

# The use of big data in supervision and economic policy

**BINUS** – 3<sup>rd</sup> International Lecture Weeks

*Digital transformation towards Business Resilience and Sustainability*

Iman van Lelyveld

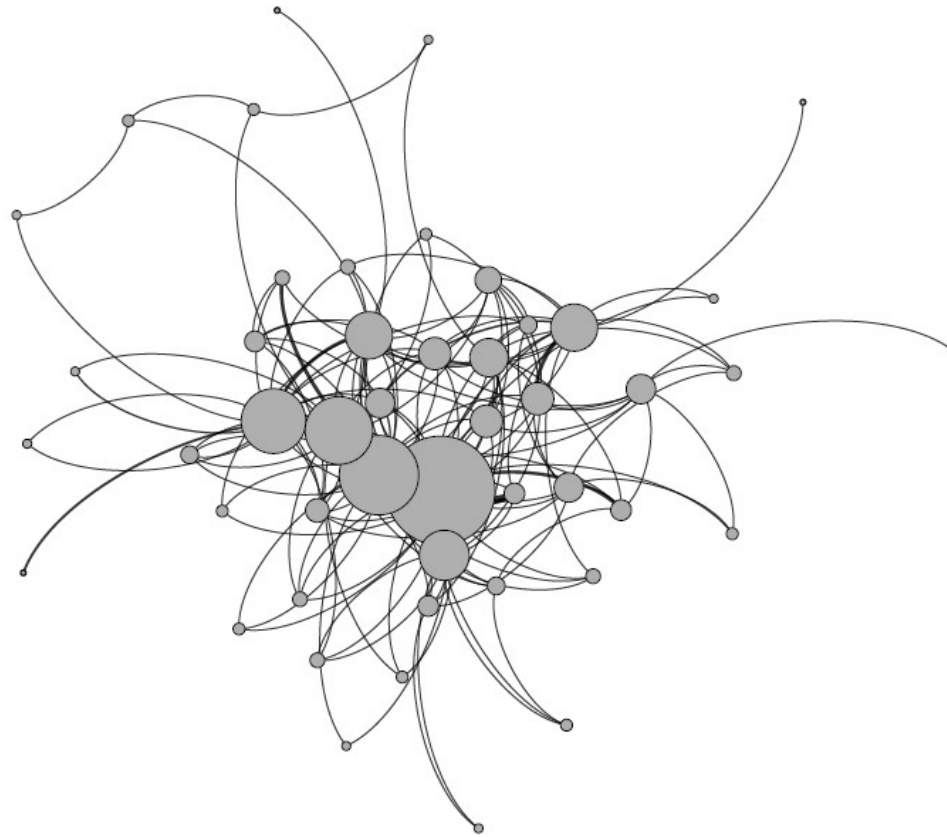








# Most financial networks have a core and a periphery





socilab

About Resources Books

## LinkedIn Network Visualization and Analysis

Hello, Iman van Lelyveld. Here is your network visualization and report. (Scroll down for the metrics and data!)

### Network Visualization

- Coloring:
- Connections to self:
- Names:

