Paths towards instability in financial networks

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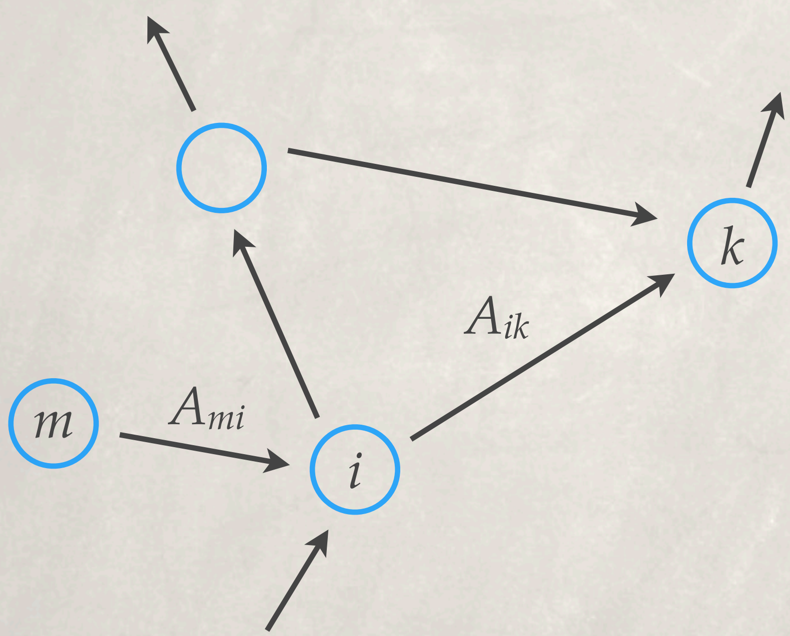
Motivations

- Larger markets can better absorb shocks, and therefore are more stable: market integration.
- From an individual perspective diversification lowers risk: more contract between banks
- But… What happens if we take interactions into account?
- Which are the implications for systemic risk and policy making?

