Climate change and financial risk

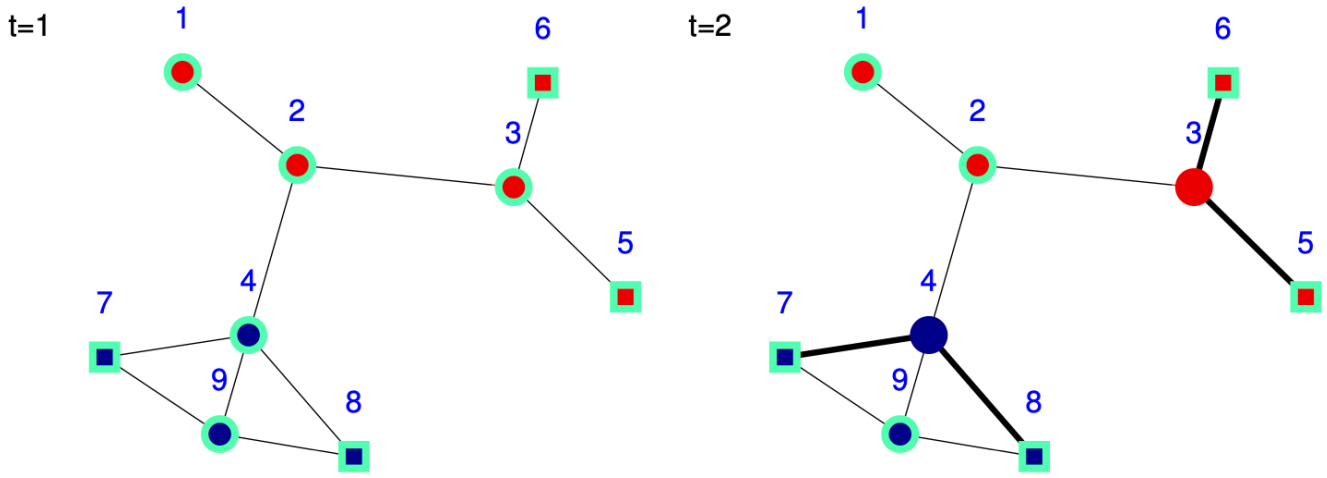
Stefano Battiston (UZH, UNIVE)

October 31, 2024

My work at SG Chair

- Methodological foundations in common: complexity science, network science
- Motivations: scientific discovery is hard work but fun and rewarding. Sometimes even useful!
- Research **meta-questions**
  - what do we learn by using these methods that we did not know before?
  - what are the implications for science and society?
  - how do we reach out to the relevant community in terms of applications?
- Example research **questions**: trust in social networks, efficiency vs stability of economic networks, systemic risk in financial networks

Trust in social networks



- Social network: agents with different competences share knowledge to some extent (cooperation level),
- What is the evolution of trust network / quality of recommendations received via the network?

[*Walter F., Battiston S., and Schweitzer F., Personalised and Dynamic Trust in Social Networks, 3rd ACM conf. Recommender systems*]

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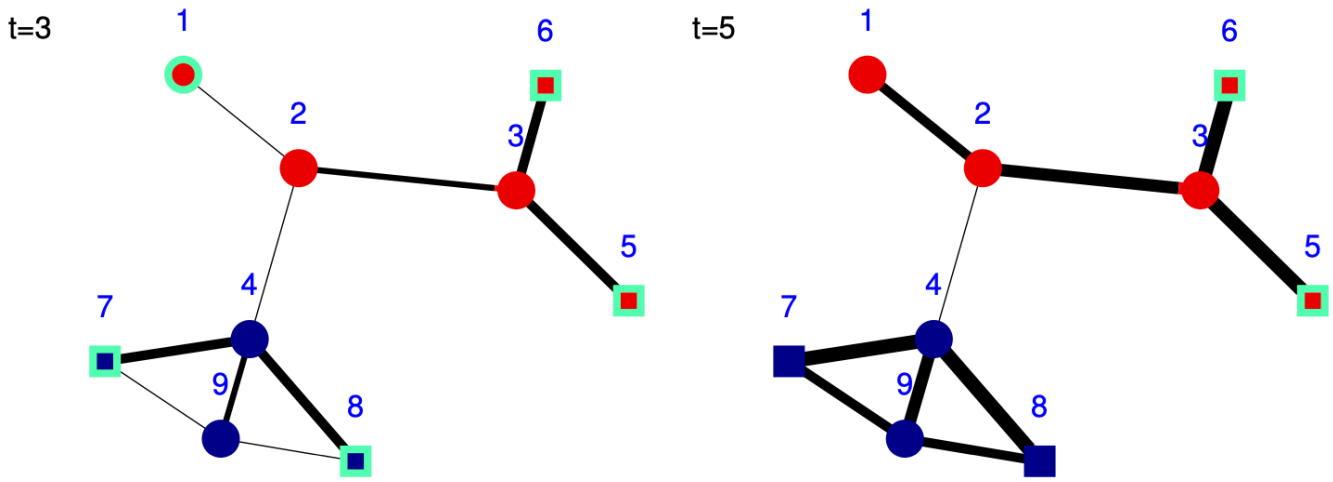