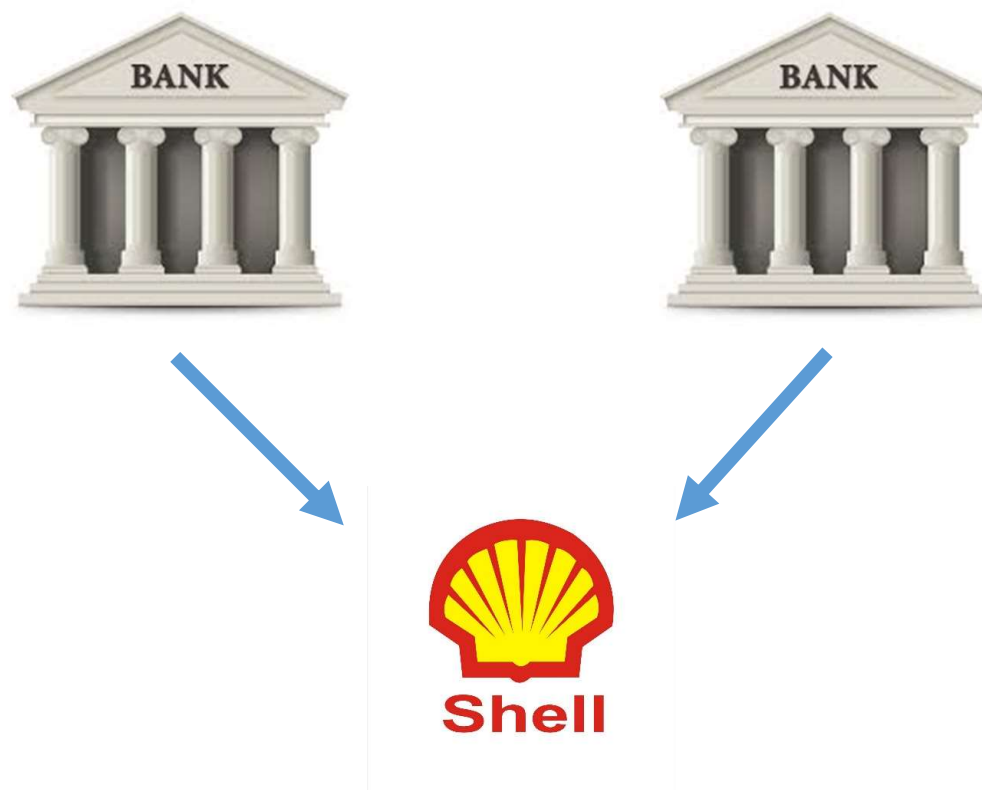
By location

DeNederlandscheBank

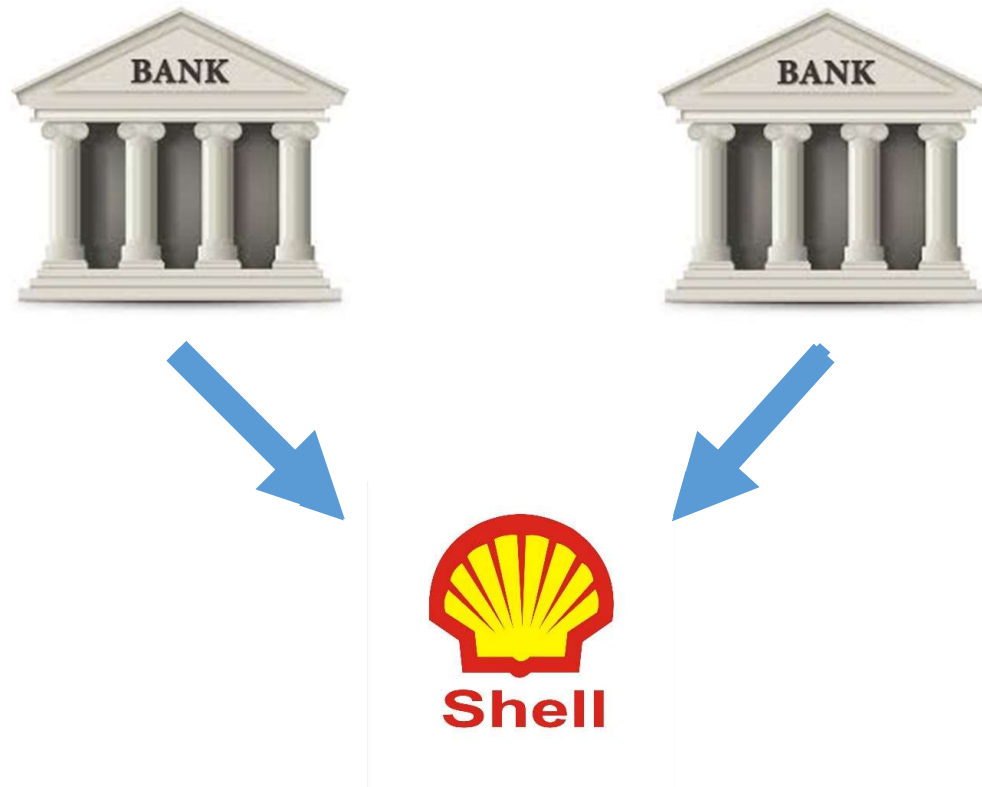
EUROSYSTEM

VU  
VRIJE  
UNIVERSITEIT  
AMSTERDAM

# Not just direct exposures ...



# Not just direct exposures ...

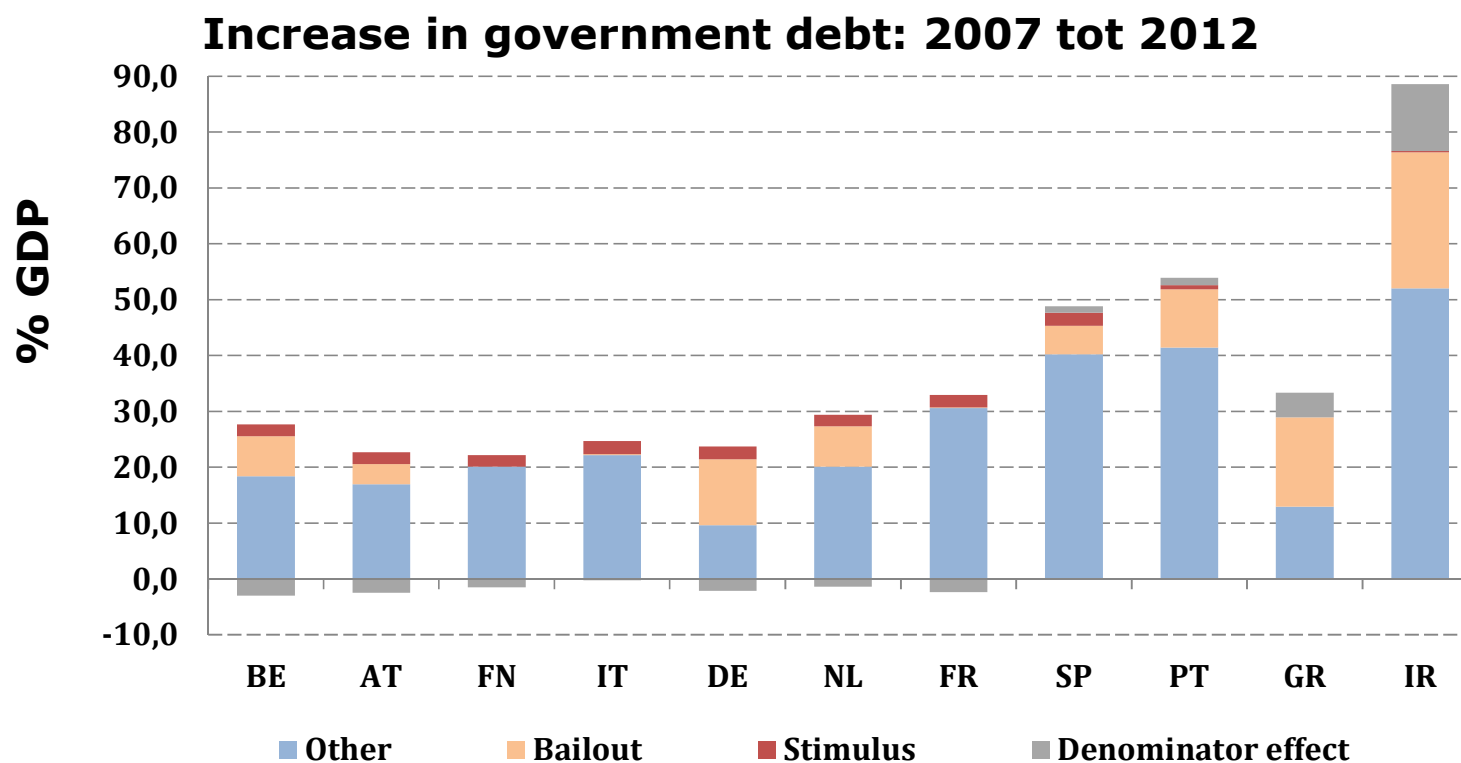




# But indirect exposures as well



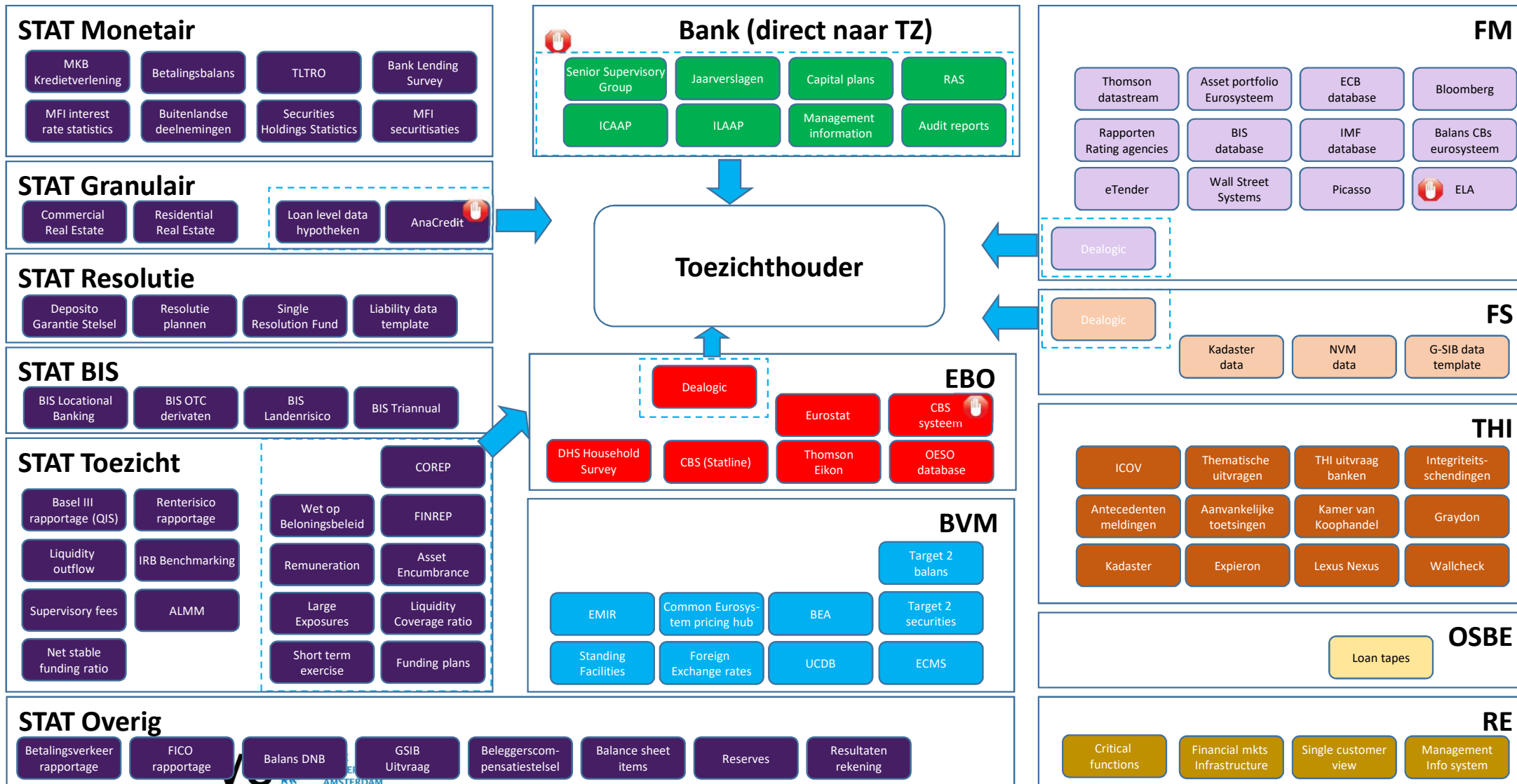
# Indirect cost larger than direct bailout



