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Complexity & Networks

Entangled economy: An ecosystems approach to modelling systemic level dynamics

- Dynamics of entangled co-evolving agents

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Why Tangled Nature ?

Last paragraph to the Origin of Species

It is interesting to contemplate a tangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent upon each other in so complex a manner, have all been produced by laws acting around us.

One may probably make a similar observation concerning the economy.

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The Approach

- Web of interdependence
- Mode and stability of dynamics

See e.g.

H.J. Jensen,
Tangled Nature: *A model of emergent structure and temporal mode among co-evolving agents*.
European Journal of Physics **40**, 014005 (2018).

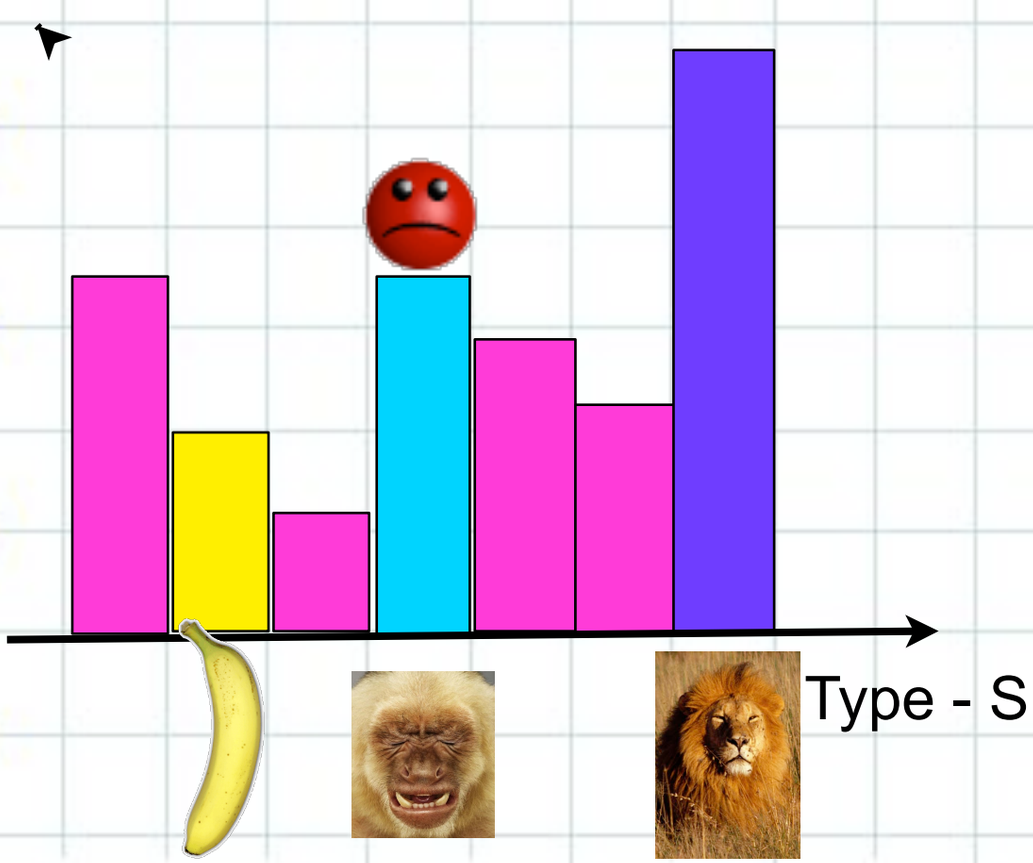
P. Anderson and H.J. Jensen,
Network Properties, Species Abundance and Evolution in a model of Evolutionary Ecology.
J. Theor. Biol. **232/4** , 551-558 (2004).

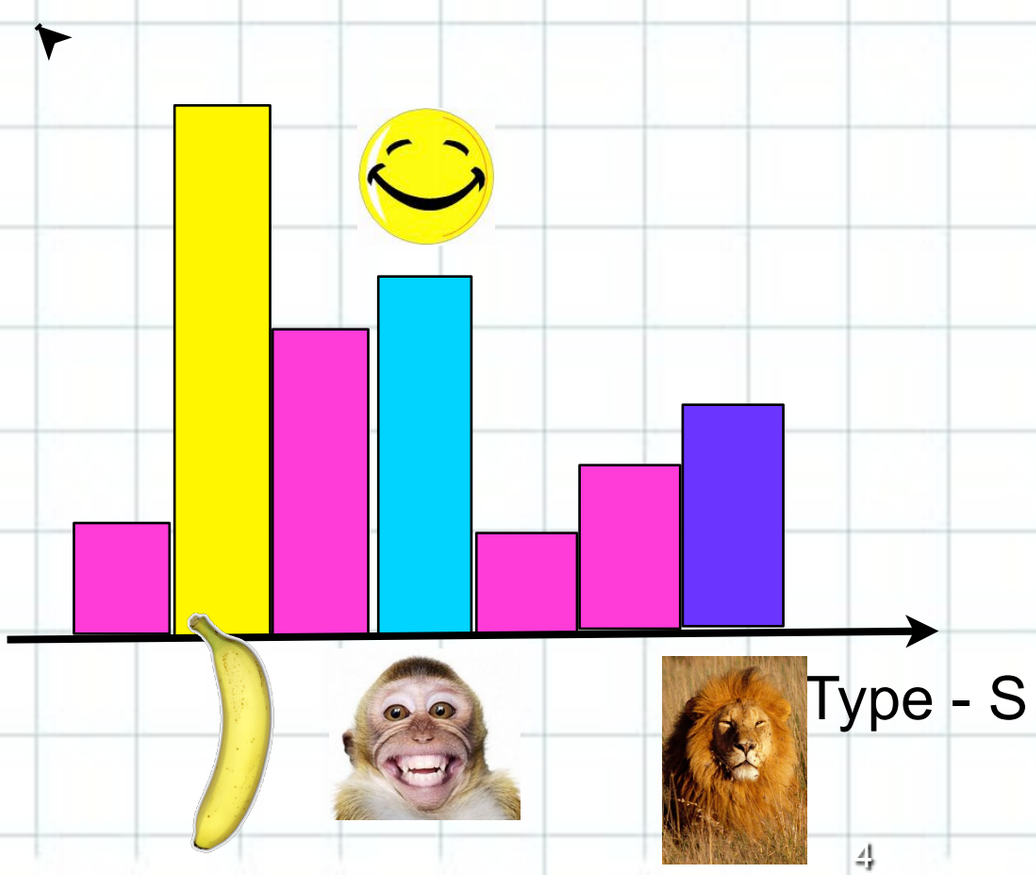
H..J. Jensen and E. Arcaute,
Complexity, Collective Effects and Modelling of Ecosystems: formation, function and stability.
Annals of the NY Acad. of Scie. **1195**, E19-E26 (2010).