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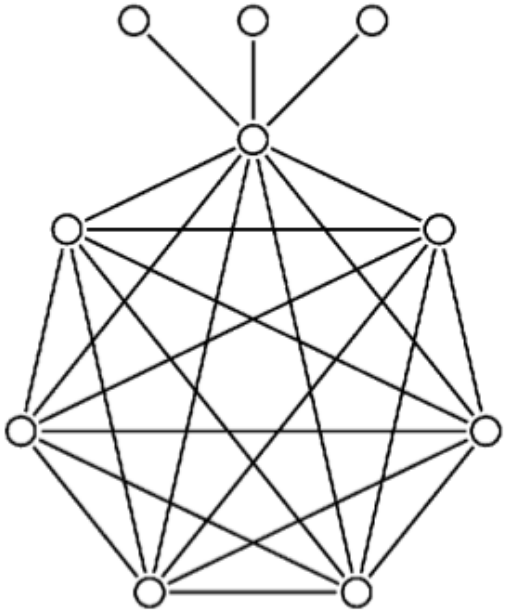
Knowledge sharing in economic networks



- Economic network: formation of a link (collaboration) has direct cost c, but brings direct and indirectly benefits from other agents.
- What network structures are efficient (maximize payoff) and which are stable (pairwise sense)?

[*Koenig M., Battiston S., Napoletano M., Schweitzer F., The efficiency and stability of R&D networks, GEB 2012*]

Knowledge sharing in economic networks

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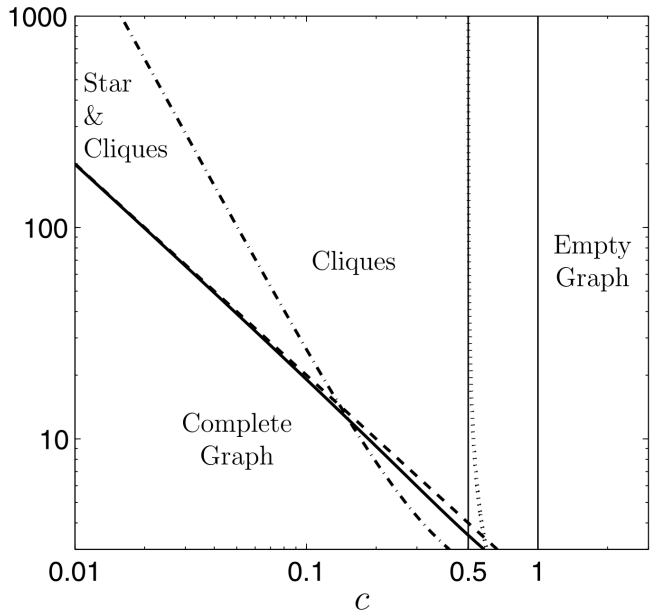

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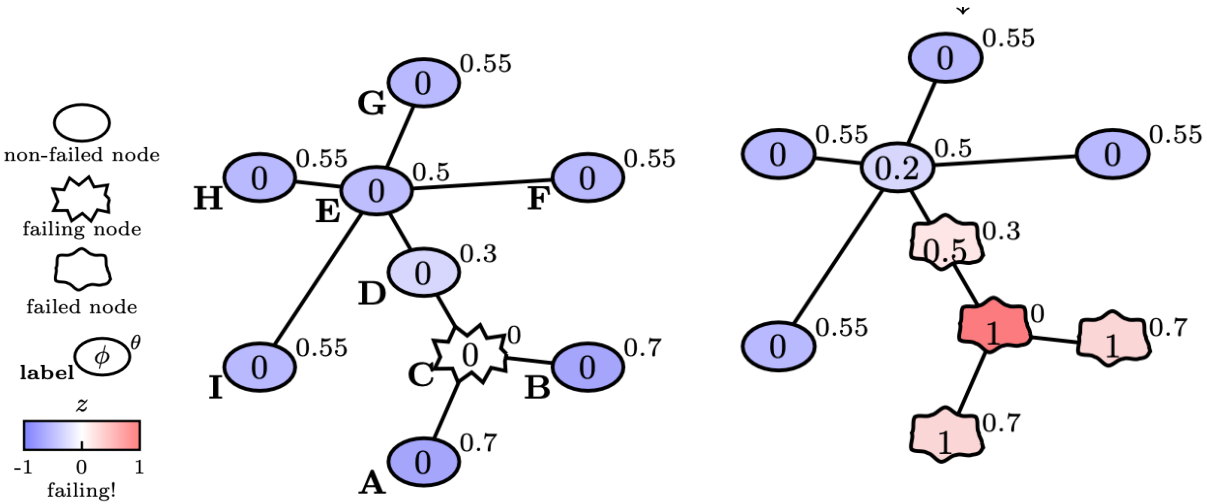
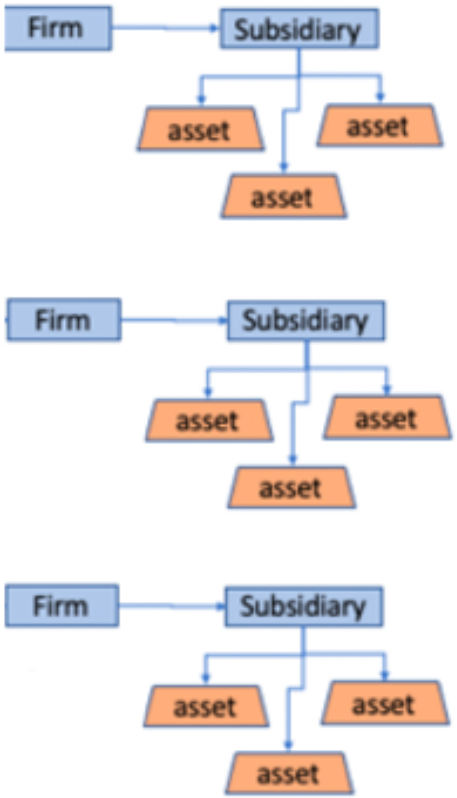
Risk in financial networks



