

Agent based modelling of economic crises

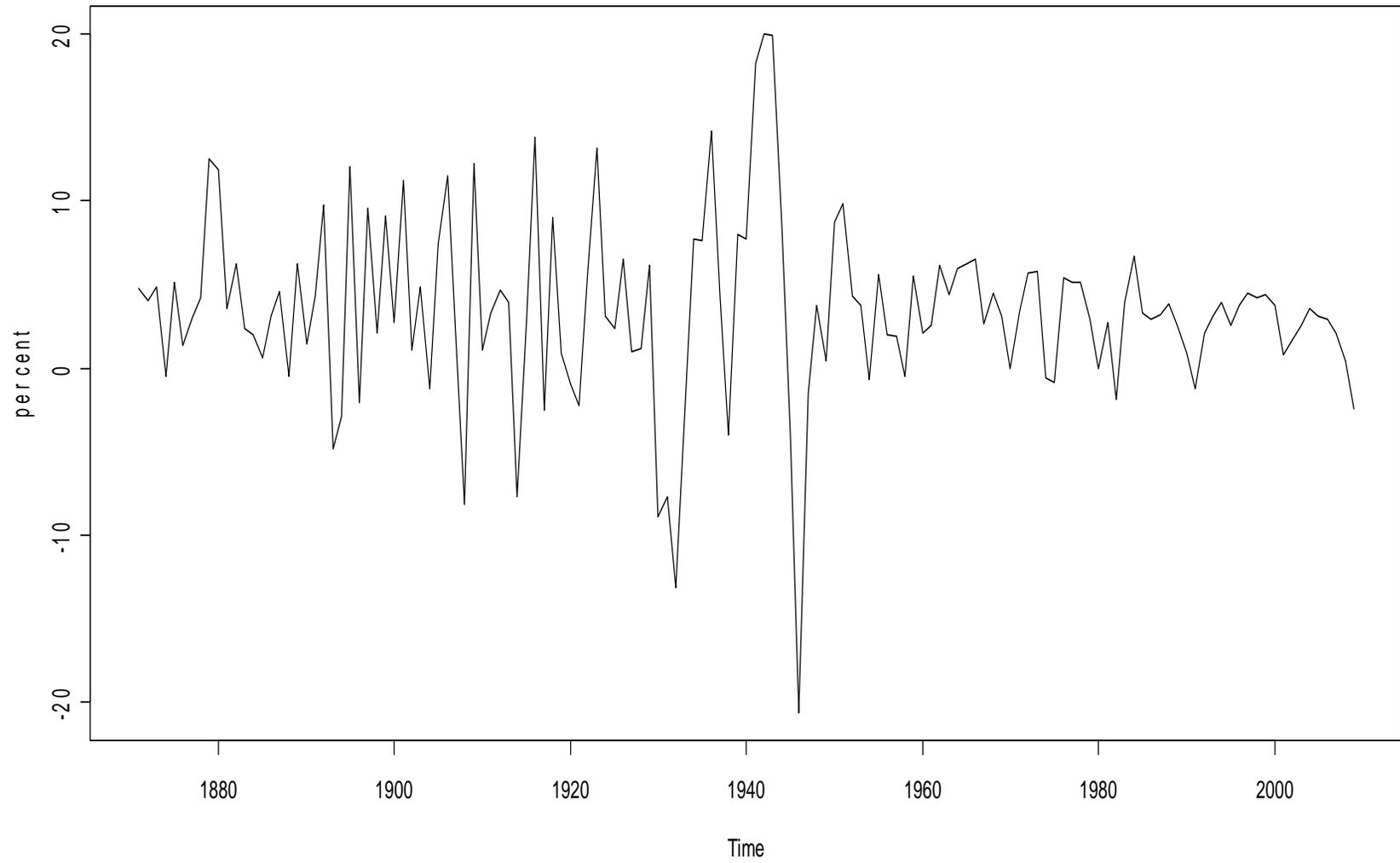
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Systems Dynamics UK Chapter Gathering

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Annual percentage change US real GDP
1871-2009