Interaction and co-evolution

The Tangled Nature model

- Individuals reproducing in type space
- Your success depends on who you are amongst

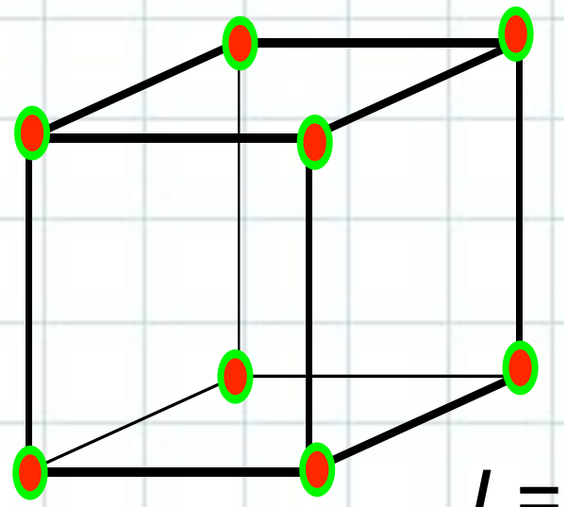




Definition

Individuals $\mathbf{S}^{\alpha} = (S_1^{\alpha}, S_2^{\alpha}, \ldots, S_L^{\alpha})$, where $S_i^{\alpha} = \pm 1$

and $\alpha = 1,2,\ldots, N(t)$



$L = 3$

Dynamics – a time step

Annihilation

Choose indiv. at random, remove with probability

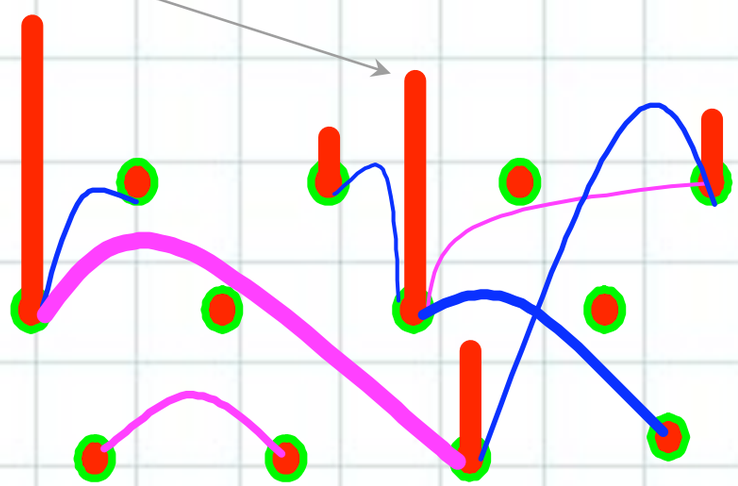
$$p_{kill} = const$$

Reproduction:

- Choose indiv. at random
- Determine

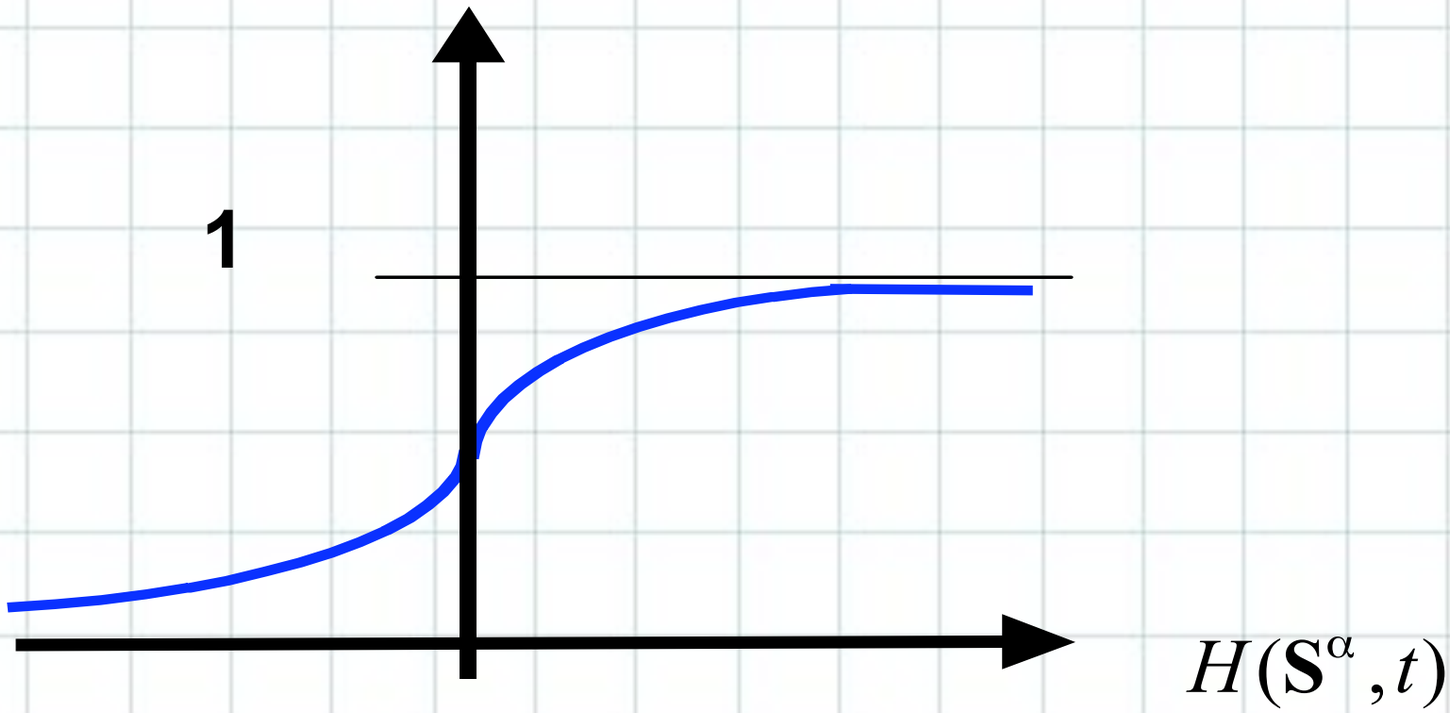
$$H(\mathbf{S}^{\alpha},t) = \frac{k}{N(t)} \sum_{\mathbf{S}} J(\mathbf{S}^{\alpha},\mathbf{S}) n(\mathbf{S},t) - \mu\, N(t)$$

$n(\mathbf{S},t) =$ occupancy at the location $\mathbf{S}$



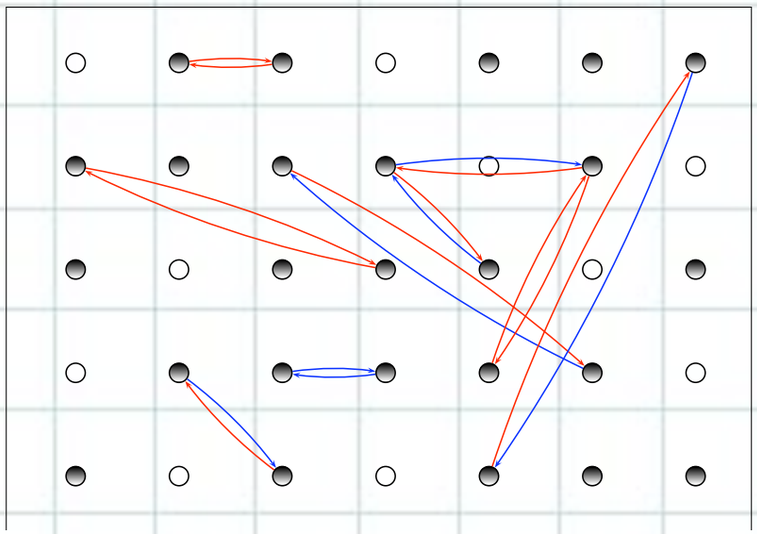
from $H(\mathbf{S}^{\alpha},t)$ reproduction probability