- Financial network: agents with different thresholds for default, import shocks from connected agents
- What evolution of financial contagion? Conditions for systemic risk emergence: structure AND process?

[*Lorenz Jan, Battiston S., and Schweitzer F., Systemic Risk in a Unifying Framework for Cascading Processes on Networks, EPJB 2009*]

Financial networks



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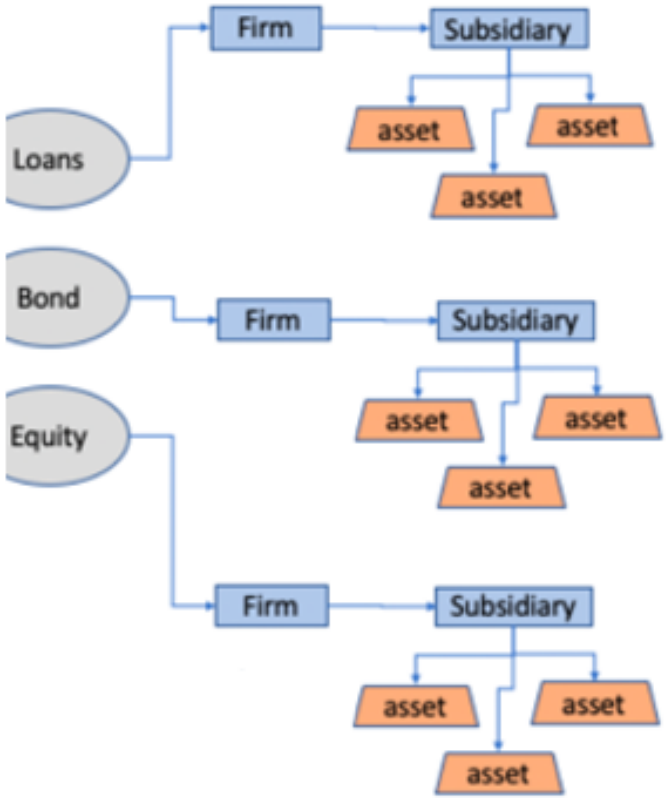