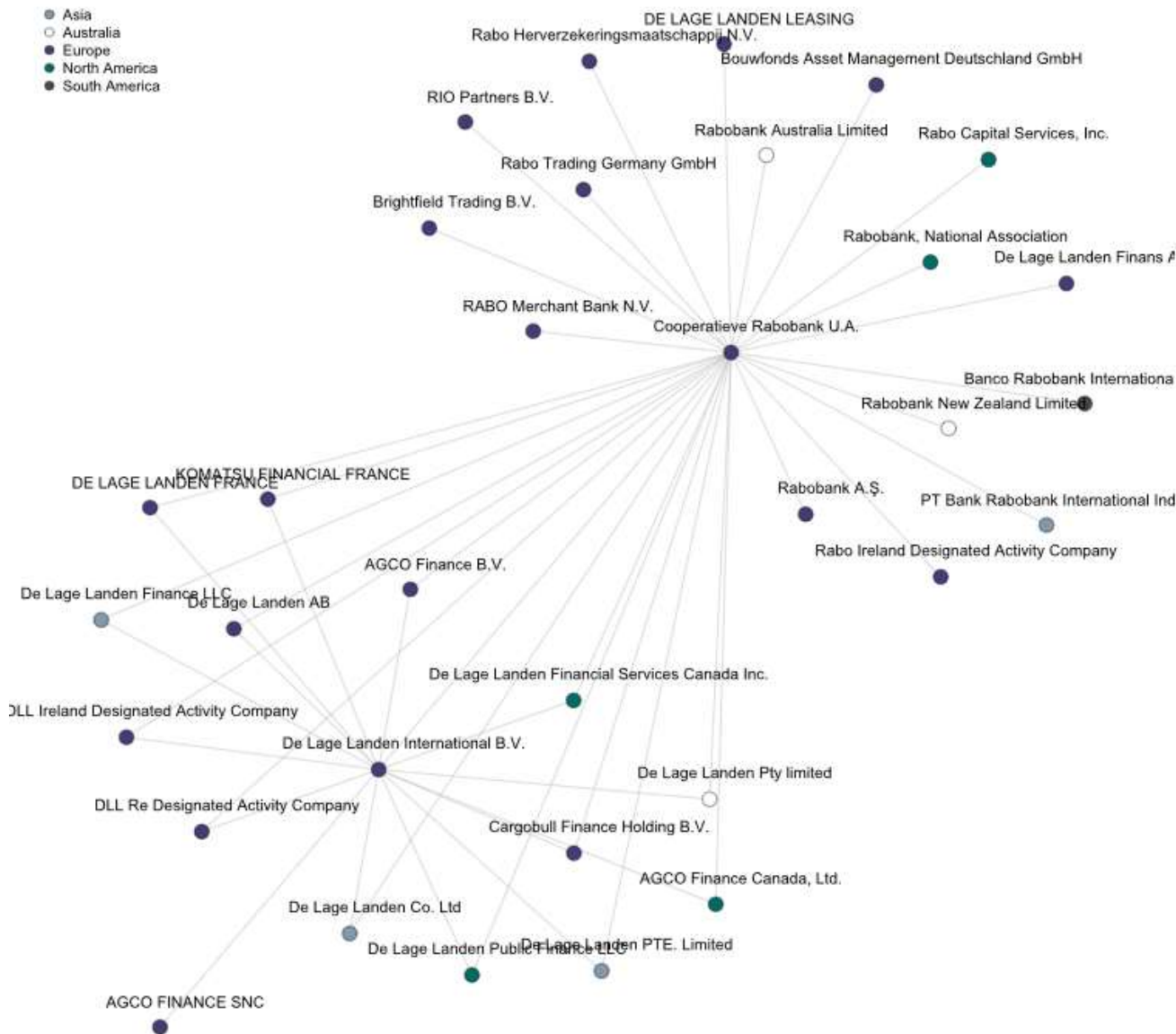
- 1.New data
- 2.New methods
- 3.New organisation



# Data comes to DNB in all kinds of ways







## Different angles

- Supervision
- Risk
- Accounting
- Macro prudential
- ...

Source: [Ullersma and van Lelyveld \(2021\) CUP](#)

# Available large granular data in the EU

Set	Description
AnaCredit	EU credit registry
EMIR	Derivates
MIFID	Trading on exchanges
MMSR	Interbank money market
SHS	Securities holdings
SFTR	Securities Finance Transactions

1.New data

**2.New methods**

3.New organisation

Science, February 19, 2016  
Policy Dashboard based on Complexity Theory

Stefano Battiston, J. Doynne Farmer, Andreas Flache, Diego Garlaschelli, Andrew G. Haldane, Hans Heesterbeek, Cars Hommes, Carlo Jaeger, Robert May, Marten Scheffer

INSIGHTS | PERSPECTIVES

## COMPLEX SYSTEMS

### *Complexity theory and financial regulation*

Economic policy needs interdisciplinary network analysis and behavioral modeling

Ry Shofano-Battistoni,<sup>10</sup> J. Doyne Farmer,<sup>11</sup>  
Andreas Fiaschi,<sup>12</sup> Diego Garlaschelli,<sup>13</sup>  
Andrew G. Haldane,<sup>14</sup> Hans Hoferich,<sup>15</sup>  
Curtis Homena,<sup>16</sup> Carlo Jaeger,<sup>16,17</sup>  
Robert May,<sup>18</sup> Martin Schreiber<sup>19</sup>

**T**raditional economic theory could not explain, much less predict, the massive collapse of the financial system and the long-lasting effects on the global economy. Since the 2008 crisis, there has been increasing interest in using ideas from complexity theory to make sense of economic and financial markets. Concepts, such as tipping points, networks, contagion, feedback, and resilience have entered the financial and regulatory lexicons.

**POLICY** and regulatory issues, the actual use of complexity models and results remain at an early stage. Recent insights and techniques offer potential for better monitoring and management of highly international economic and financial systems and, thus, may help anticipate and avert future crises.

**TIPPING POINTS, WARNING SIGNALS.** Researcher-made have historically exhibited sudden and largely unforeseen collapses, a systemic risk. Such "phase transitions" may in some cases have been triggered by unpredictable stochastic events. More often, however, there have been endogenous underlying processes at work. Analysis of complex systems ranging from the climate to ecosystems reveal that, before a major transition, there is often a gradual and universal loss of resilience. This makes the system brittle. A small disruption can trigger domino effect that propagates through the system and sends it into a crisis state.

[illegible]

Recent research has revealed that complex systems possess quantitative indicators of resilience that may be used across complex systems to detect tipping-points. Markers include rising temporal correlation, variance, and skewness of fluctuation patterns. These indicators were first predicted mathematically for simple systems, but have been experimentally used in real complex systems, including living networks (2). A recent study of the Dutch railway network (3) showed that the network model could only lead to late detection of the 2006 crisis, although a more multiscale and heterogeneous network model could detect the crisis from the first shift (Fig 1).

Ecologists have developed tools to quantify the stability robustness, and resilience of ecosystems (4). These tools are dependent on the topology of the network and the strength of interactions (5). Ecosystems have been tools to gauge the potential for a system to resist or recover from perturbations, to identify super-spreaders and compare resilience to infection persistence, and to design strategies to prevent or limit the

Extrapolating results from the natural sciences to economics and finance presents challenges. For instance, publication of an early warning signal will change behavior and affect future dynamics (the Lucas critique (5)). But this does not affect the case where indicators are known only to regulators or when the goal is to build better network barriers to slow the spread of an infection.