Output growth

- Why do economists talk about the 'business cycle'
- It is a piece of jargon but it does have meaning
- Autocorrelation functions are in general flat except possibly weakly positive at lag one
- Periodicity is poorly determined in the frequency domain
- But in general the different sectors of the economy tend to move together (Lucas 1977) – positive cross-correlations of sectoral output growth across the 'cycle'

Recessions

- There are many recessions, and they are not the same
- In 17 Western economies 1871-2009, over 200 individual examples of recessions
- The size distribution is very similar across countries (excluding the collapses at the end of WW2 in the defeated economies), so we might reasonably aspire to some general theorising

Cumulative fall in GDP, per cent, all recessions since 1871
17 Western countries

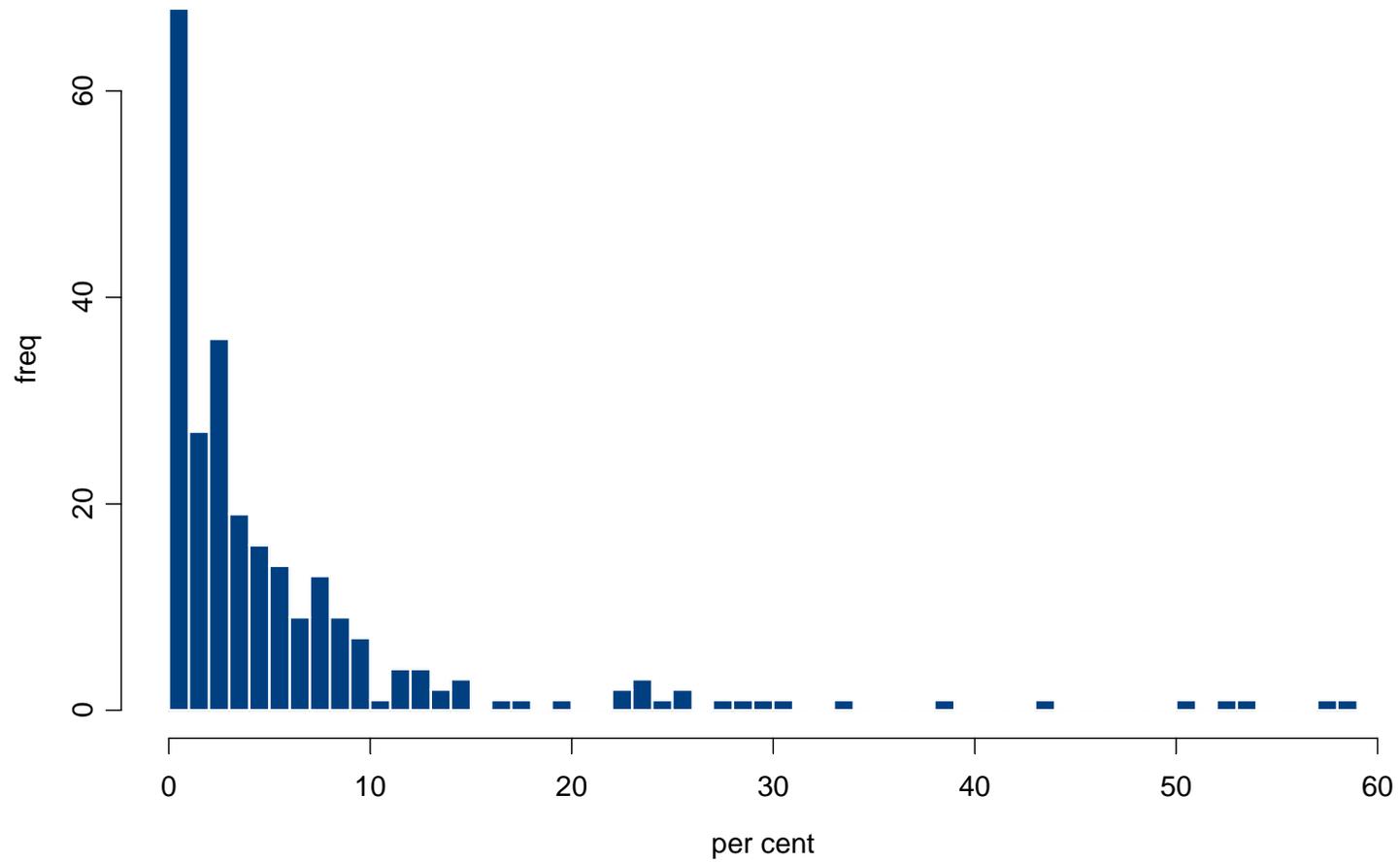


Table 1 *Duration of recession, years, i.e. number of consecutive years in which real GDP growth is less than zero*