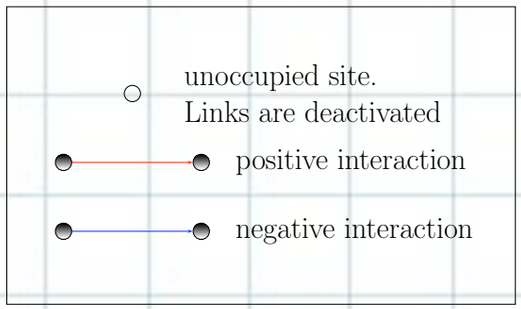
$$p_{off}(\mathbf{S}^{\alpha},t)=\frac{\exp[H(\mathbf{S}^{\alpha},t)]}{1+\exp[H(\mathbf{S}^{\alpha},t)]}\in[0,1]$$

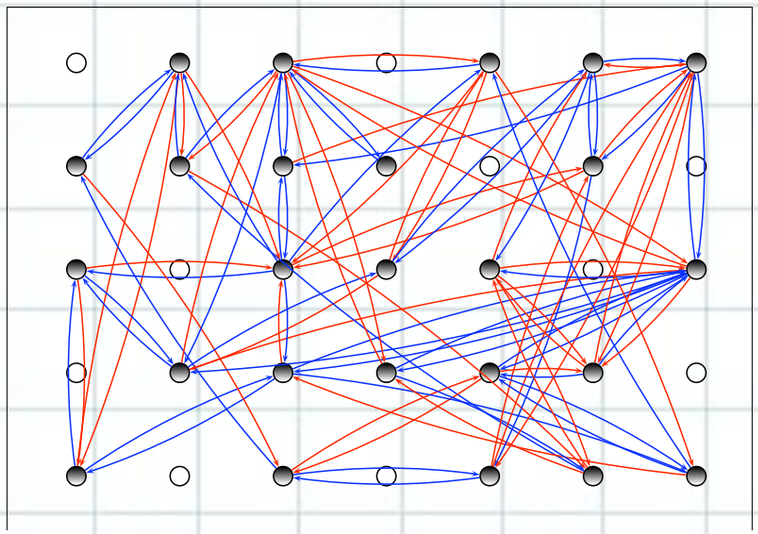


The coupling matrix J(S,S')

- Either consider J(S,S') to be uncorrelated
- or to vary smoothly through type space
- and sparse or dense



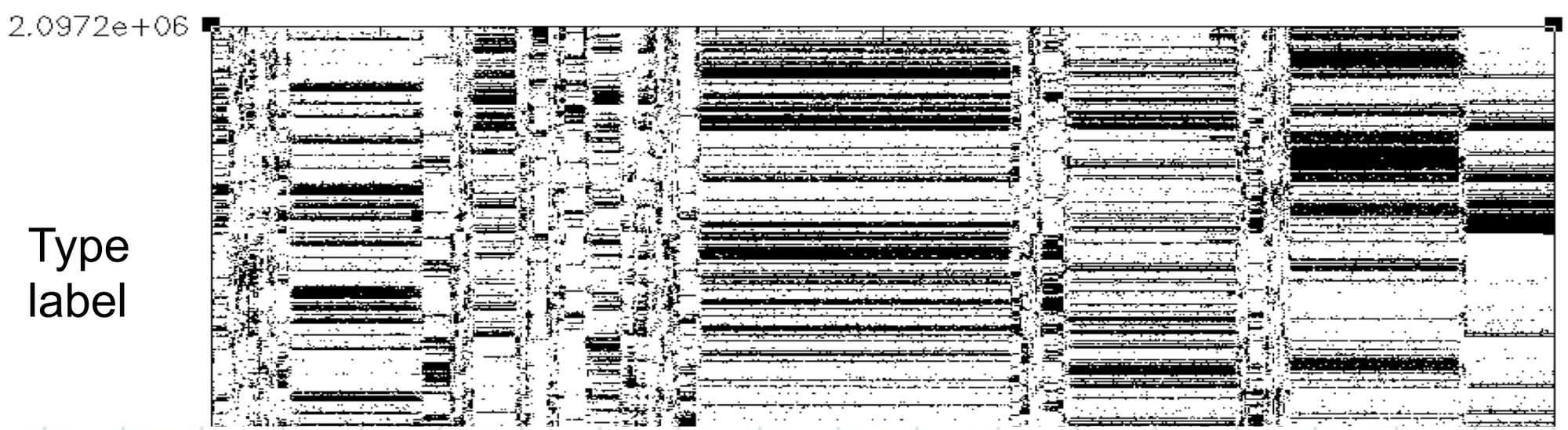




Macro dynamics:

Non correlated

Graph courtesy to Matt Hall



1 generation
= $N(t) / p_{kill}$

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Tangled Economy

with

Juan D Robalino

now

Economics Department

Cornell University

J D Robalino and H.J. Jensen,
Entangled economy: An ecosystems approach to modeling systemic level dynamics,
Physica A 392, 773 (2012)

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Use correlated $J(S_1,S_2)$

Consider **S** to label economical entities, say companies of capital C(**S**,t)

Dynamics:

Define

$$P_{gain} = \frac{\exp[H(\alpha,t)]}{1+\exp[H(\alpha,t)]}$$

Replacement

$$n(\mathbf{S},t) \rightarrow C(\mathbf{S},t)$$

Dynamics

With probability $P_{gain}(\mathbf{S},t)$:

$$C(\mathbf{S},t+1) = C(\mathbf{S},t)(1+c_g \frac{J^+(\mathbf{S})}{J^{Tot}(\mathbf{S})})$$

With probability $1-P_{gain}(\mathbf{S},t)$:

$$C(\mathbf{S},t+1) = C(\mathbf{S},t)(1-c_l \frac{J^-(\mathbf{S})}{J^{Tot}(\mathbf{S})})$$

Model versus reality

Comparison of growth rates

J.D. Robalino, H.J. Jensen / Physica A 392 (2013) 773–784

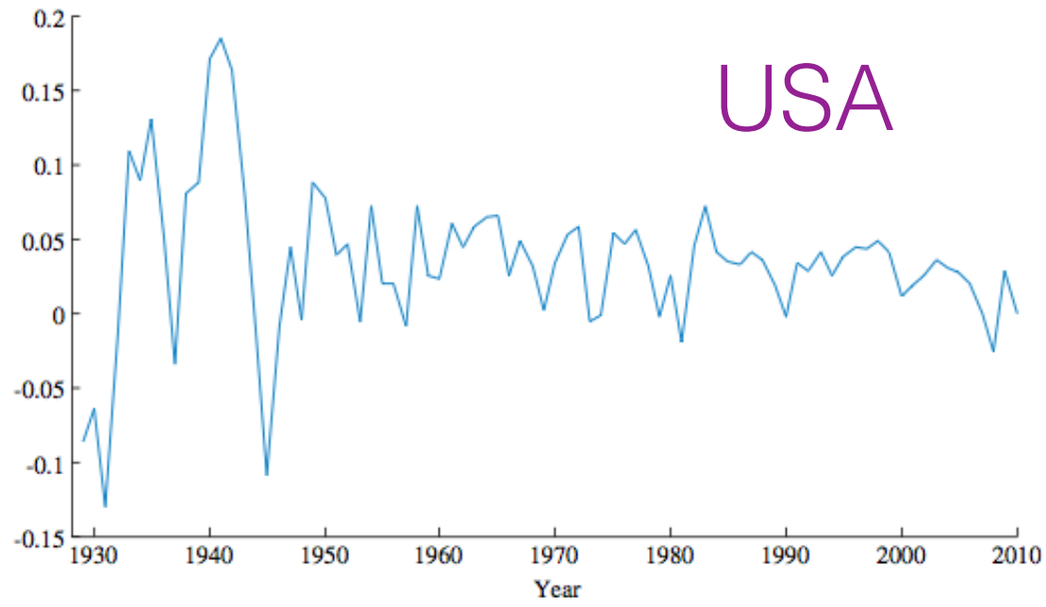

Fig. 2. US GDP growth 1929–2010. Corrected for inflation.
Source: Bureau of Economic Analysis.