**TOO GENERAL TO FAIL.** Network effects matter to financial-economic stability because shock amplification may occur via strong cascading effects. For example, the Bank of International Settlements recently developed a framework drawing on data on the interconnections between banks to gauge the systemic risk posed to the financial network by Global Systemically Important Banks. Recent research on contagion in financial networks has shown that network topology and position of banks matter; the global financial network may collapse even without individual banks' going under. Comparing these effects is essential for quantifying, stress, on individual banks, and on

Information asymmetry within a network—e.g. when a bank does not know about troubled assets of other banks—can be problematic. The banking network may

*"...policies and financial regulation...are successful in stabilizing experimental macroeconomic systems"*

cally displays a core-periphery structure, with a core consisting of a relatively small number of large, densely interconnected banks that are not very diverse in terms of business and risk models. This implies that core banks' defaults tend to be highly correlated. Thus, in turn, can generate a collective moral hazard problem (i.e., players vote on more risk, because others will bear the costs in case of default), as banks recognize that they are likely to be supported by the authorities in situations of distress, the likelihood amplifies their incentives to herd in the same policy.

Estimating systemic risk relies on granular data on the financial networks. Unfortunately, business interactions between banks are often hidden because of confidentially issues. Tools being developed to reconstruct networks from partial information and to estimate systemic risk (7) suggest that publicly available bank information does not allow reliable estimation of systemic risk. The estimate would improve greatly if banks publicly reported the number of connections with other banks, even without dis-

In addition to data, understanding the effects of interconnections also relies on integrative quantitative metrics and concepts that reveal important network aspects, such as systemic repercussions of the failure of individual nodes. For example, DebtRank, which measures the systemic importance of individual institutions in a financial network (8), shows that the issue of too-connected may be even more important than too-large-fail.

**AGENTS AND BEHAVIOR.** Agents—be it individuals (AAs) or a computer program—act in the world by observing the state of the world, which the behavior of agents and their interactions are explicitly represented as a decision rule mapping agents' observations onto actions. Although AAs are less well understood than the formal models of the systems that in, e.g., traffic control, epidemiology, or battlefield conflict analysis, they have produced promising results. Asell (9) developed a simple AAI that explores more than 100,000 states of a simple system of fire formation without recourse to external models. AIME provides a good explanation for why the volatility of prices in clustered and synchronized (10) and herd-like (11) systems is so high.

Laboratory experiments with human subjects provide controlled studies of individual decision rules of agents, their interactions, and emergent macro behavior. Recent experiments studying behavior of a group of individuals in the laboratory have revealed counterintuitive results, significantly from natural efficient equilibria at both individual and aggregate levels (24). The generic features of positive feedback systems lead to persistent deviations of systems from equilibrium and emergence of speculation-driven bubbles and crashes, strongly amplified by coordination or word-of-mouth and herding behavior (25). These are strong, sustained influences

monetary and fiscal policies and financial regulation, designed to weaken positive feedback, are successful in stabilizing experimental macroeconomic systems when properly calibrated (26). Complexity theory provides a useful conceptual understanding of these effects.

**POLICY DASHBOARD.** It is an opportune time for academic economists, complexity scientists, social scientists, ecologists, epidemiologists, and researchers at financial institutions to join forces to develop tools from complexity theory as a complement to existing economic modeling approaches (7). One ambitious option would be an online, financial-economic dashboard that integrates data, methods, and indicators. This might monitor and visualize the global socioeconomic and financial system in something close to real time, in a way similar to what is done with other complex systems, such as weather systems or social networks.

The funding required for essential policy-relevant and fundamental interdisciplinary research in these areas is substantial and needs to be secured with the same care of systemic financial failures or the collapse of the global financial-economic system. ■

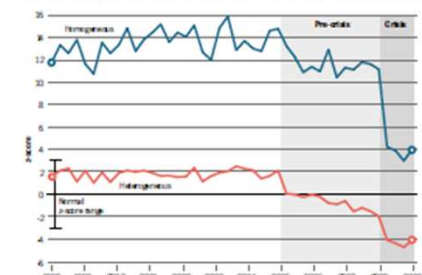
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16. T. Diao, D. H. Huo, and M. Wu, "A new parallel hybrid control approach for flexible and rigid link feedback impedance control," in *Proceedings of the 2005 IEEE Conference on Decision and Control*, 2005, pp. 3933–3938.

17. A. J. H. Hobbs, "Chronic occupational noise exposure," in *Handbook of Occupational and Environmental Epidemiology*, L. David and C. L. Pearce, Eds., 2002, pp. 103–110. [Online]. Available: <http://www.tnfrs.org.uk>

ACKNOWLEDGMENT

We also would like to thank the support from the Netherlands Institute of Public Health and the Environment and the Dutch Science and Technology Organization for Scientific Research, the Leiden University, and the TNO research institute.



Early working together in the 20th century, the Dutch inventors, Theunis posthumus van Helvoort and de Boer, of *harknet* are at the same time dealer and artist in his own right. Although the reviewer of the book is not very informed about possible ongoing structural changes, his comparison with a random network model heuristically (2) accomplishes a number of standard deviations by which the number of two loops in the random network deviates from expected value in the model. Small magnitude  $\chi$ -squares (3) indicate approximate match between the model, whereas larger magnitude indicates statistically significant deviations. Two different random network models were used: *abomogeneous* networks where the same total number of links are in the real network (4a) and a *heterogeneous* network where every link has the same amount of connections to its neighbours (5b). In *abomogeneous* models, often used in standard network, higher order correlations are not taken into account (6). In 2008, two different *heterogeneous* models also fitted the correlation coefficient's variance (7) (see (2008-2009-2010), Unpublished from (2)).

to test systemic risk implications of reforms developed by the Basel Committee on Banking Supervision, which show how dynamically changing risk limits can lead to booms and busts in prices (11, 12). ABMs of market dynamics can be linked with ABM work on opinion dynamics in the social sciences (13) to understand how propagation of opinions through social networks affects emergent market behavior, which is critical to managing the stability and resilience of socio-economic systems.

A simple behavioral model, with agents gradually switching to better performing heuristics, explains individual, as well as emergent, market behavior in these laboratory economies. The experiments also provide a general mechanism for managing social contagion in such systems. By carefully