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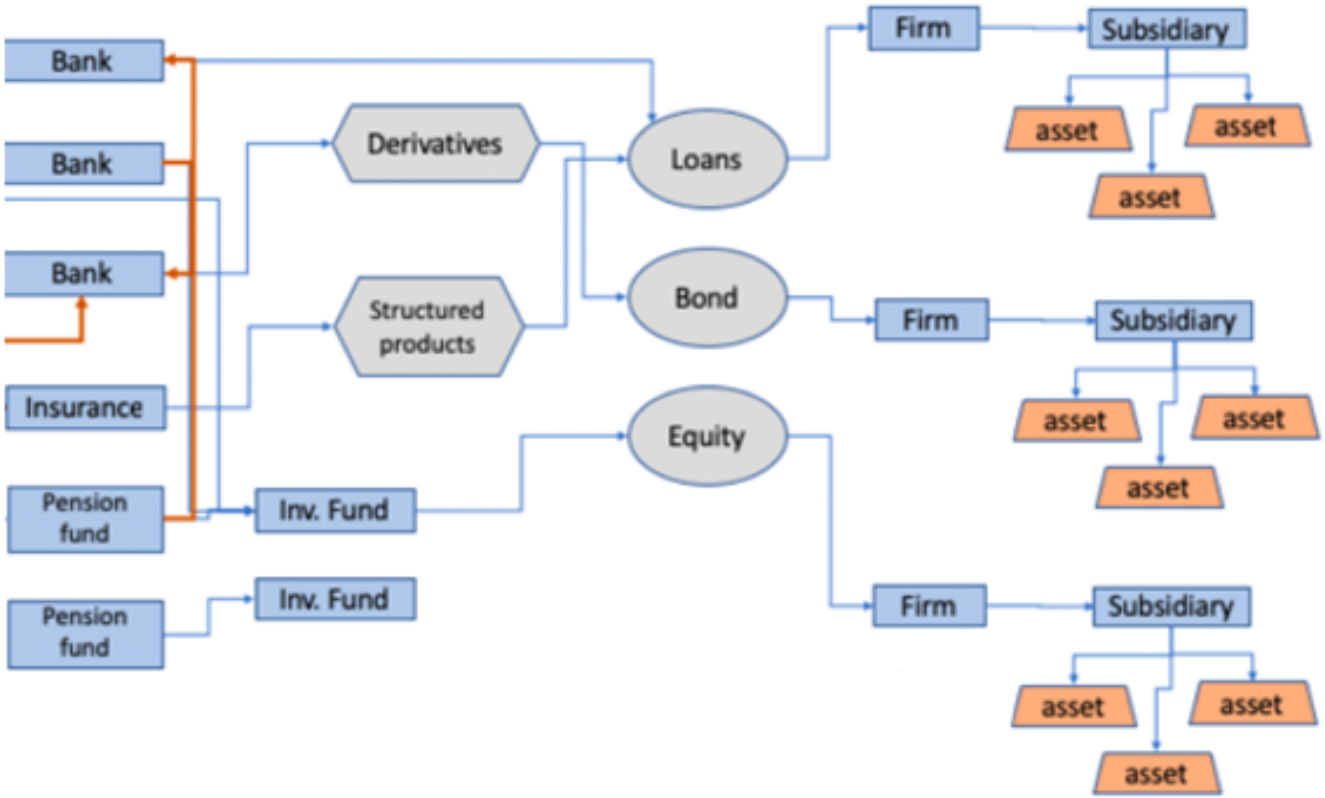

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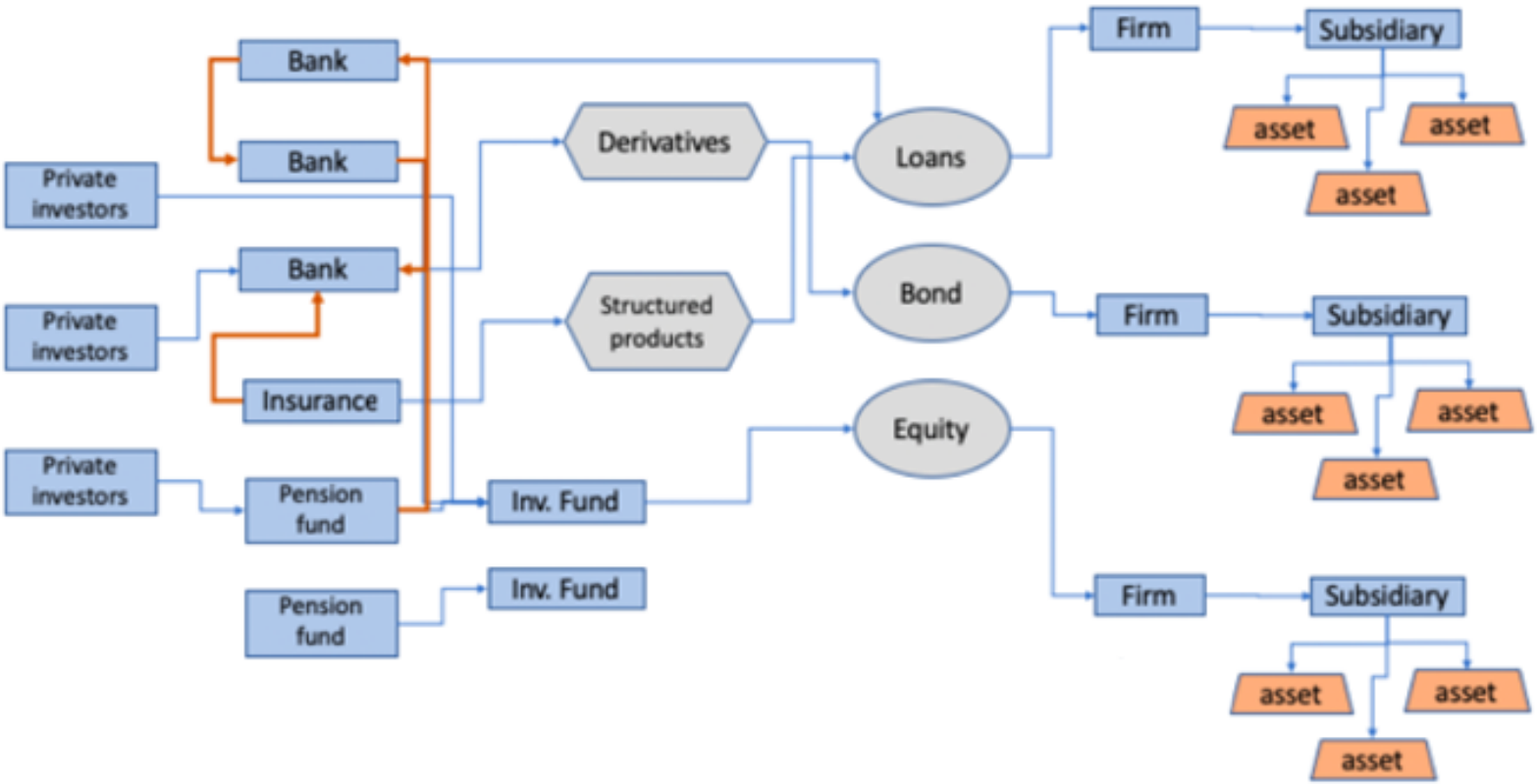