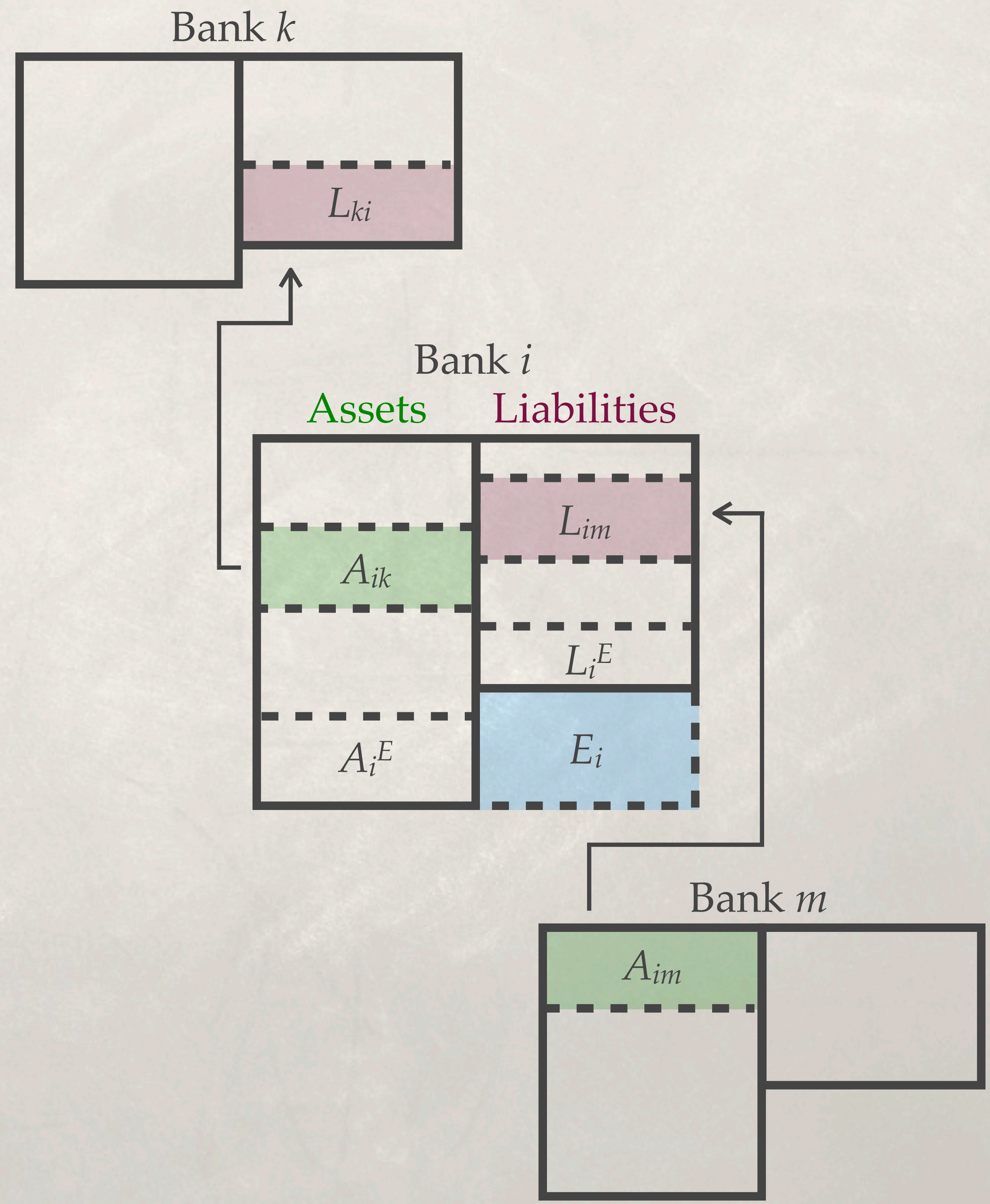
Networks of banks

A_{ik}: money bank k borrows from bank i



but there is a balance sheet identity:

$$E_i = A_i^E - L_i^E + \sum_j A_{ij} - \sum_j L_{ij}$$

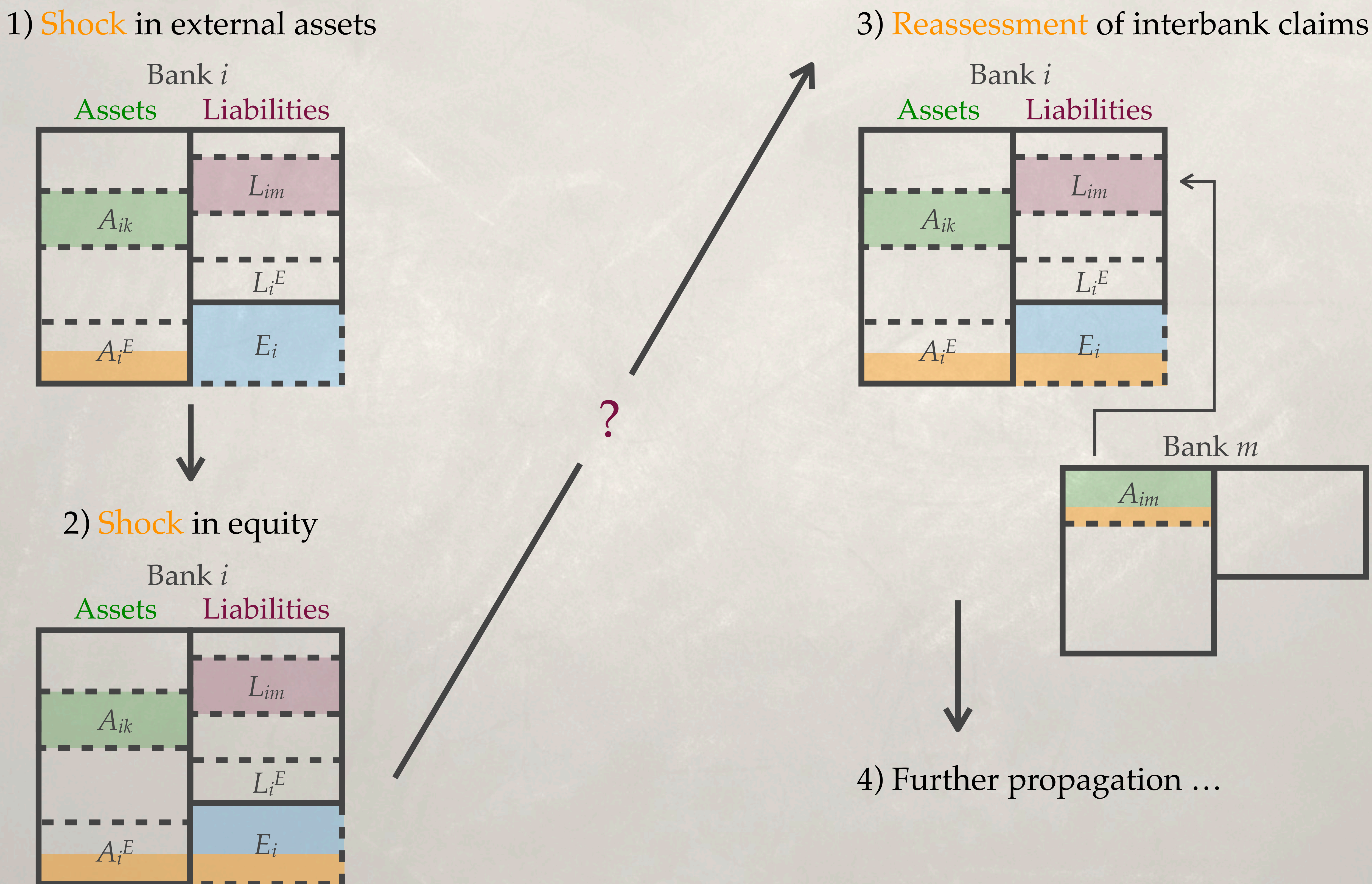


DebtRank

- DebtRank is an algorithm for propagating shocks in the interbank network.
- Shocks refer to distress (opposed to default): a banks becomes dangerous before it defaults via devaluation of lender's claims.
- It can be interpreted as an algorithm propagating information so that all banks can agree on a common evaluation of assets.
- DebtRank is applied by the European Central Bank for experimental stress tests and we have an ongoing collaboration with the Bank of England.