# Network structure can help to see change early



## OPEN Early-warning signals of topological collapse in interbank networks

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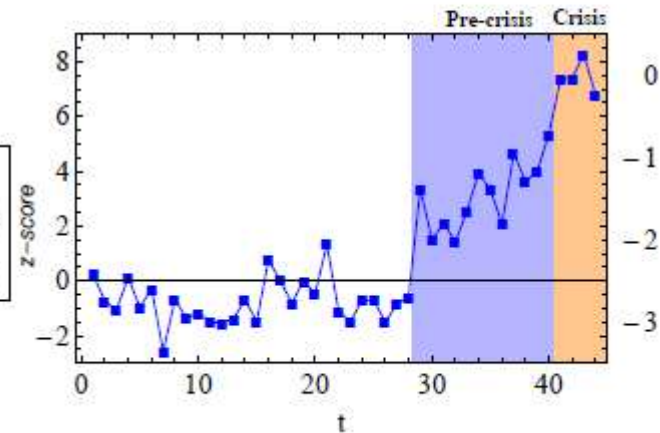
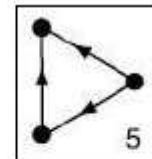
SUBJECT AREAS:  
INFORMATION THEORY  
AND COMPLEXITY  
STATISTICAL PHYSICS  
ARTIFICIAL PHYSICS  
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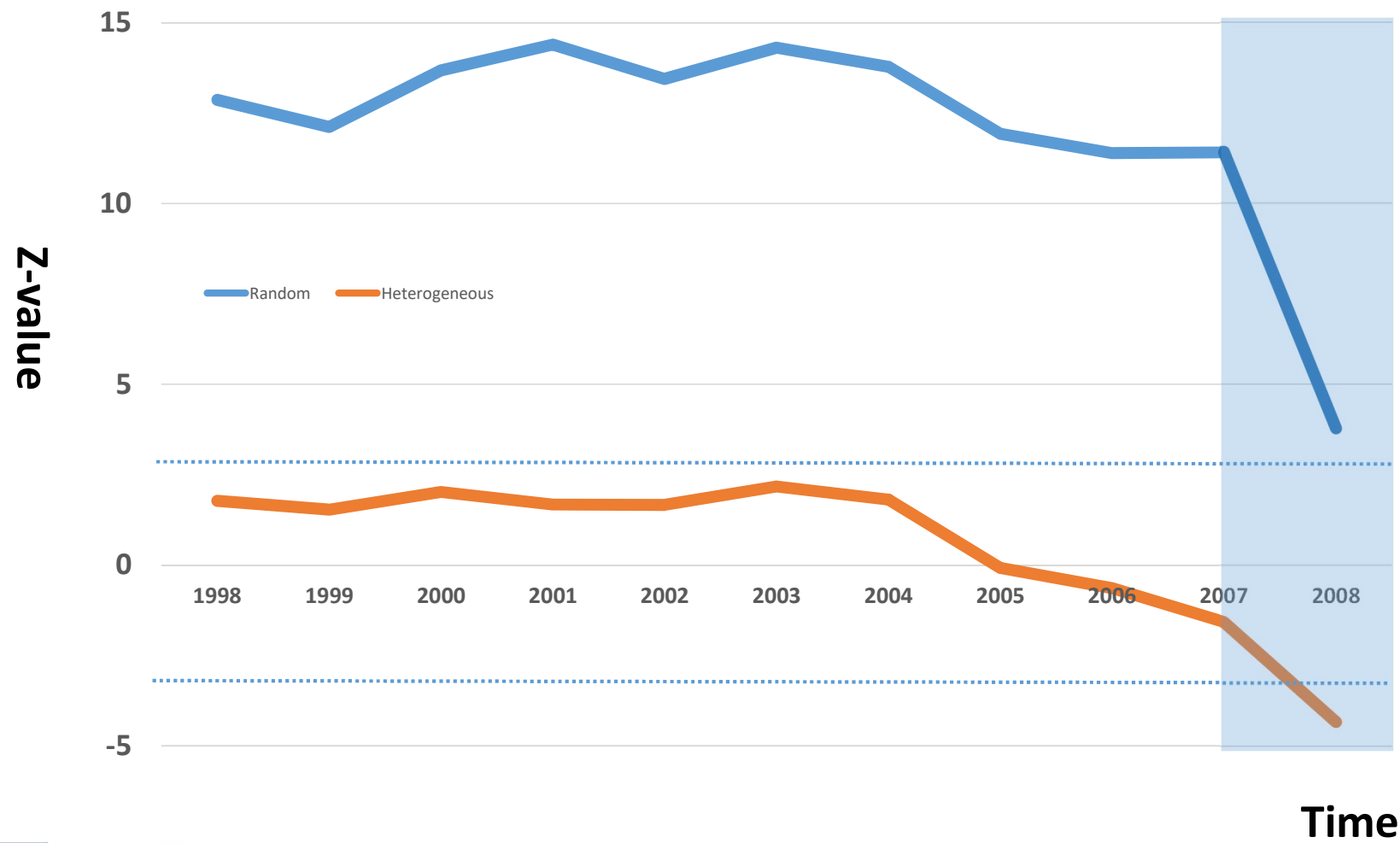
Correspondence and  
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should be addressed to  
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leideninstitute.nl)

The financial crisis clearly illustrated the importance of characterizing the level of “systemic” risk associated with an entire credit network, rather than with single institutions. However, the interplay between financial distress and topological changes is still poorly understood. Here, we analyse the quarterly interbank exposures among Dutch banks over the period 1998–2008, ending with the crisis. A fair controlling for the link density, many topological properties display an abrupt change in 2008, providing a clear – but unpredictable – signature of the crisis. By contrast, if the heterogeneity of banks’ connectivity is controlled for, the same properties show a gradual transition to the crisis, starting in 2005 and preceded by an even earlier period during which anomalous debt loops presumably favoured the underestimation of counter-party risk. These early-warning signals are undetectable in an otherwise constructed from partial bank-specific data, as routinely done. We discuss important implications for bank regulatory policies.

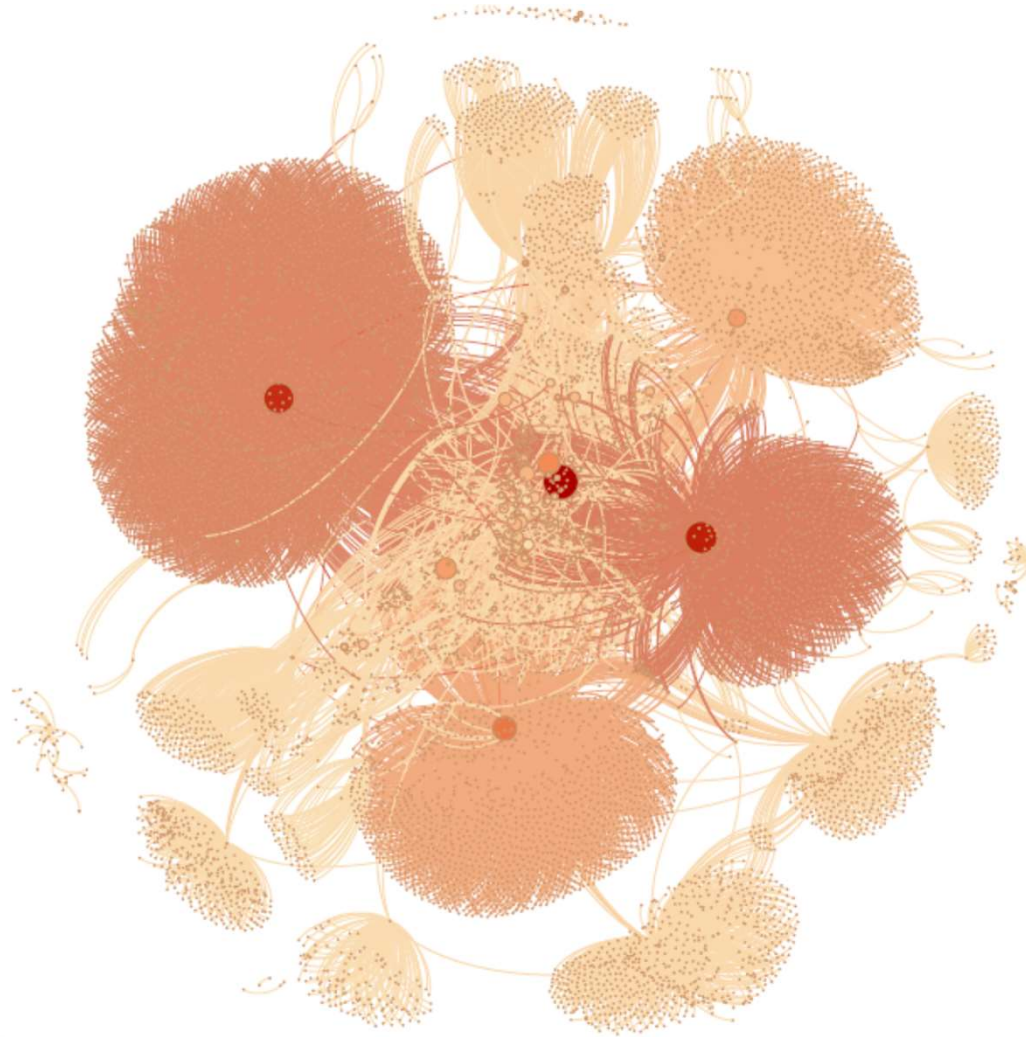
Financial and banking systems are strongly interconnected networks of institutions exposed to both endogenous and exogenous fluctuations<sup>1,2</sup>. When defaults occur, they cascade throughout the network and can cause the collapse of an entire system, as dramatically witnessed by the recent financial crisis<sup>3</sup>. As a consequence, the analysis of economic and financial networks as the propagation channel for distress has received a lot of attention<sup>4–6</sup>. Much effort has been devoted to the search for regularities in the structure of financial networks, i.e. looking for degree heterogeneity, a core-periphery or a modular structure<sup>7–11</sup>. Similarly, null models have been introduced in order to understand whether part of the observed topological complexity can be explained naturally simply in terms of the observed heterogeneity of vertices<sup>12–14</sup>. For interbank networks specifically, a lot of attention has been devoted to quantifying the level of systemic risk (the risk of the collapse of the system) as a function of characteristics of the network structure and the exposure of individual banks to the system<sup>15–17</sup>.