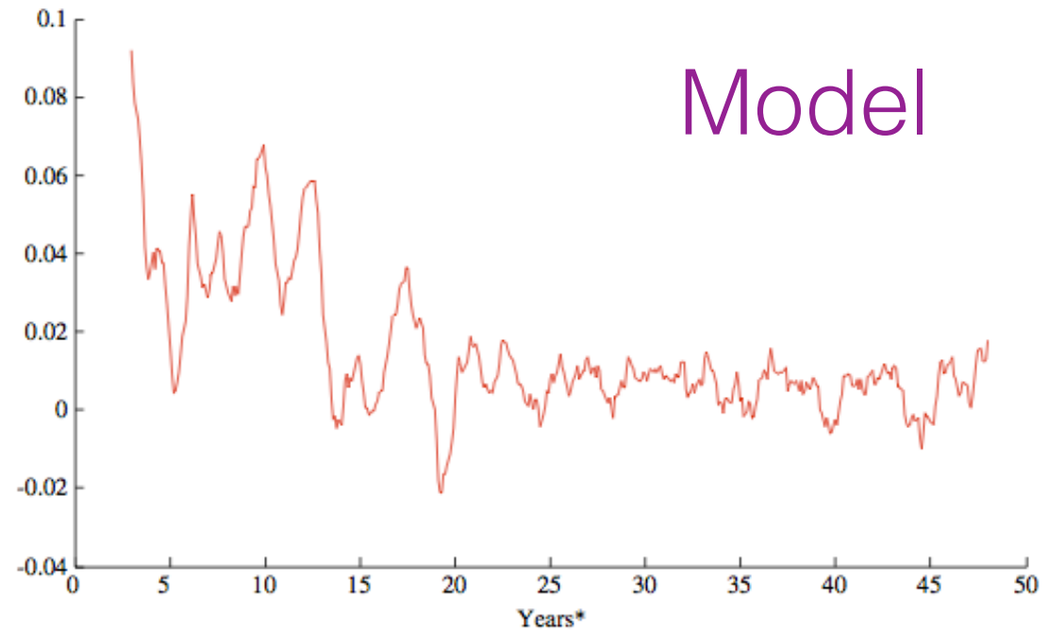

Fig. 3. Model annual GDP growth. * 1 year = 100 iterations.

Model versus reality

Distribution of company sizes
as measured by capital

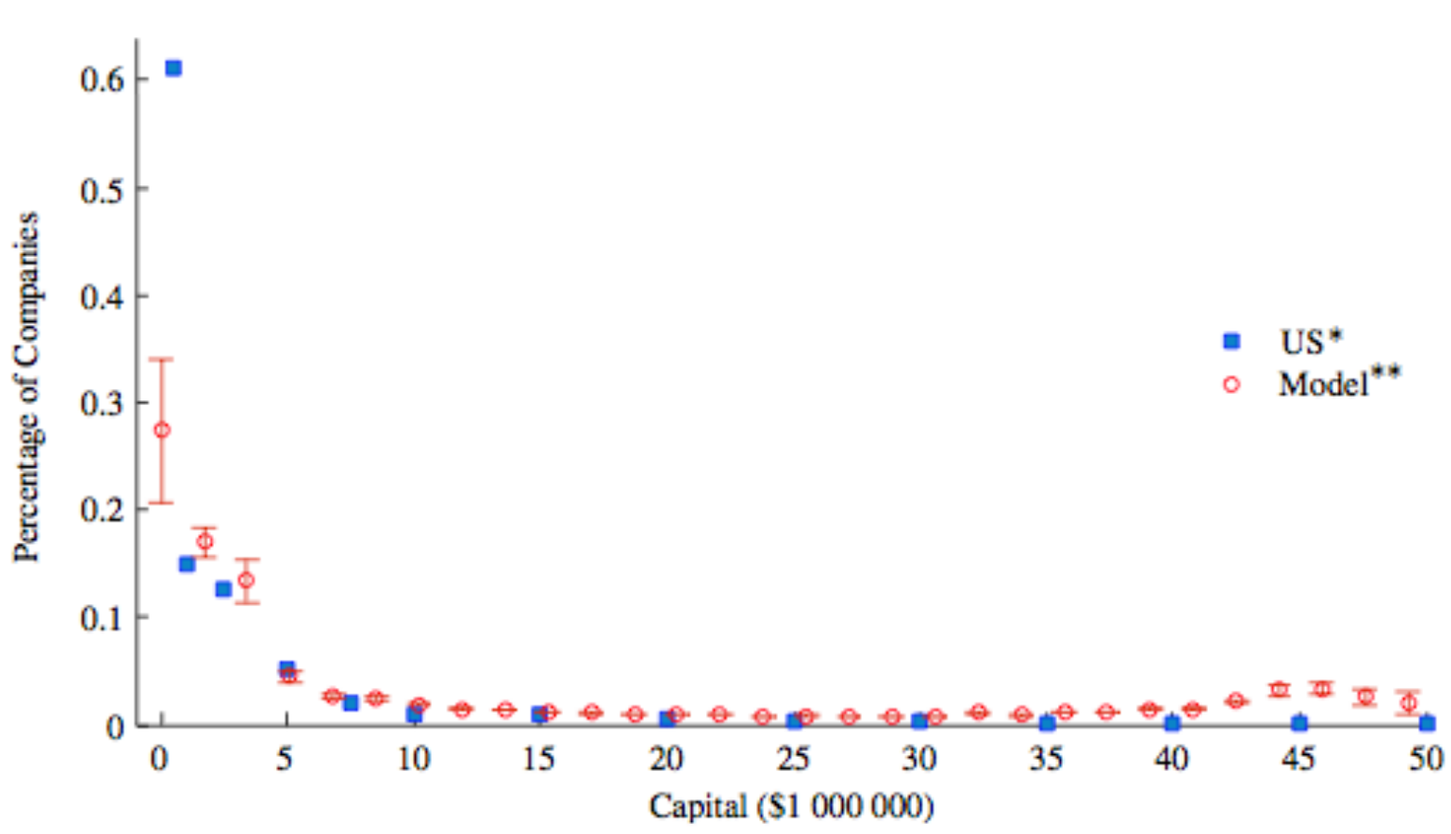

Fig. 6. Histograms of companies' capital. * Source: US Census Bureau 2007. Capital measured by companies' receipts' size. ** Model at $t = 4900$; $1 = 0.0006 model currency.