S. Battiston et al., *Sci. Rep.* **2**, 541 (2012)

Shock Propagation



“Microscopic” approach

- Equities and interbank assets are consistent with the balance sheet identity at any time step:

$$E_i(t) = A_i^E(t) - L_i^E + \sum_j A_{ij}(t) - \sum_j L_{ij}$$

- Shocks propagate as lenders reassess the value of their assets depending on the probability of default of borrowers:

$$A_{ij}(t+1) = A_{ij}(0)(1 - p_j(t)) + (1 - \rho)A_{ij}(0)p_j(t)$$

- The simplest assumption is that the probability of default is equal to the relative cumulative loss:

$$p_i(t) = \frac{E_i(0) - E_i(t)}{E_i(0)}$$

Stability

- The dynamics in-between defaults is linear and one can easily study the stability of the banking system.

- The crucial quantity is the interbank leverage matrix: $\Lambda_{ij}(t) = A_{ij}(t) / E_i(t)$.

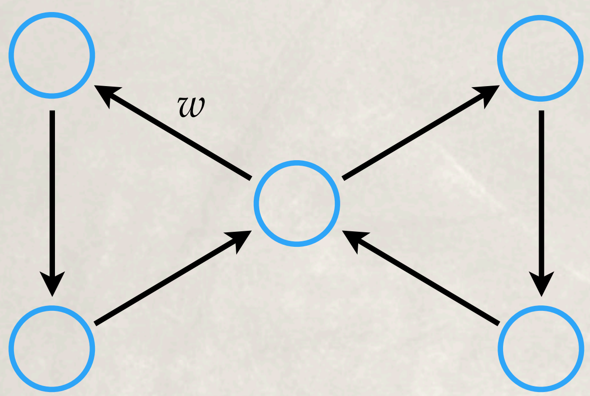
- If $|\lambda_{\max}| < 1$ the system is stable, otherwise is unstable and at least one bank will default. Interbank leverages change after the default and a previously unstable system can become stable.

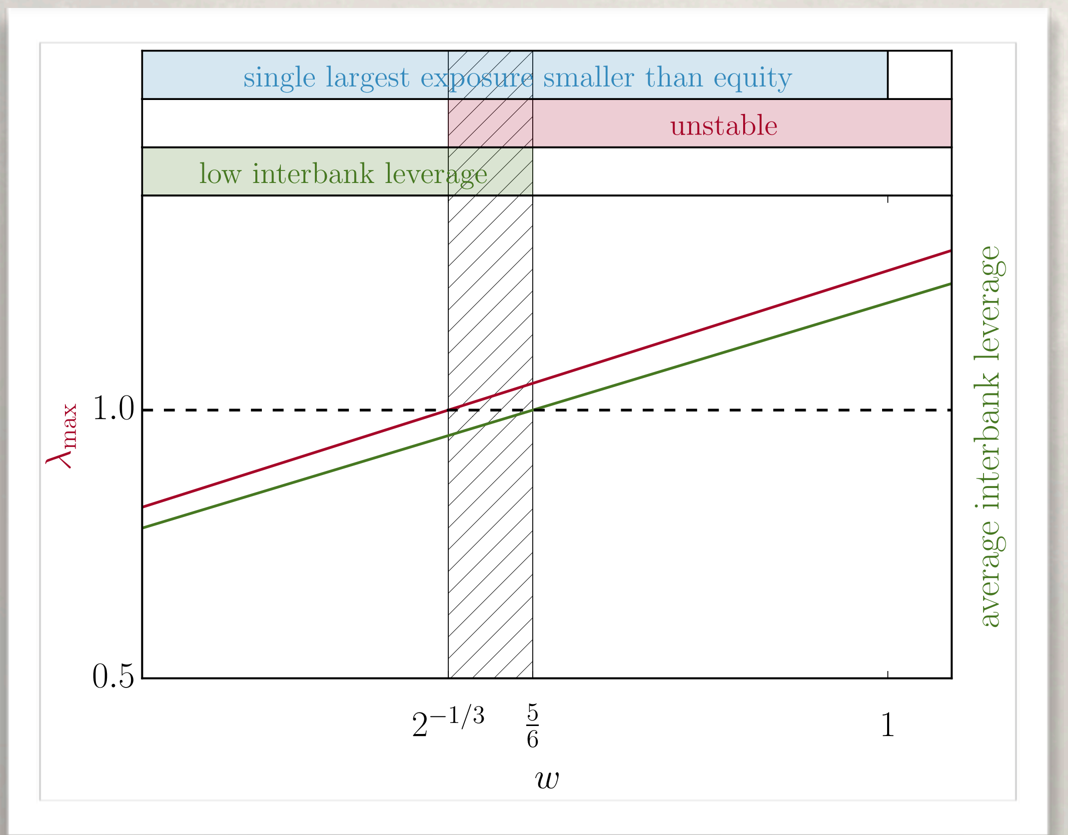
- Any (reasonable) dynamics has DebtRank as its linear approximation close to the stable fixed point $\Delta h = 0$.

