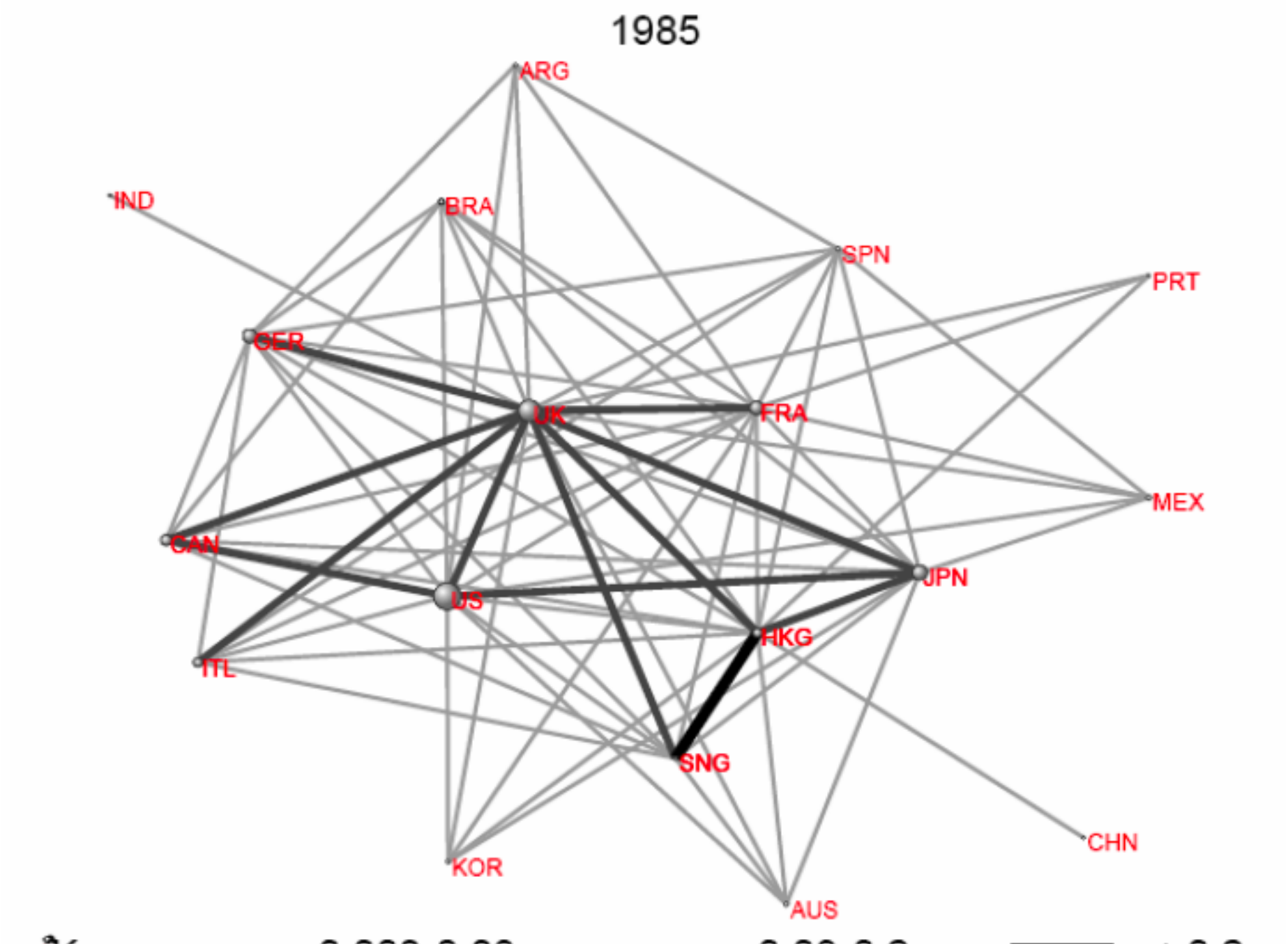


Chart 2: Global Financial Network: 1995