Years	1	2	3	4	5	6	7
Number	164	58	20	6	5	1	1

ABM methodology

- There is usually a strong stochastic component to ABMs
- So we do not try to replicate any particular historical time series
- Instead, we try to replicate the system wide key features from agent-based rules
- So, aggregate output (GDP) is a key emergent property:
 - flat autocorrelation with perhaps mild positive 1st order
 - weakly determined 'cycles' (5-10 years)
 - most recessions are very short
 - non-Gaussian (exponential/Weibull) size distribution

Standard approaches

- Econometrics: fit planes through n-dimensional data to 'explain' a variable
- Equilibrium theory (Real business cycle, dynamic stochastic general equilibrium)
- In these models, recessions are caused by external shocks, the economy has a tendency to remain in equilibrium
- A single agent represents the whole economy (creditors and debtors??)
- It maximises its utility by selecting in every period between work and leisure. It then allocates output to consumption or investment
- On the theory, the Great Depression (25 per cent unemployment in some countries) was an extended voluntary holiday (Krugman)

ABMs and system dynamics

- These approaches have much in common
- The fluctuations are generated within the system, not externally (though such shocks can be administered)
- There is a non-mainstream tradition in economics which takes this view e.g. Marx, Hayek, Keynes
- SD models specify a probability of transition between two different states of the world which is common across agents
- ABMs allow for different probabilities (heterogeneous agents)

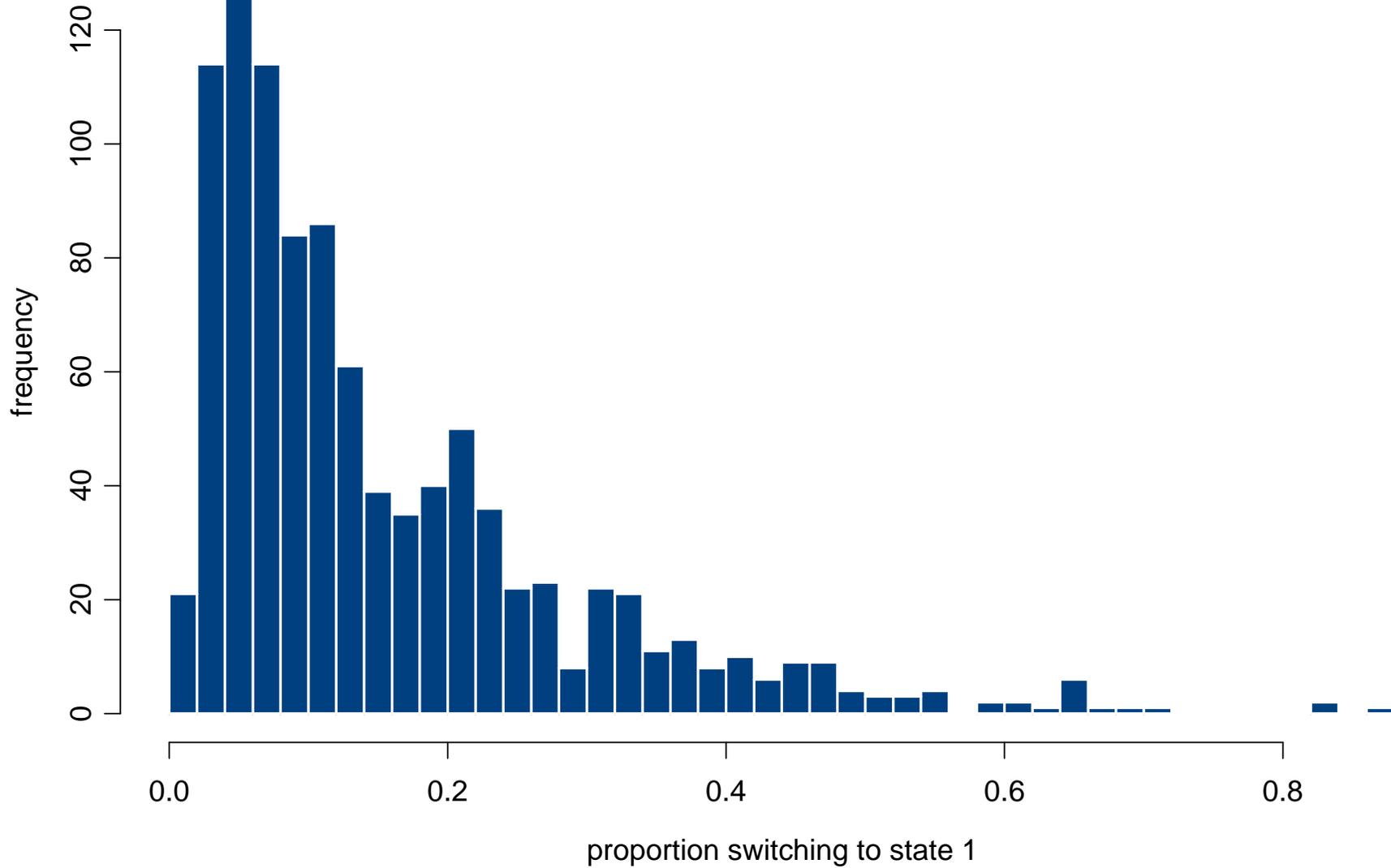
Some macro theory (long) before equilibrium models