MB, S. Battiston, G. Caldarelli, F. Caccioli, *PLoS One* **10**(7), e0134888 (2015)

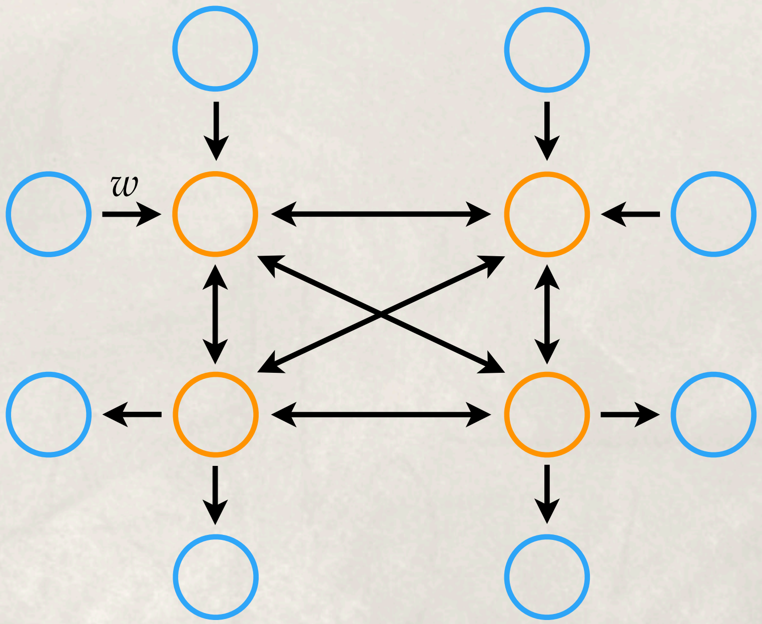
Unstable Topologies

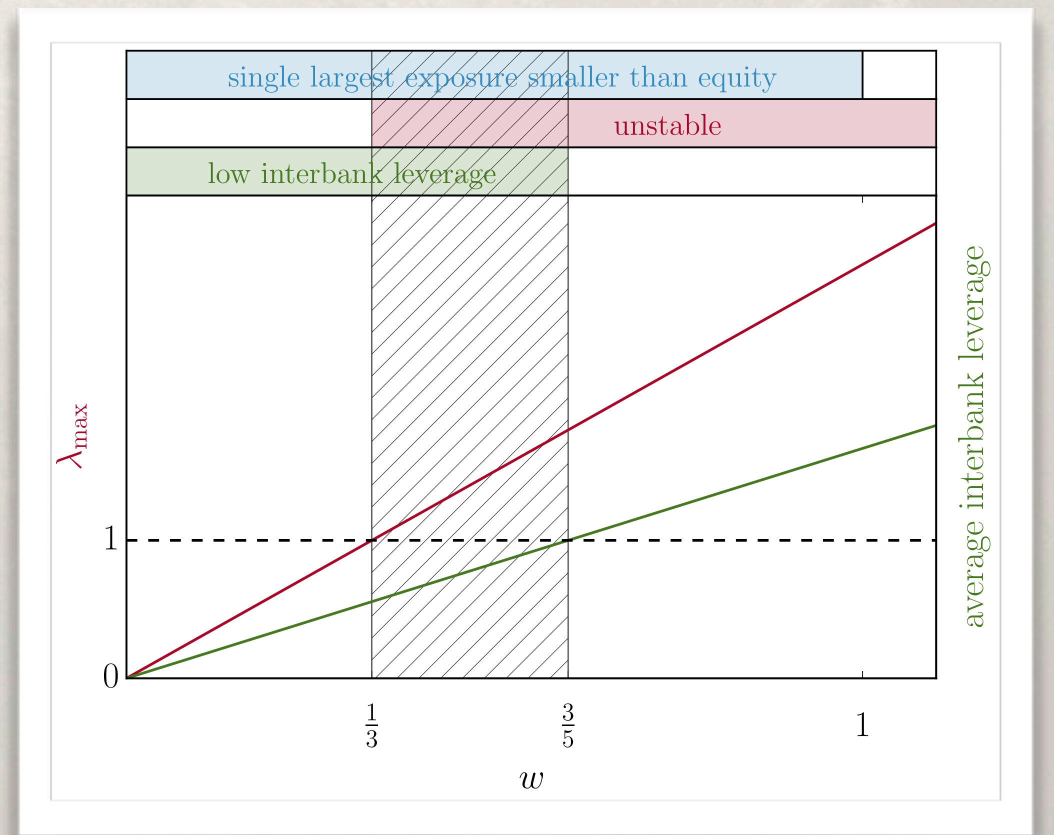
Butterfly





Core-periphery network





Adding nodes

Wigner-May theorem for an ecosystem with n species, interaction strength α, and connectivity p. A large system is stable if:

$$n\, p\, \alpha^2 < 1$$

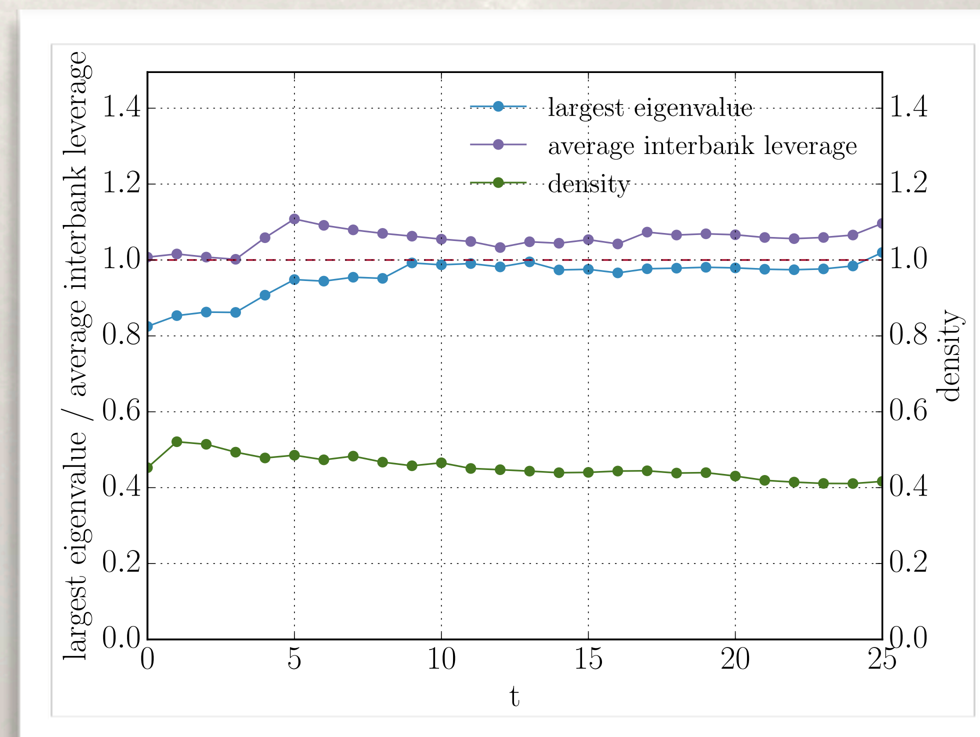
and unstable otherwise.

An interbank system with n banks, connectivity p, and mean interbank leverage μ/n is stable if:

$$(n - 1)\, p\, \mu < 1$$

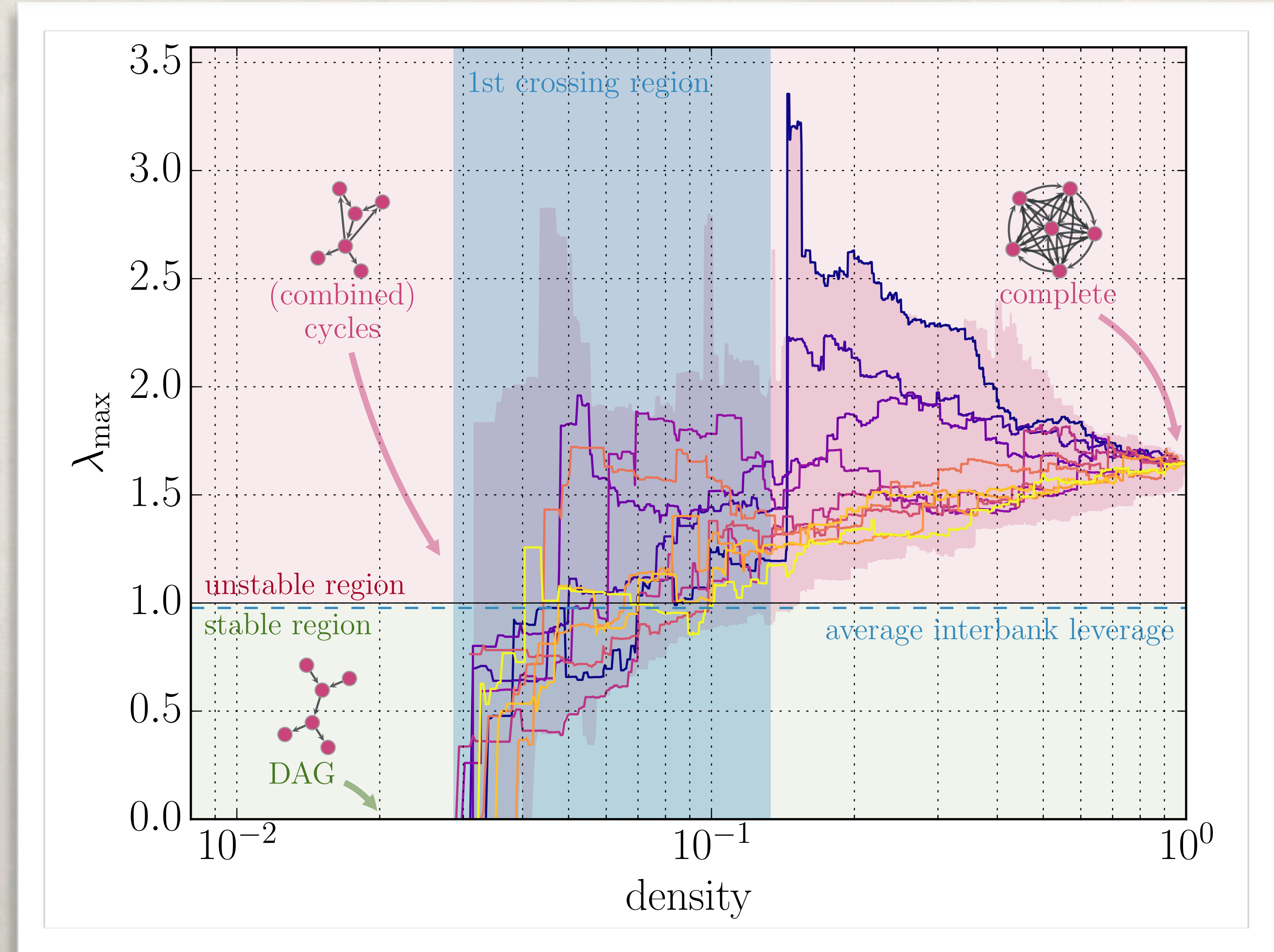
and unstable otherwise. (Entries of interbank leverage matrix i.i.d.)

What happens if we simulate a growth process starting from a finite network in the "wrong" phase?



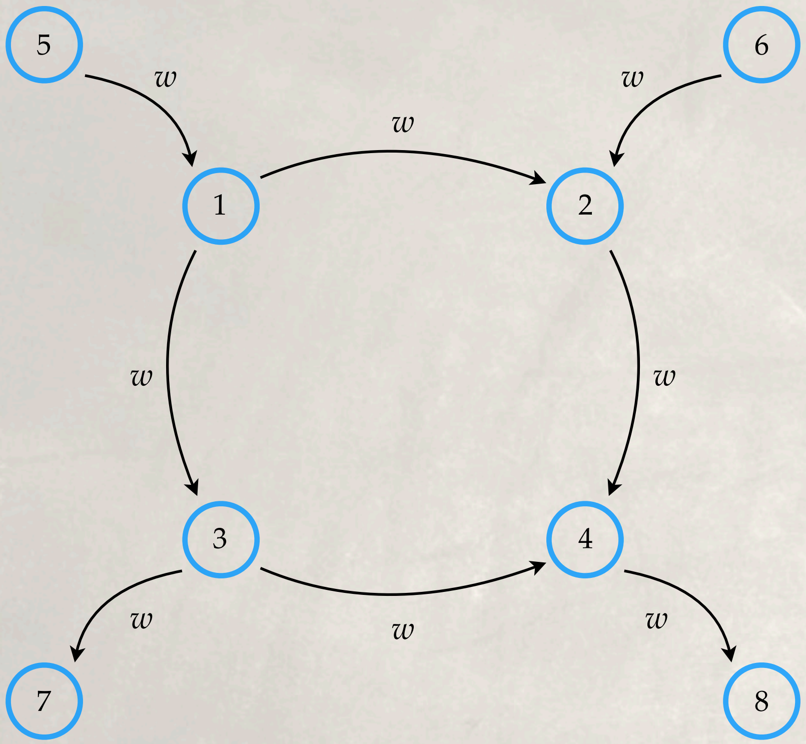
Adding edges

Top 50 EU banks: from a DAG to a complete graph, keeping consistency with balance sheets: instability arises already at density equal to 3%