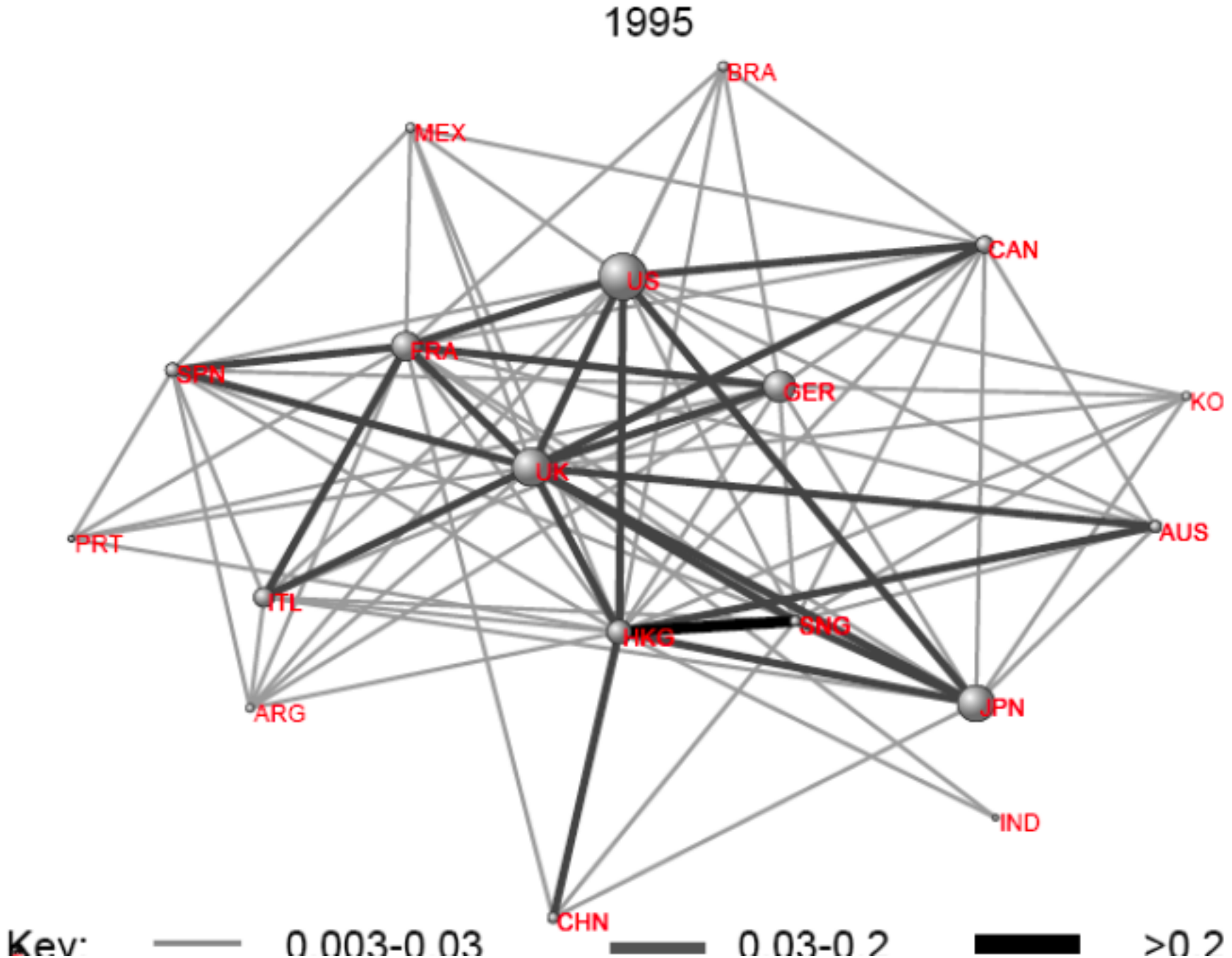
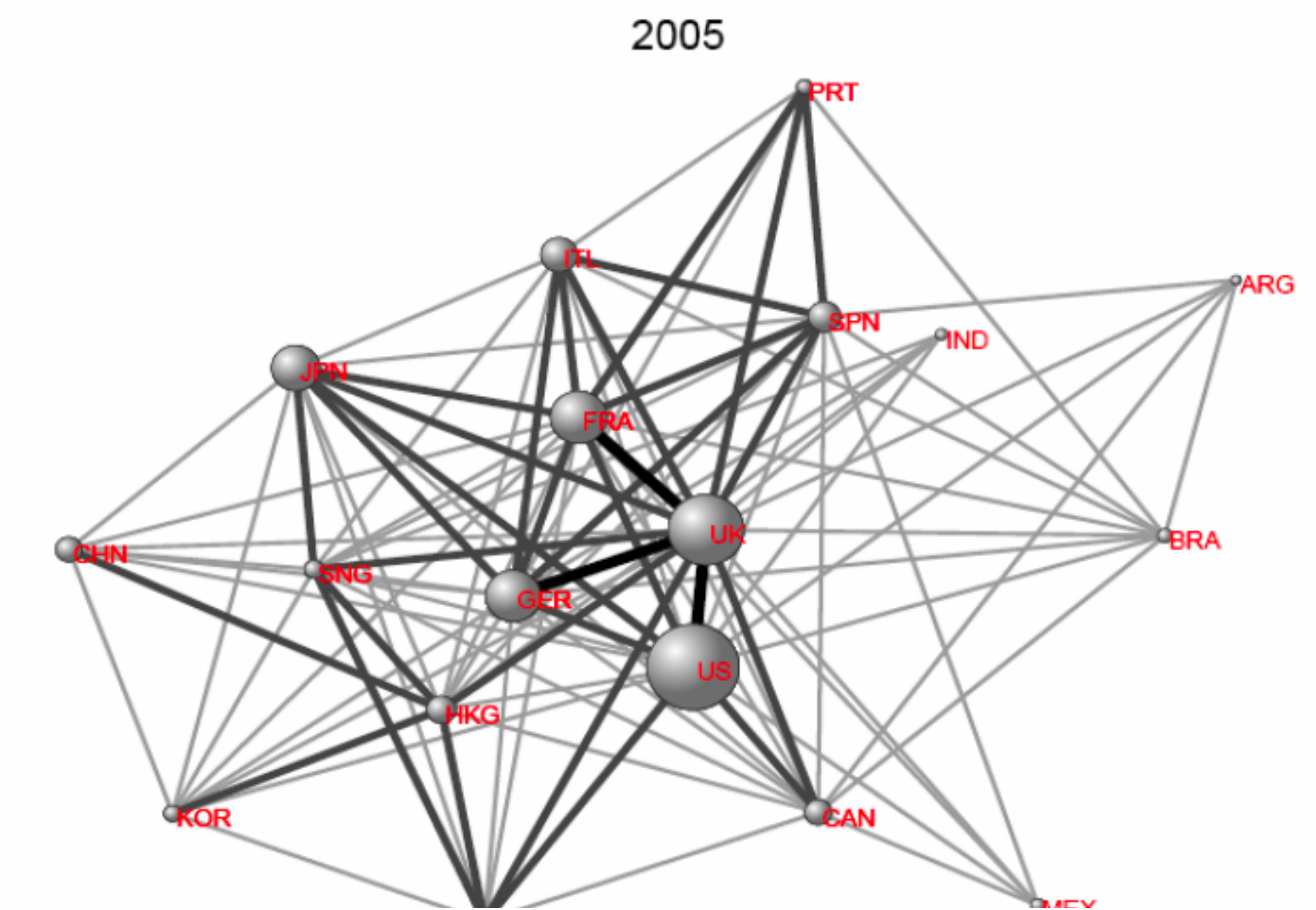