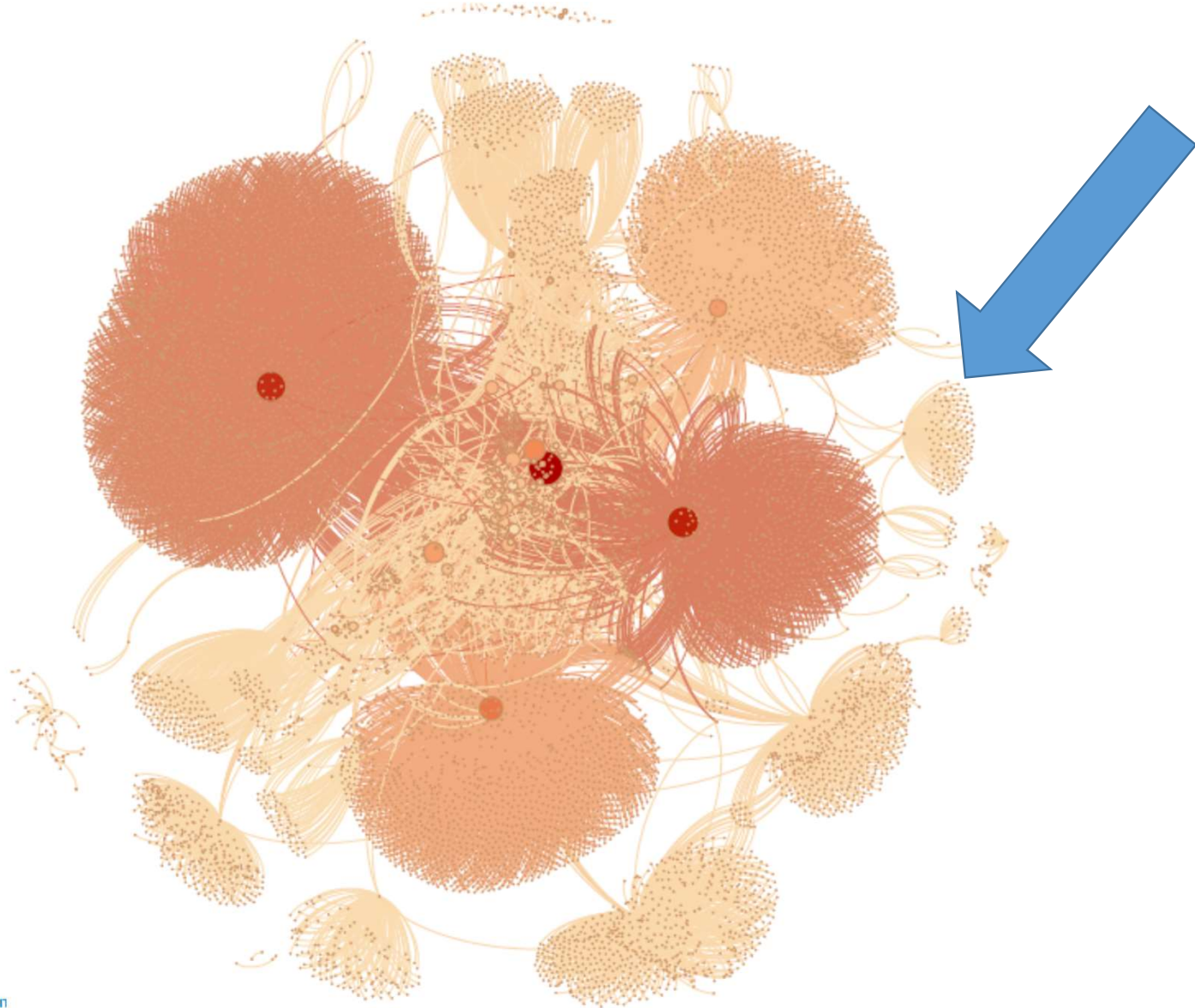


# The interest rate swaps (IRS) hairball

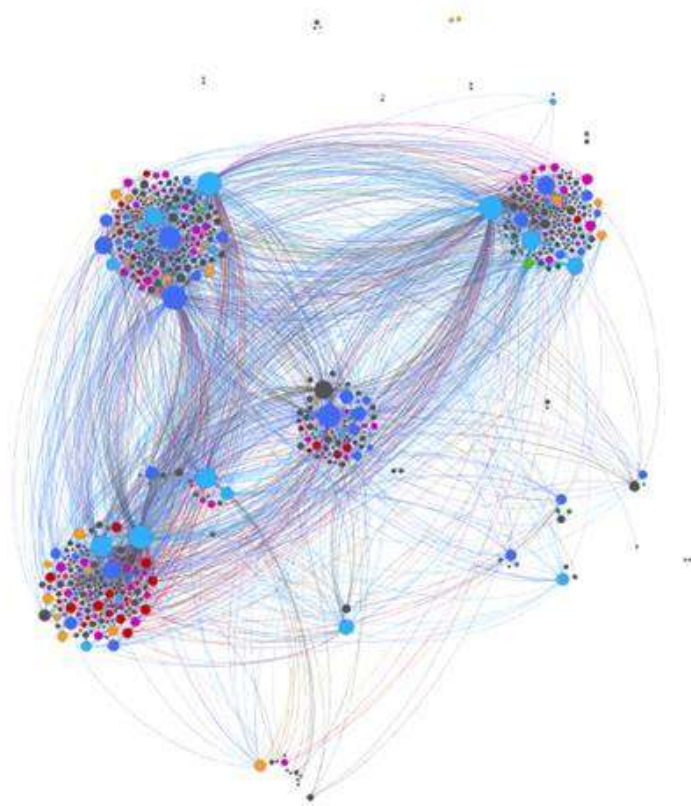




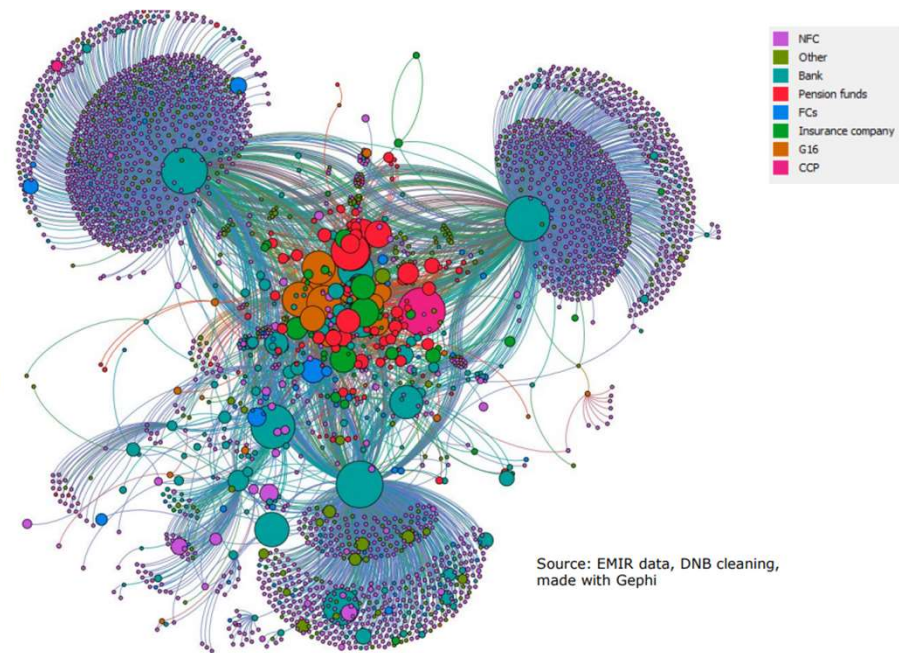




## Stocks and bonds



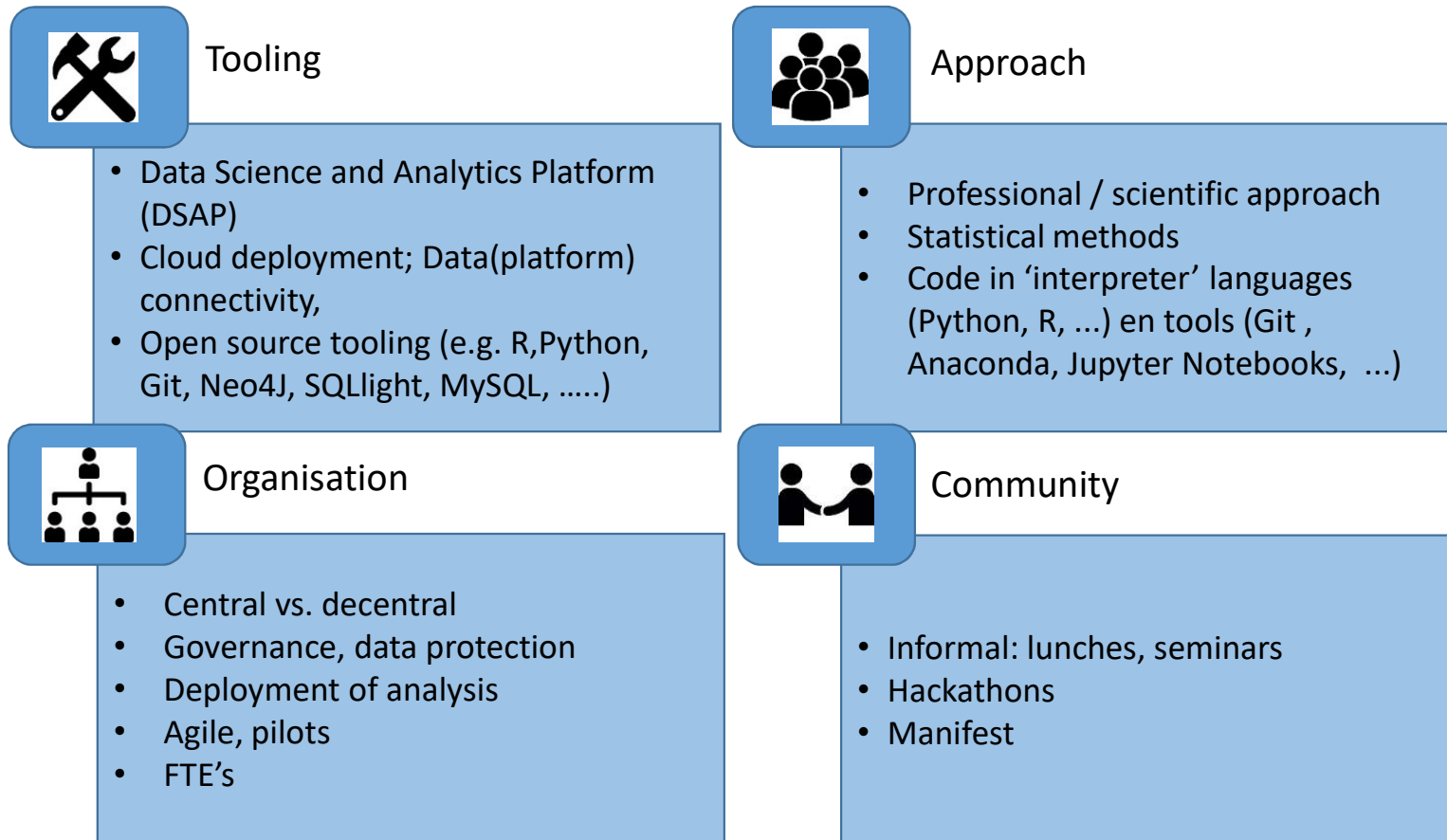
## IRS





- 1.New data
- 2.New methods
- 3.New organisation**

# Necessary elements for Data Science

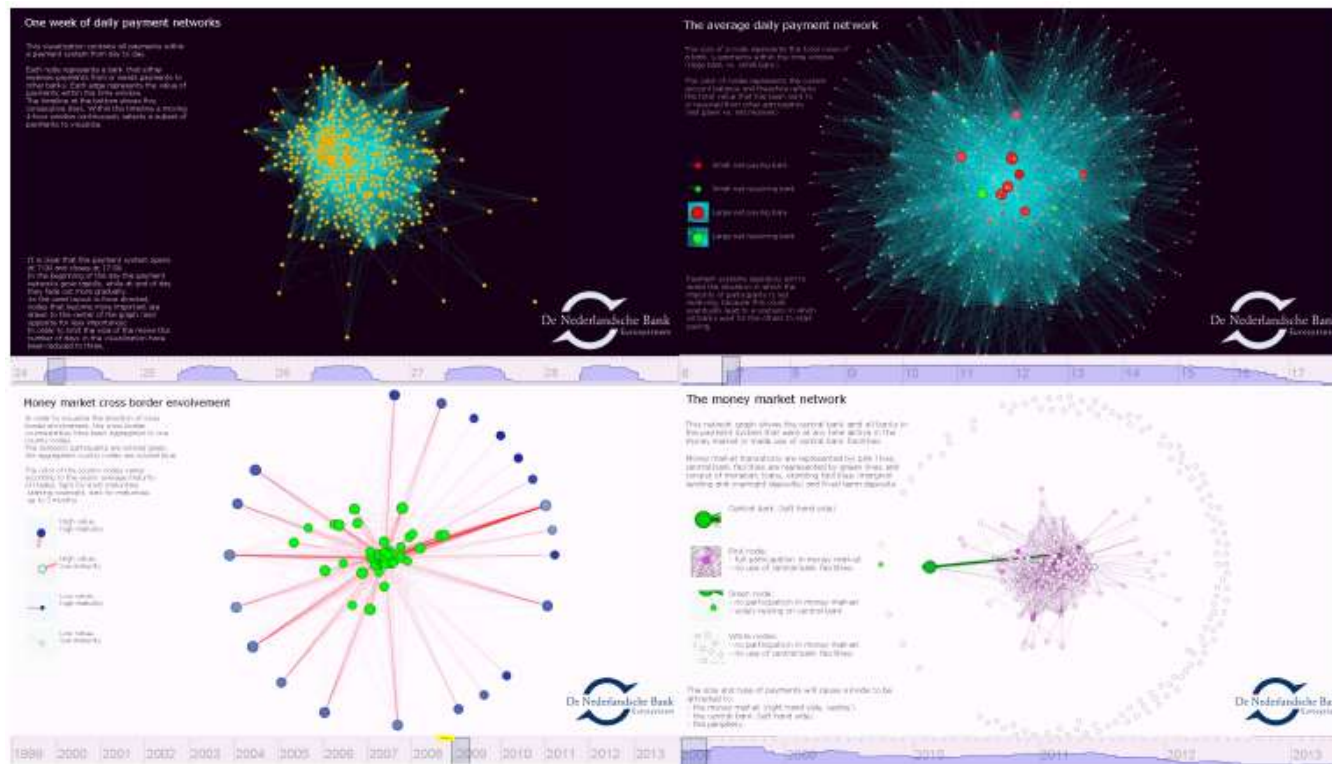


Thank you for your attention

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# Annexes

# Dynamic visualisations as an additional tool



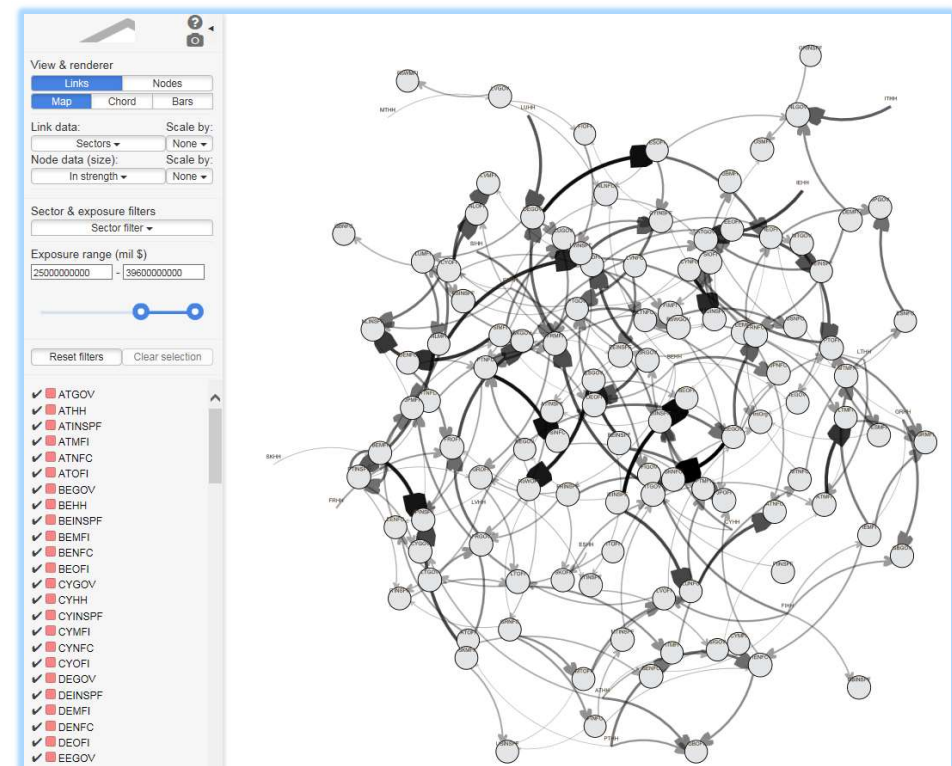