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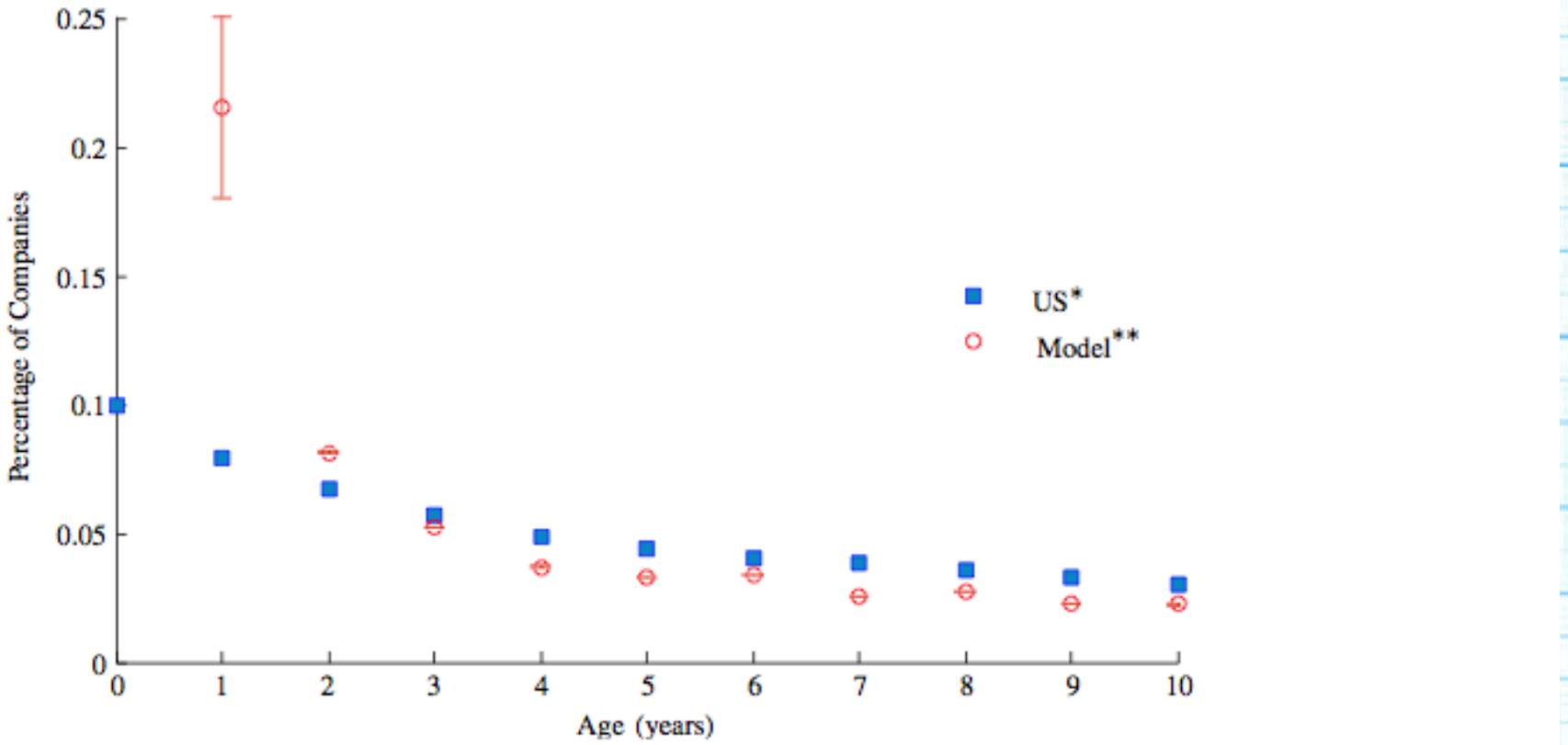

Fig. 7. Histogram of companies' age. * Source: US Census Bureau 2007; data points for age 6–10 are estimates from the 5-year average. ** Model at $t = 4900$; 1 year = 100 iterations.

The GDP growth rates are computed with a lag of 100 iterations giving realistic values for annual growth rates.
We use this comparison to calibrate the time scale of the model against real economical time, i.e. think of 100 iterations of the model as representing a one-year period in the real world.

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Applying the "entangled" approach

- **Crashes**
- **Collusion**

E. Viegas, M. Takayasu, W. Miura, K. Tamura, T. Ohnishi, H. Takayasu and H.J. Jensen,
Ecosystems perspective on financial networks: diagnostic tools.
Complexity **18**, 34 (2013)

- **Merger**

E. Viegas, S.P. Cockburn, H.J. Jensen and G.B. West
The dynamics of mergers and acquisitions: ancestry as the seminal determinant.
So be submitted or see arXiv:1401.5314

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Stability - crashes

with

Eduardo Viegas

Imperial and PwC

Imperial College London
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Evolutionary dynamics (copy the successful) generates crashes

(i) the dynamics of infection of business strategies within the banking sector and of culture dissemination within the investment and fund management community

(ii) the topological aspects of the network of interactions.

E. Viegas, M. Takayasu, W. Miura, K. Tamura, T. Ohnishi, H. Takayasu and H.J. Jensen,
Ecosystems perspective on financial networks: diagnostic tools.
Complexity **18**, 34 (2013)

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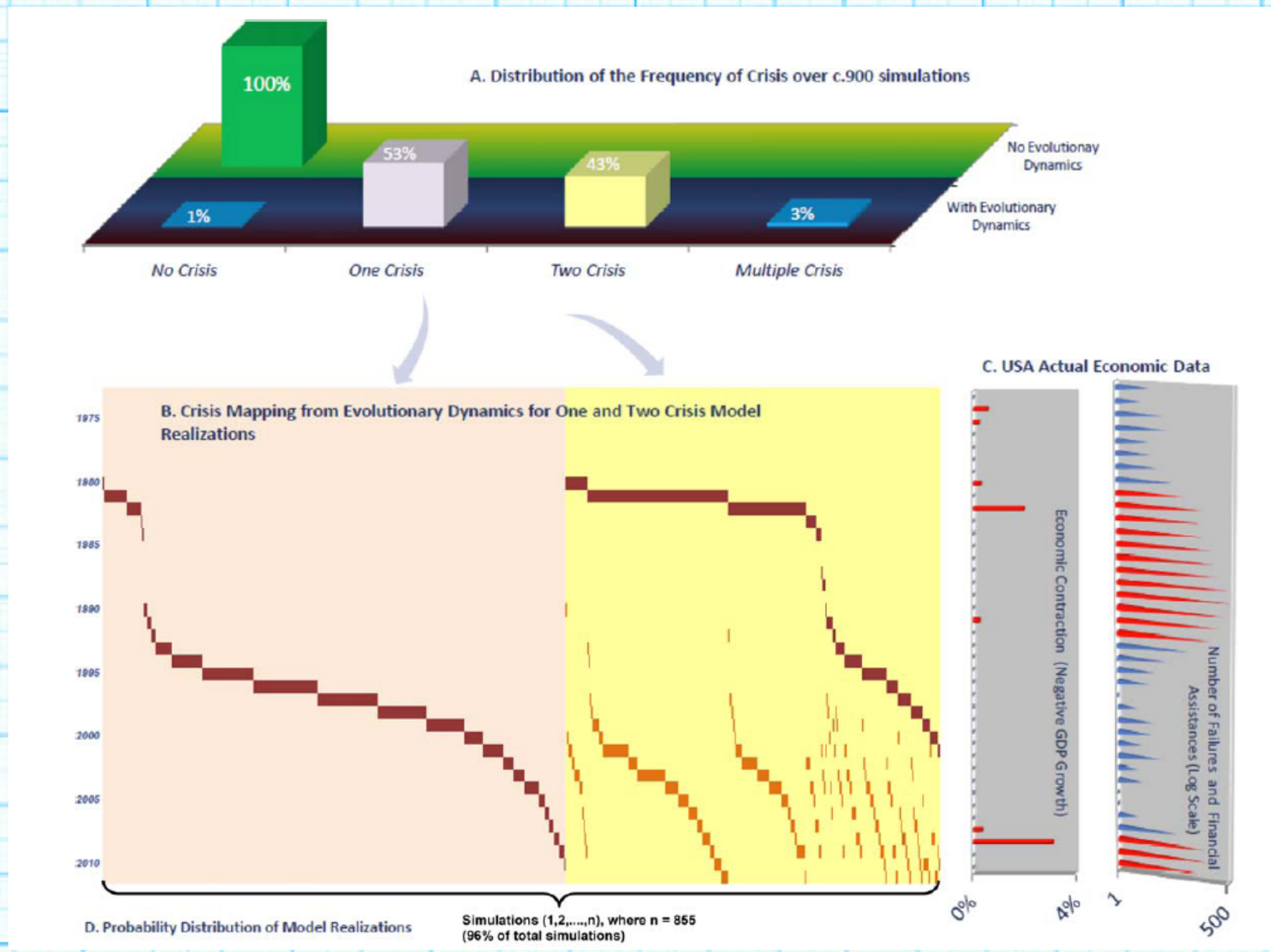