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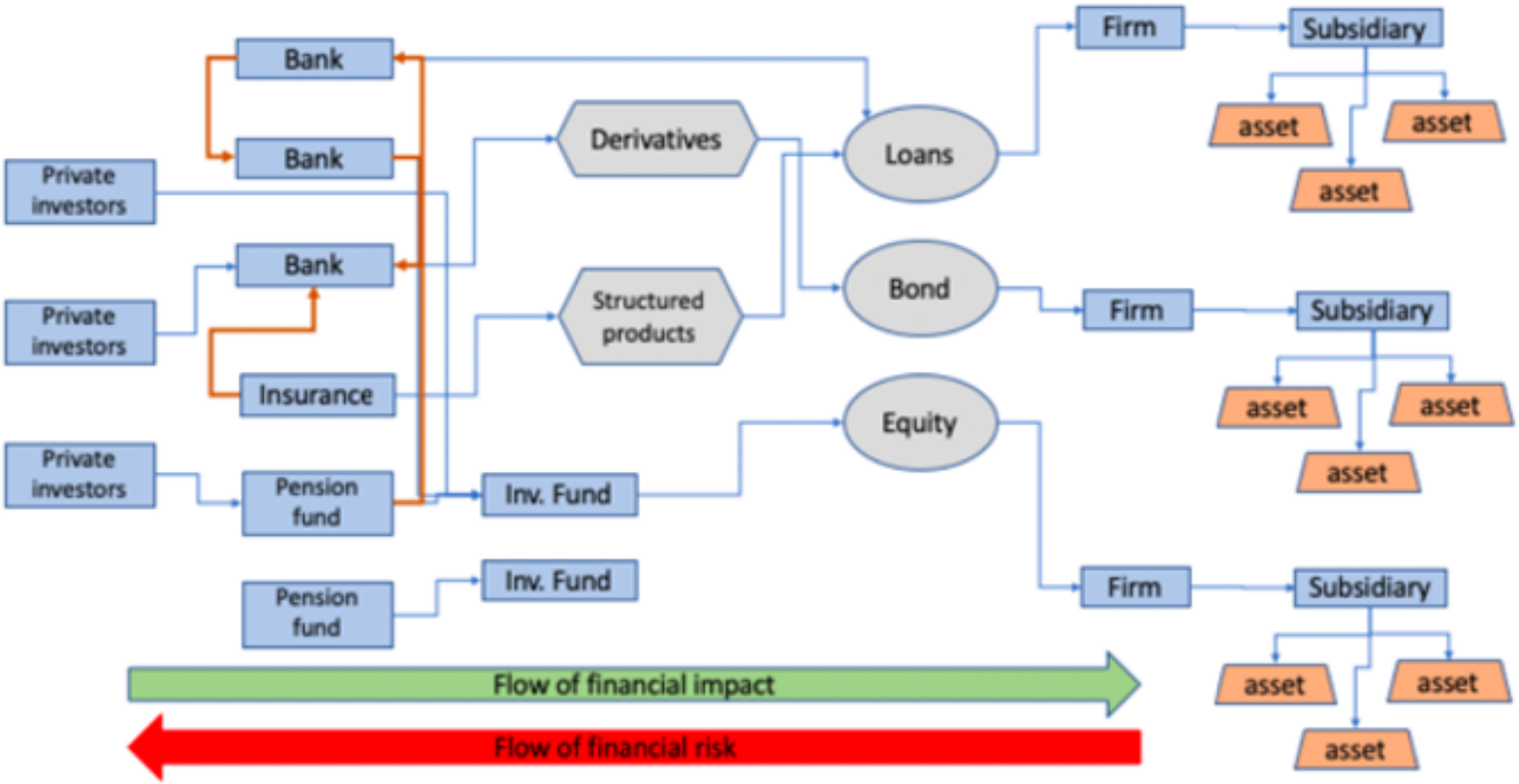
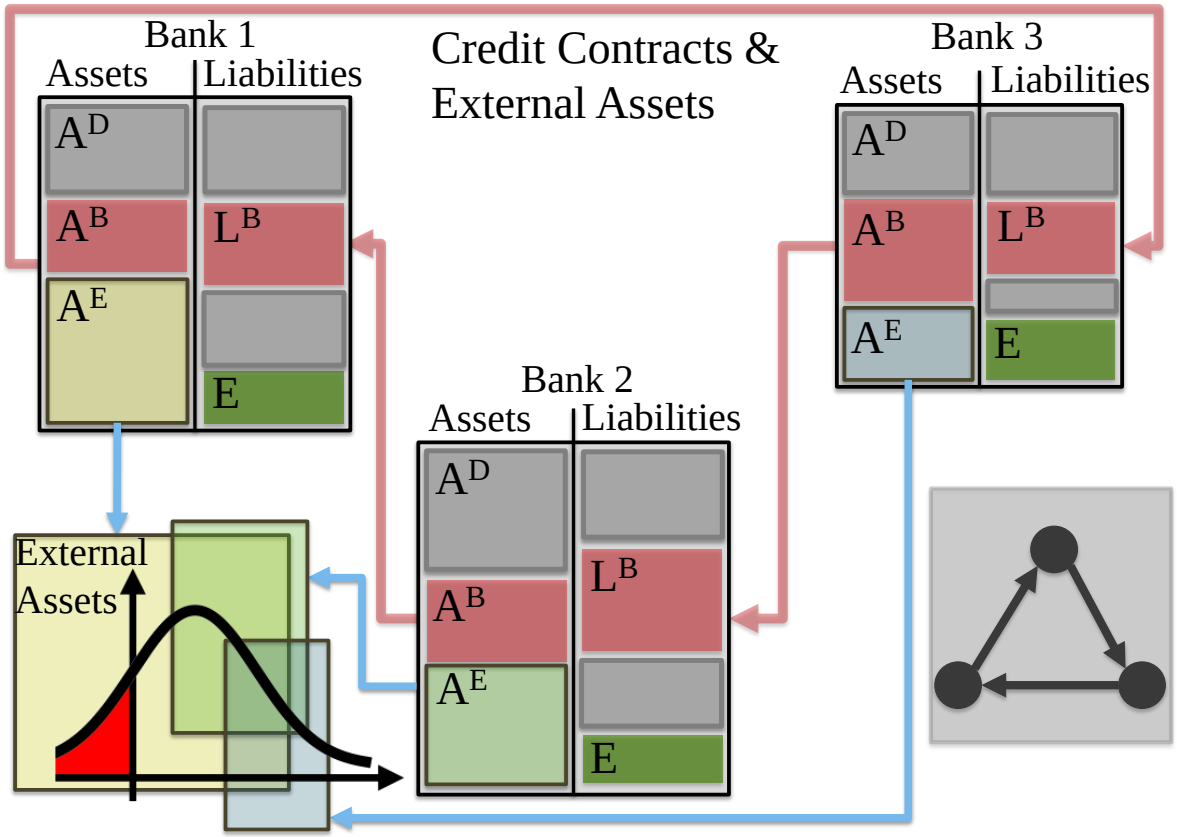