- Keynes stressed uncertainty not just in the *General Theory* but in *Treatise on Probability*
- the outstanding fact is the extreme precariousness of the basis of knowledge on which our estimates of prospective yield [of a new investment] have to be made ... If we speak frankly, we have to admit that our basis of knowledge for estimating the yield ten years hence of a railway, a copper mine, a textile factory, the goodwill of a patent medicine, an Atlantic liner, a building in the City of London amounts to little and sometimes to nothing; or even five years hence': Keynes *General Theory*
- Hayek: inherent limits to knowledge
- Hayek and the business cycle: Firms and governments operate in such a complex environment that not only are their expectations often proved wrong, but they are unable to learn sufficient from the past in order to avoid the same mistake in future. The level of uncertainty is so high that even the central bank cannot learn to offset expectations by changes in monetary policy in order to smooth out the cycle and restore equilibrium.

Sentiment

- A key feature is the percolation of sentiment across networks
- At its simplest, this is a binary choice: optimistic or pessimistic
- Watts 'Global cascades on random networks', *Proceedings of the National Academy of Sciences*, 2002
- Agents in state of world 0 or 1, initially all in zero
- Each agent allocated a threshold from a uniform random on $[0,1]$
- The agent switches if the proportion of those to which it is connected in a different state is above its threshold
- Small number of agents selected at random to switch to state 1
- How far does the cascade spread?

Distribution of size of cascade: identical initial shock
1000 solutions, small world network



A very simple ABM

- The origin of most of the fluctuations is in the corporate sector
- Model of top 500 firms
- Firms set rate of growth of output and level of 'sentiment'

Each agent sets its rate of growth of output in period t by:

$$x_i(t) = [Y(t-1) + \varepsilon_i(t)] \quad (1)$$

where $x_i(t)$ is the rate of growth of output of agent i in period t , $Y(t-1)$ is the average sentiment of all agents (the weighted sum of the level of sentiment of all individual agents). Equation (1) implies that in making the

The sentiment of the i th agent is determined by the following:

$$y_i(t) = (1 - \beta)y_i(t-1) - \beta[X(t-1) + \eta_i(t)] \quad (2)$$

Results

- Solve the model 1000 times, say
- This very simple model gives a good replication of the key empirical features of aggregate output noted above
- And there is positive cross-correlation of the growth rates of the individual firms