E. Viegas, M. Takayasu, W. Miura, K. Tamura, T. Ohnishi, H. Takayasu and H.J. Jensen,
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Emergence of dominate strategy

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Networks perspective

with

Misako and Hideki Takayasu

Tokyo Inst of Technology and Sony Research

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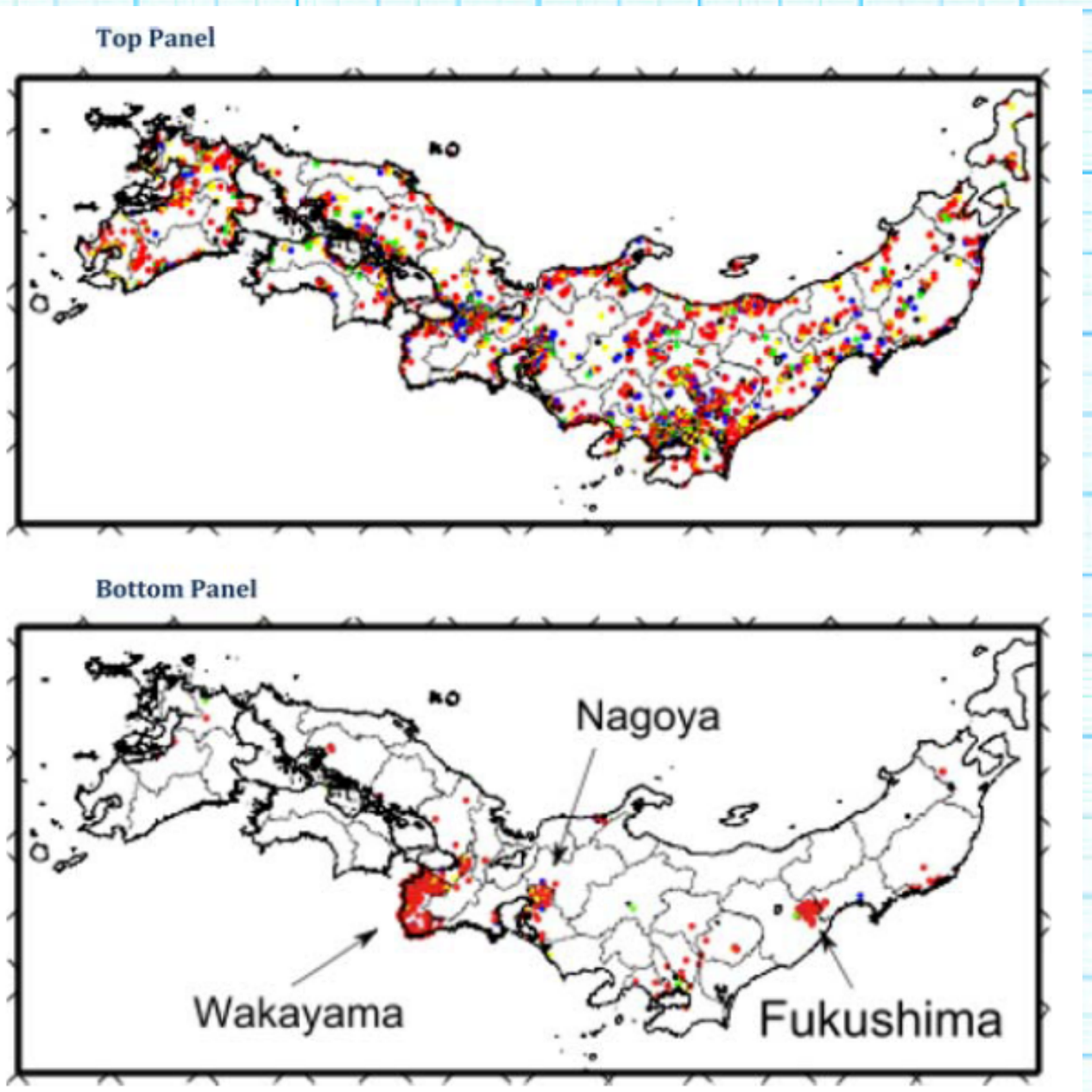
Network topology reveals collusion

Removal of nodes in descending order of degree



E. Viegas, M. Takayasu, W. Miura, K. Tamura, T. Ohnishi, H. Takayasu and H.J. Jensen,
Ecosystems perspective on financial networks: diagnostic tools.
Complexity **18**, 34 (2013)

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Phenotype - genotype: Dynamics of merger

with

Eduardo Viegas

Stuart P Cockburn

Imperial and PwC

Geoffrey West

Santa Fe Institute and Imperial

Imperial College London
Henrik Jeldtoft Jensen

Complexity & Networks

From

The dynamics of mergers and acquisitions: ancestry as the seminal determinant

Eduardo Viegas,[1,2] Stuart P. Cockburn,[2] Henrik J. Jensen,[1] and Geoffrey B. West[1,3]

Proc. R. Soc. A 2014 **470**, 20140370

Agent base dynamics

- Chose agent (bank) with probability
- Chose another agent at random (uniform)
- Merge