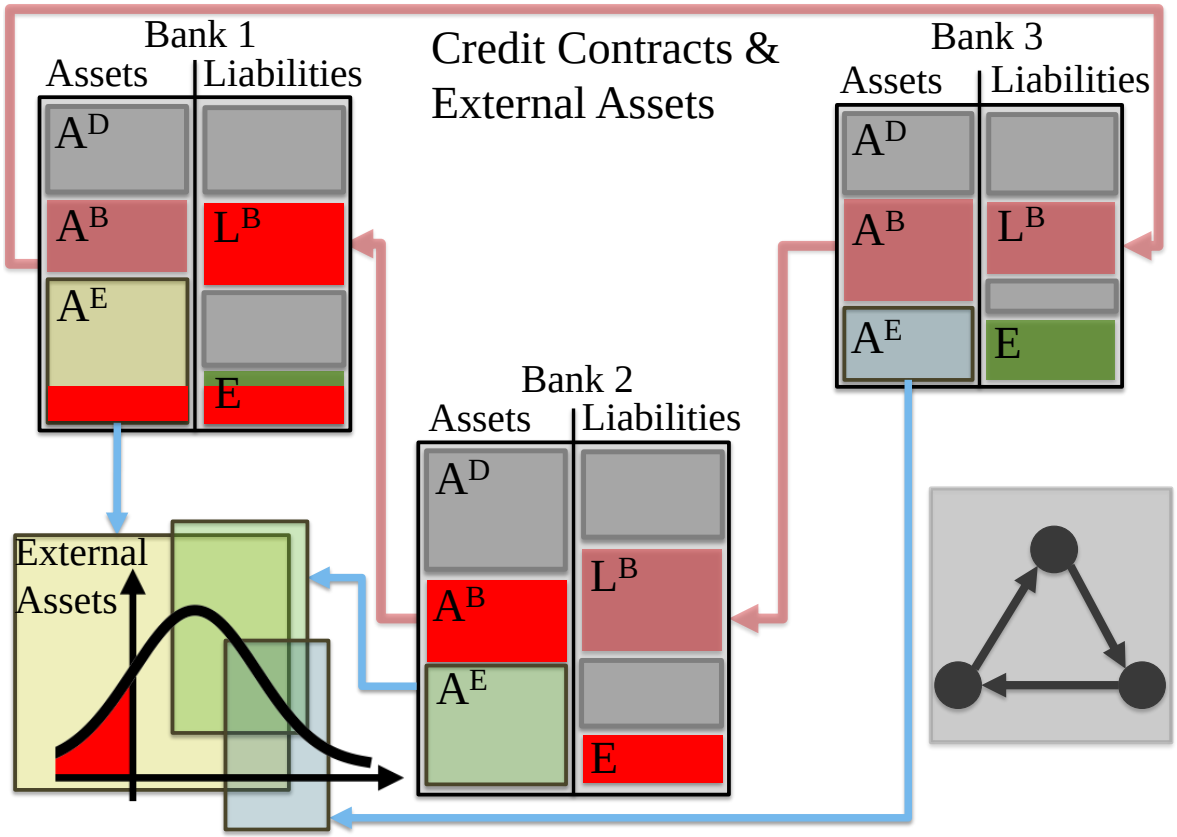
Flow of impact and risk across the network of financial contracts in the economy.