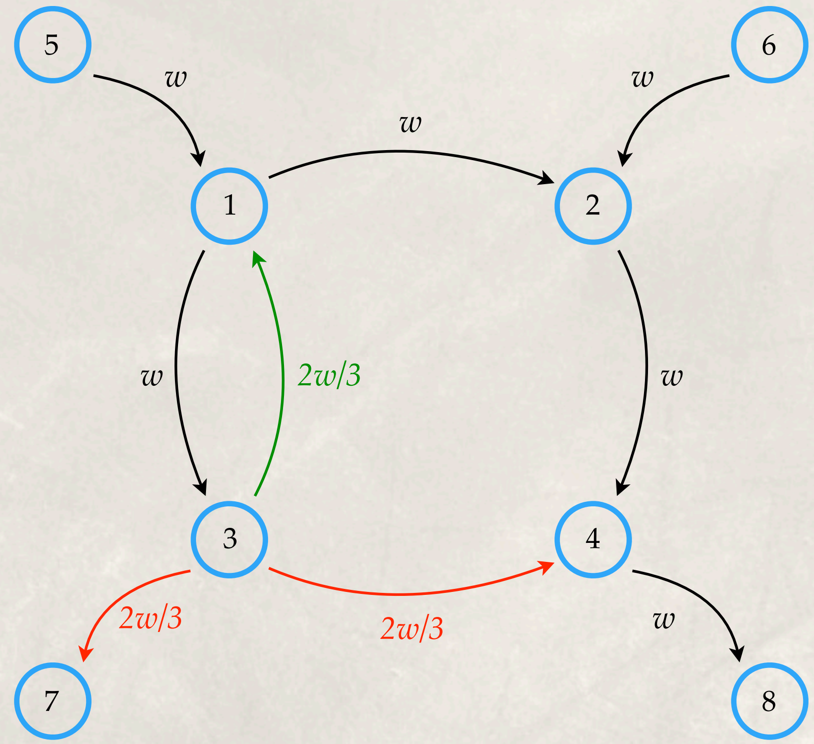


2013 (similar for 2008, …, 2012)