"Phenotype"
Eagerness to merge

$$p_{\text{merger}} = p(1 + n_{\text{A}})^{3/2}$$

"Genotype"
Number of mergers

From distribution of ancestry

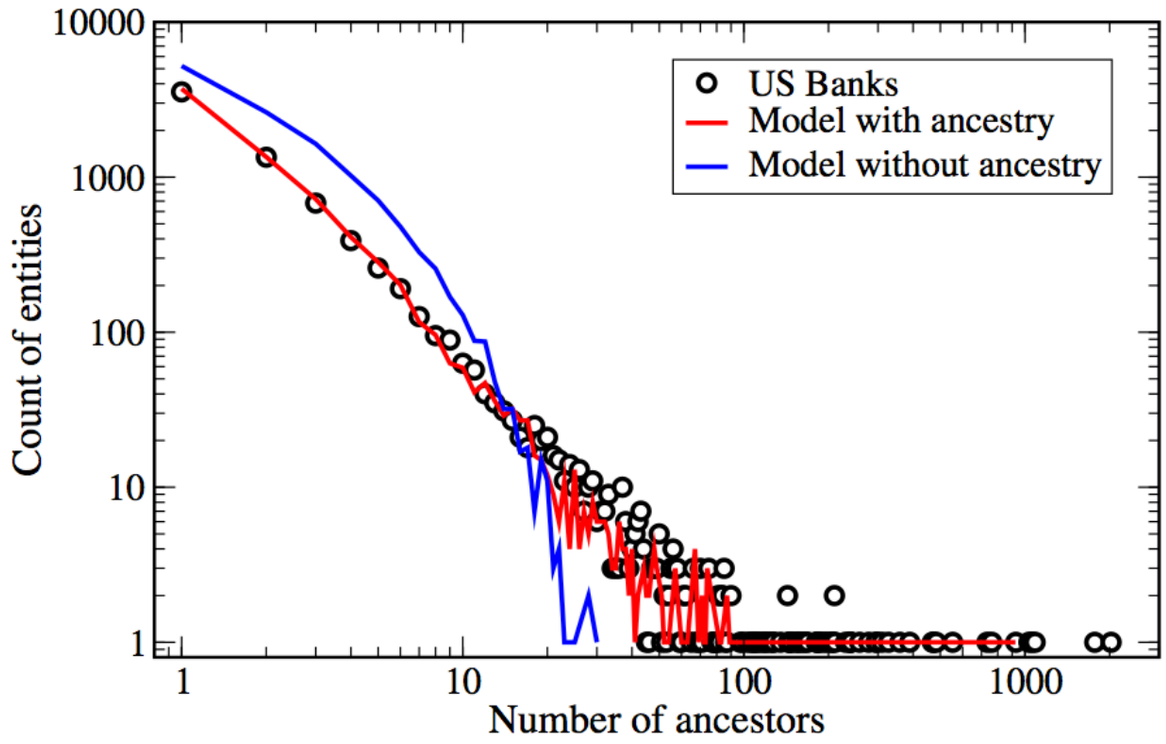

FIG. 3. **Importance of ancestry weighting to dynamics.** *A comparison is shown between US banking ancestry data and model simulations with (blue) and without (red) an ancestry weighted merger probability. Clearly the former leads to a far closer agreement with the US data.*

Ancestry determines eagerness for new acquisitions

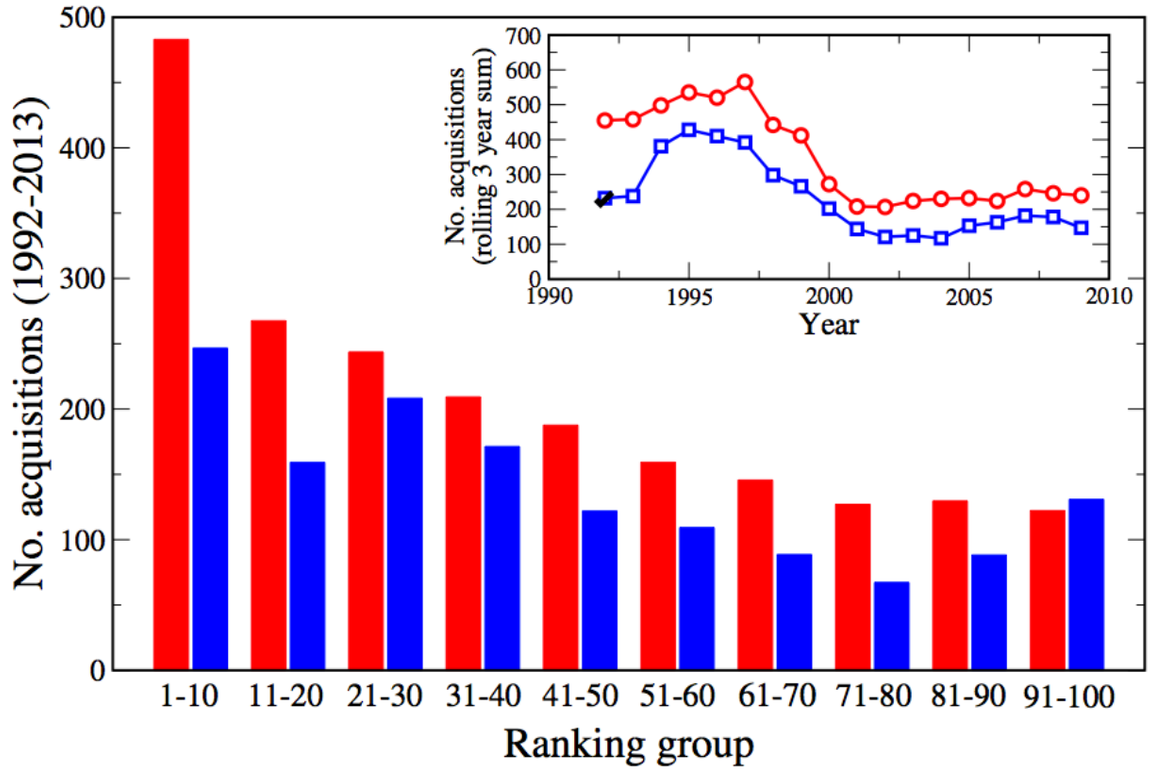

Figure 1: ***Comparison of ranking methods to predict merger activity for US banks: Ancestry (red) vs. balance sheet size (blue).*** *US banks are ranked based on ancestry (red) or balance sheet size (blue). The bar chart shows the time averaged number of mergers between banks (vertical axis) by ranking group (horizontal axis). Here, an increasing ranking group corresponds to a decrease in ancestor number or balance sheet size, as appropriate. For each ranking group, the number of acquisitions is averaged over a three year period, starting at each year between* 1992 *and* 2013. *The inset shows the ancestry (red) and balance sheet (blue) ranking methods as a function of time. Each data point shows the number of mergers that occurred within a* 3 *year window from the year indicated by its position on the horizontal axis. This is done for the top* 100 *banks.*