Chart 3: Global Financial Network: 2005



The danger signs

1. The scale and interconnectivity of the international financial network has increased significantly over the past two decades.
2. Nodes have increased 14-fold and links have increased 6-fold.
3. The degree distribution has a long-tail. Measures of skew and kurtosis suggest significant asymmetry in the distribution. There is a small number of financial hubs with multiple spokes.
4. The average path length of the international financial network has shrunk over the past twenty years. Between the largest nation states, there are fewer than 1.4 degrees of separation.

Result: Vulnerability

- Such systems are vulnerable to the transmission of problems, particularly those originating in one of the large nodes.
- But nobody planned that the system should develop in this way, it is the result of self organisation.

Regulating the system

- My main argument in this context is that the sort of complex system I have described is intrinsically difficult to control
- If we put in place a set of constraints and rules today they will have to be continually adapted as markets adapt
- We cannot simply design from scratch a « new regulatory framework » and then let things run.

Regulating the system

- Ben Bernanke again,

  « I just think it is not realistic to think that human beings can fully anticipate all possible interactions and complex developments. The best approach for dealing with this uncertainty is to make sure that the system is fundamentally resilient and that we have as many fail-safes and back-up arrangements as possible »

  Interview with the IHT May 17th 2010

Conclusion

- We have been wedded to an architecture which has simply revealed itself to be inadequate as a model of the evolution of the contemporary economy.
- It will not be enough to add considerations of the sort I have evoked to the standard model.
- We have to rethink the paradigm