Heijmans, R., R. Heuver, C. Levallois, I. van Lelyveld (2016), "Dynamic visualization of large financial networks", *Journal of Network Theory in Finance*





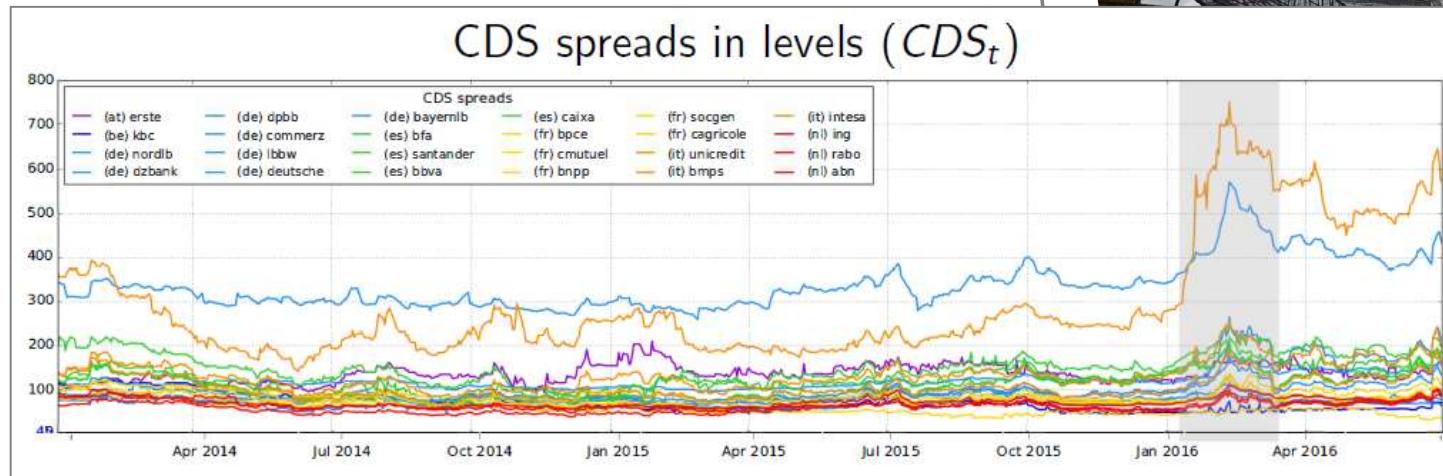
# New tools to visualise massive amounts of securities data (SHSs)

- Each quarter 2,5 GB in Stata format
- Sector-country holdings of securities (ISIN) issued by other sector-country units
  - Granularity too high → collapse
- Build an interactive visualisation tool (with the help of Peter Sarlin)
- Helps to identify linkage

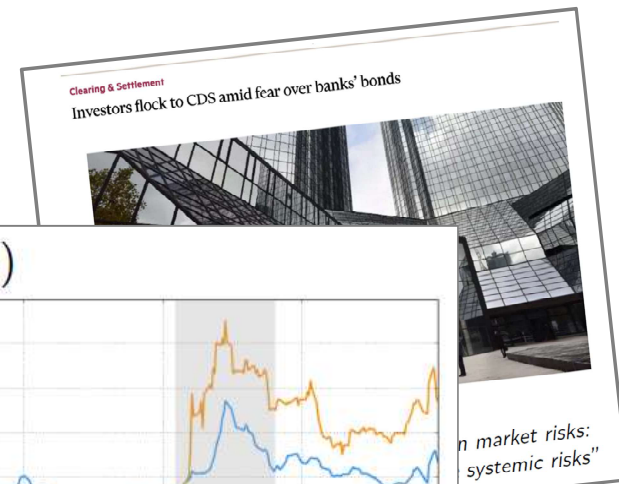


# Contagion in bank CDS

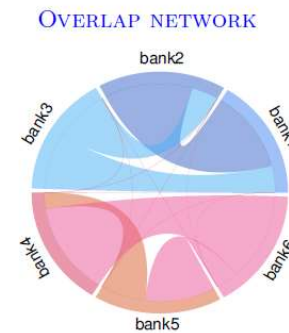
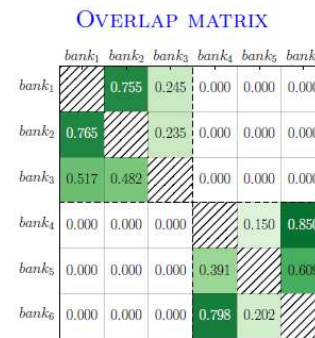
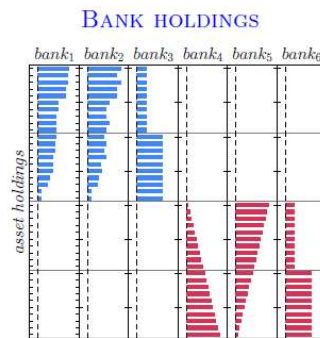
Dieter Wang



- Credit Default Swaps (CDS) prices reflect the (perceived) credit risk of the underlying entity (ie. bank)
- Poorly explained by structural (bank-specific or economic) variables
- Hypothesis: Banks with similar holdings likely affect each other in stress times -> **contagion**



# Capturing the underlying network



- Model contagion network by looking for similarity of bank's holdings
- Use to simulate default contagion in stress

## CHAIN OF CONTAGION SELECT A BLOCK!