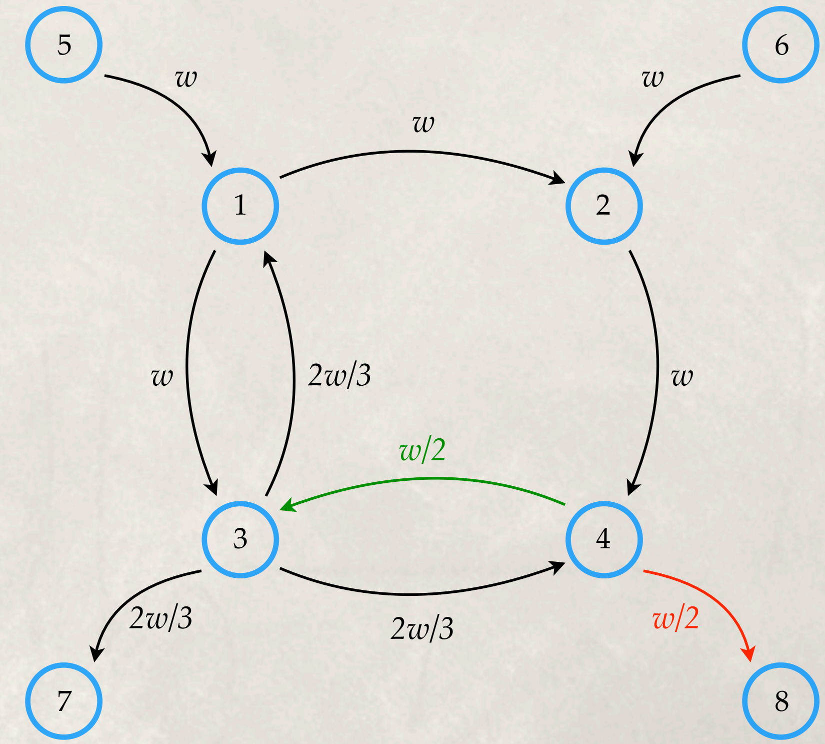
Bumpy paths



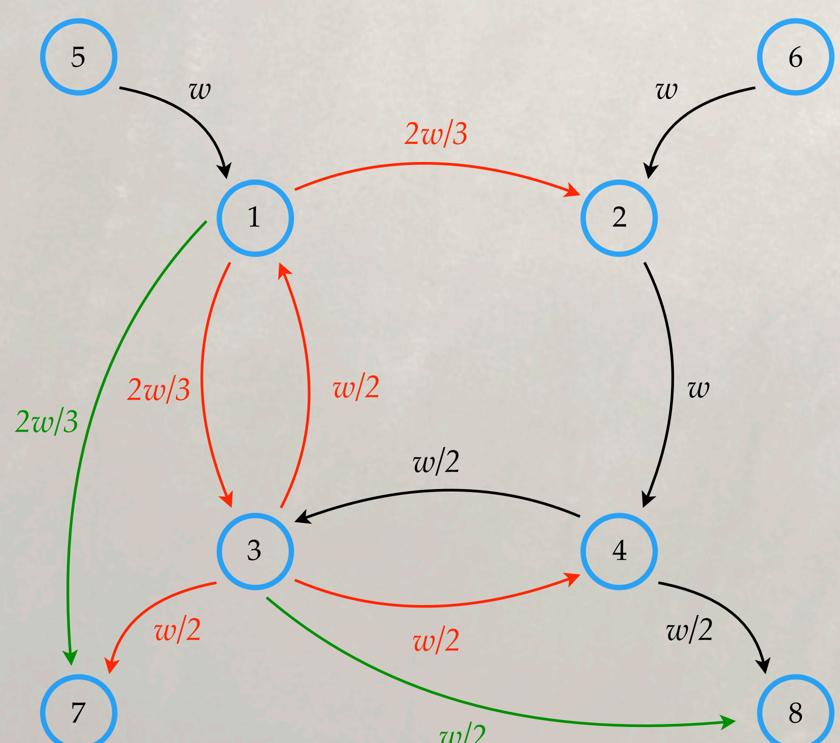
a: $\lambda_{max} = 0$



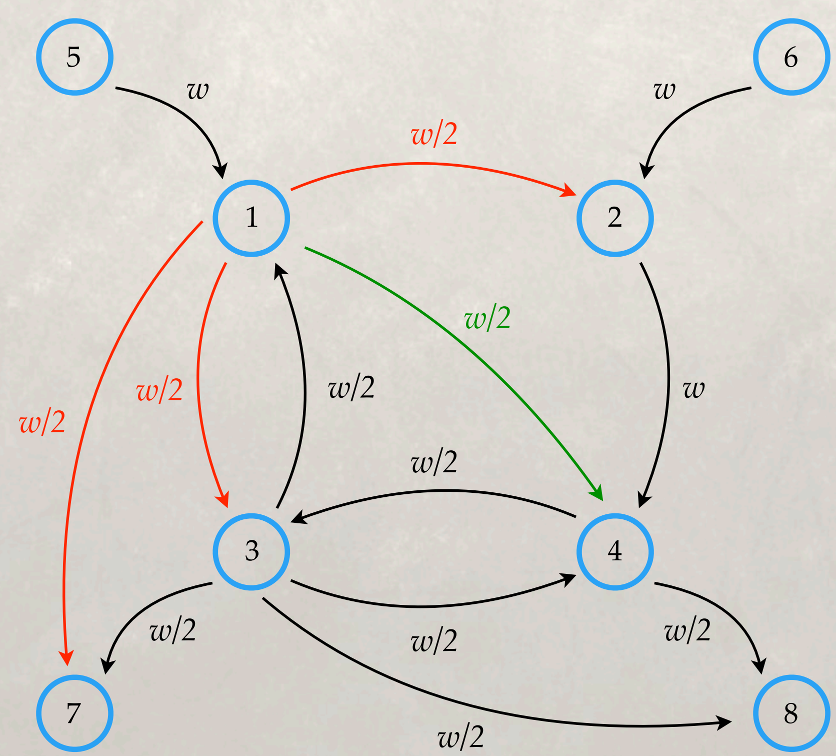
b: $\lambda_{max} = 0.8165\ w$



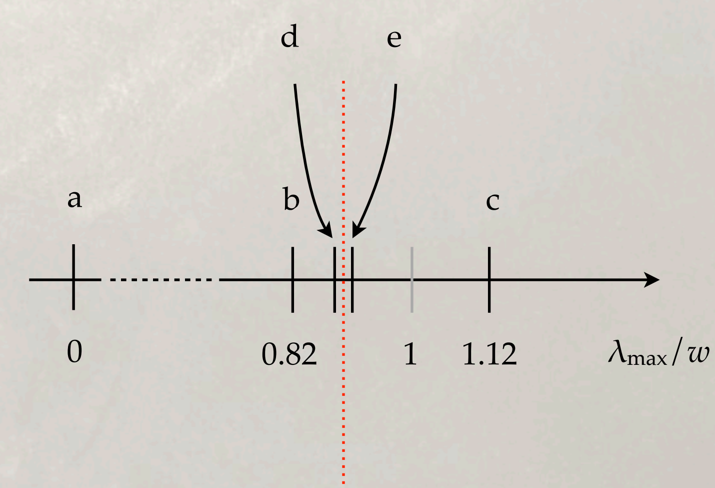
c: $\lambda_{max} = 1.1242\ w$



d: $\lambda_{max} = 0.8907\ w$



e: $\lambda_{max} = 0.8927\ w$



Conclusions

- We establish a framework to assess the stability of the interbank network (we can account for recovery too).
- We show that standard policy recommendation might not capture possible sources of instability.
- We prove the analogous of the Wigner-May theorem for the interbank network. Adding nodes to an anomalously stable network makes it unstable.
- Increasing the interconnectivity of the network while keeping the interbank leverage constant is a (possibly bumpy) path towards instability.

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