General model set-up



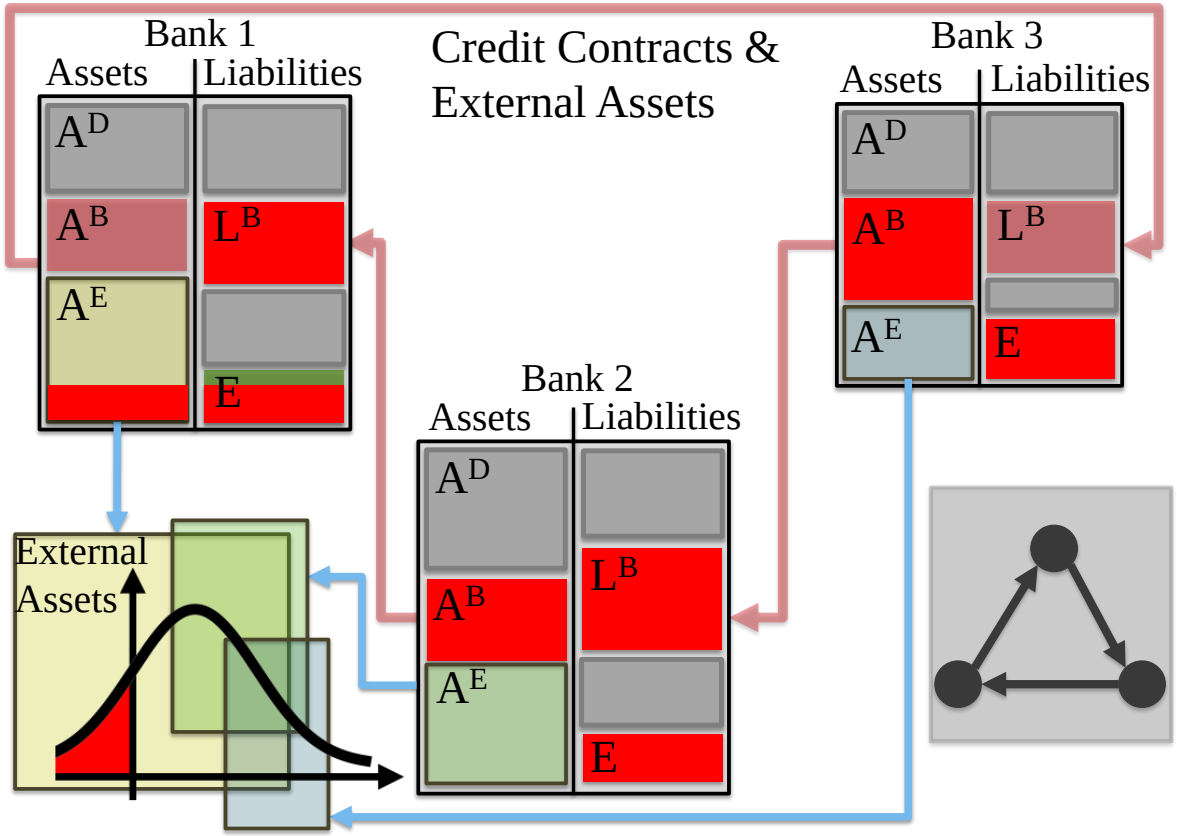
- Time 1: banks allocate assets and liabilities, with strategy and complete information.