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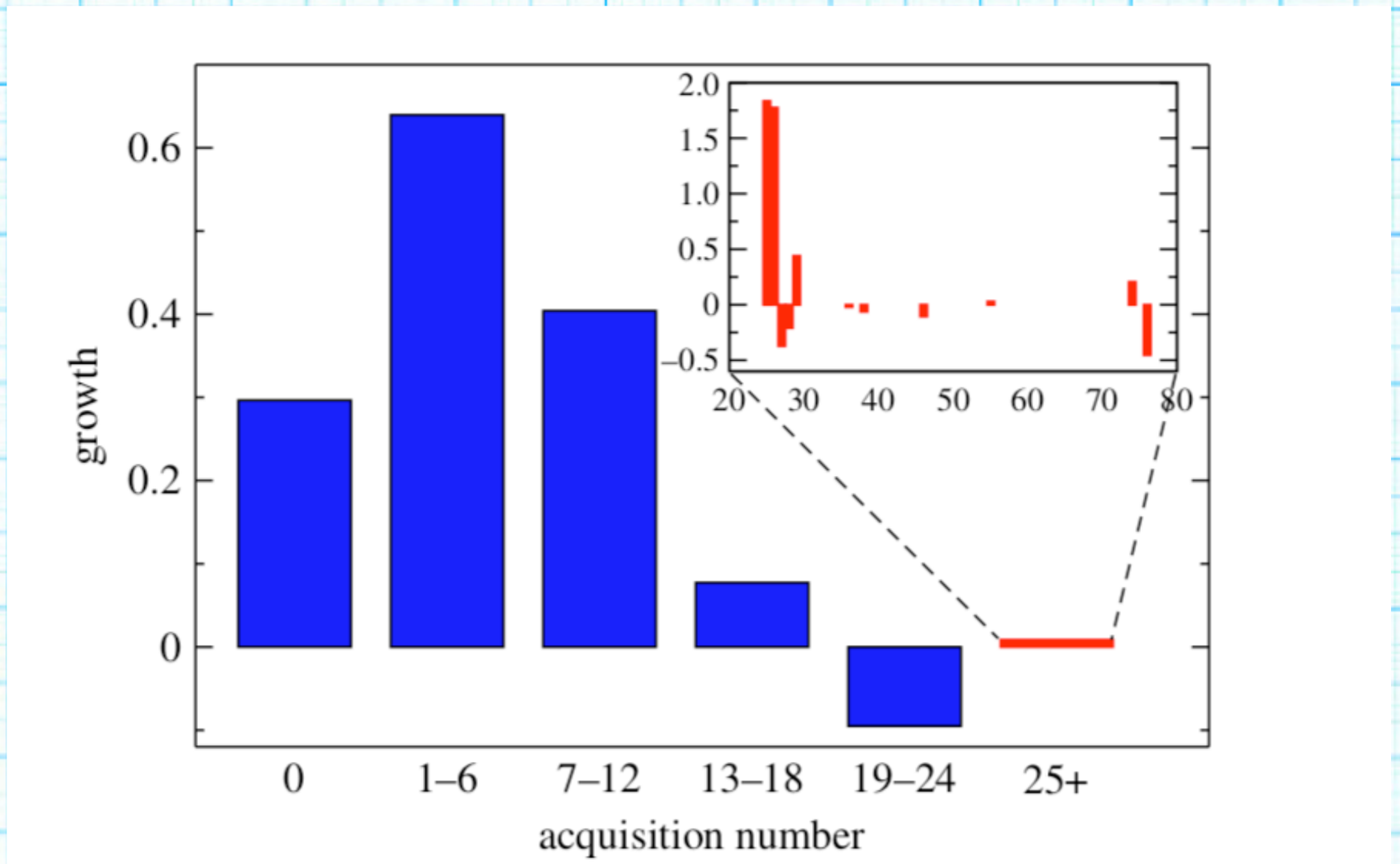
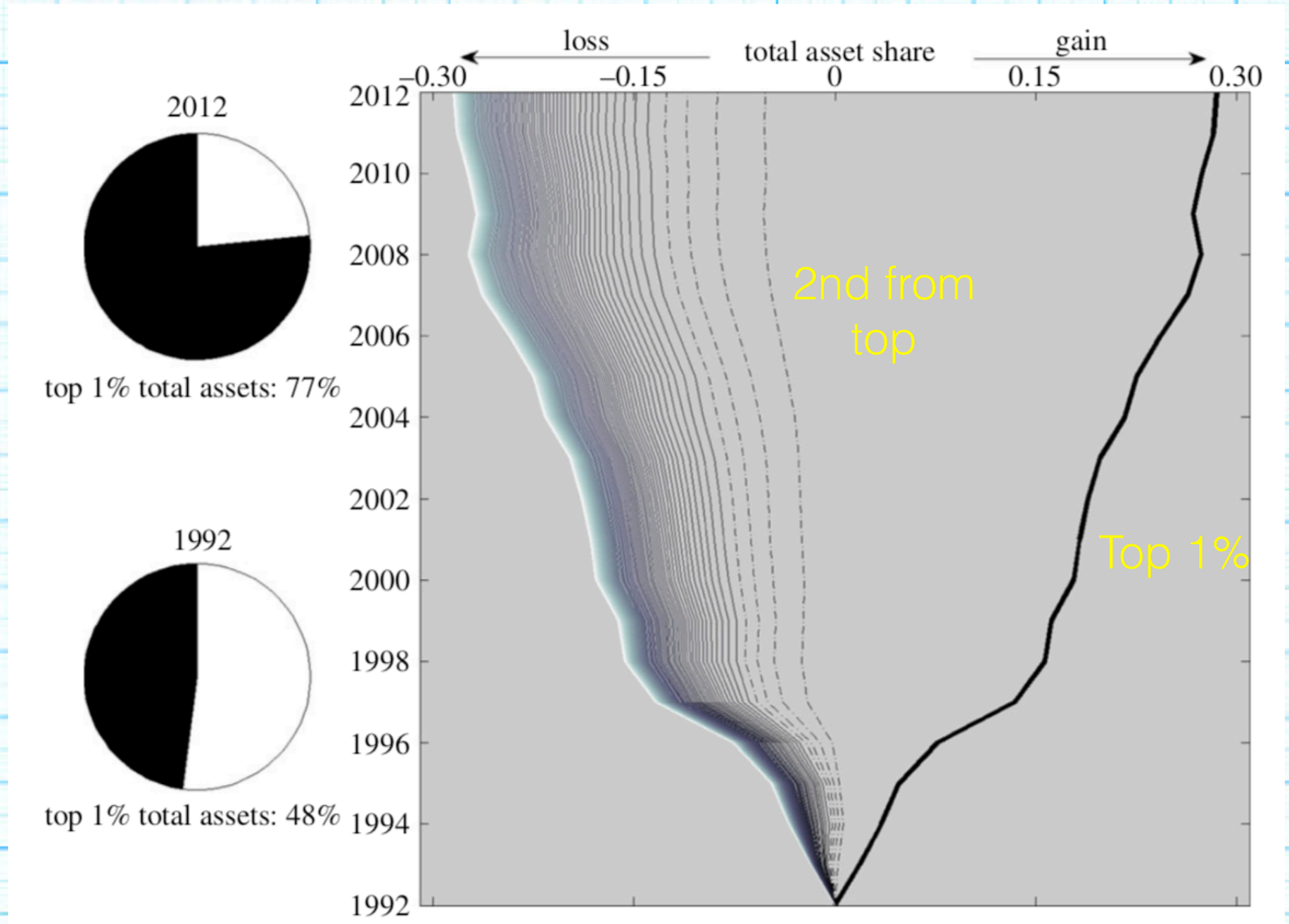
Merger and growth relative to GDP



Real growth hampered by too much merger

and leads to bi-modal success distribution



Conclusion

Co-evolutionary dynamics and networks perspective essential

From http://scientometrics.wordpress.com/tag/knowledge-management/

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Thank you

Collaboration with

Stuart P Cockburn

Juan D Robalino

Misako Takayasu

Hideki Takayasu

Eduardo Viegas

Geoffrey West

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