General model set-up



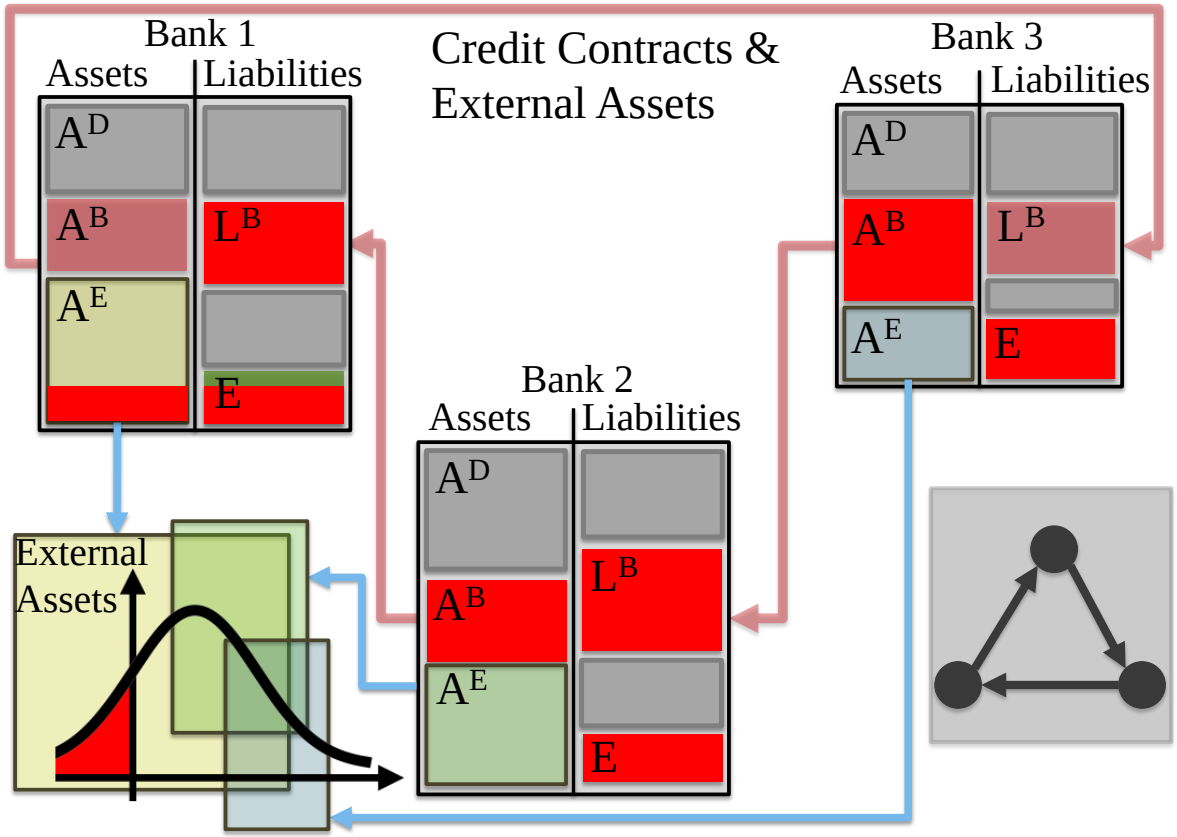
- Time T: stochastic shocks hit banks' external assets, debt contracts mature, some banks may default

General model set-up



- Time $T+1$: defaulted banks's assets liquidated, creditors get (endogeneous) **recovery rate** R recursively depending on default status of obligors.

General model set-up



- Time t $(1 \leq t \leq T)$: valuation of obligations, given available information at t, how to compute price of contracts (i.e. default probability of counterparties)?

General model set-up

Timing

- At time 1: Risk neutral agents decide to establish credit contracts with each other, based on expected returns in presence of bankruptcy costs
- At time T: Agents suffer exogenous shocks leading to possible chain of defaults at T+1
- At time t (with $1 \leq t \leq T$): Agents carry out valuation of obligations with available information

Questions

- How individual and systemic **default probability** depend on **network structure** and **type of contracts**? (e.g. Battiston ea. 2012 JEDC; 2016 PNAS; Schuldenzucker ea. 2021 MngSc)
- What are **equilibrium network structures** when actors can form contracts through a decentralized process? Are they efficient in terms of **resilience** to systemic risk? (Battiston & Stiglitz 2024 "Unstable by Design?" on-going work).

Stability in financial network models: what insights?

- *Liaisons Dangereuses*: full **risk diversification** is **not optimal** in the presence of **trend reinforcement** (Battiston ea. 2012 JEDC) and in presence of fixed bankruptcy costs (Battiston ea. 2012 JFS)
- *DebtRank*: algorithm to measure **systemic impact** of one or more actors capturing **distress** propagation even in absence of defaults (Battiston ea. 2012 Sci.Rep; 2016 Stat.Risk.Mod.; Barucca ea. 2020 Math. Fin.)
- *Price of complexity*: **network complexity** increases probability of **systemic defaults** as well as it **uncertainty** (Battiston ea. 2016 PNAS)
- *Pathways to instability*: sufficient conditions on **closed cycles** for **instability** (Bardoscia ea. 2017 Nature Comm.)
- *Default ambiguity*: **closed cycles** of Credit Default Swaps can lead to **market clearing break down**; sufficient conditions to restore existence/uniqueness (Schuldenzucker ea. 2021 Mng.Sc.)

Climate finance research: societal impact

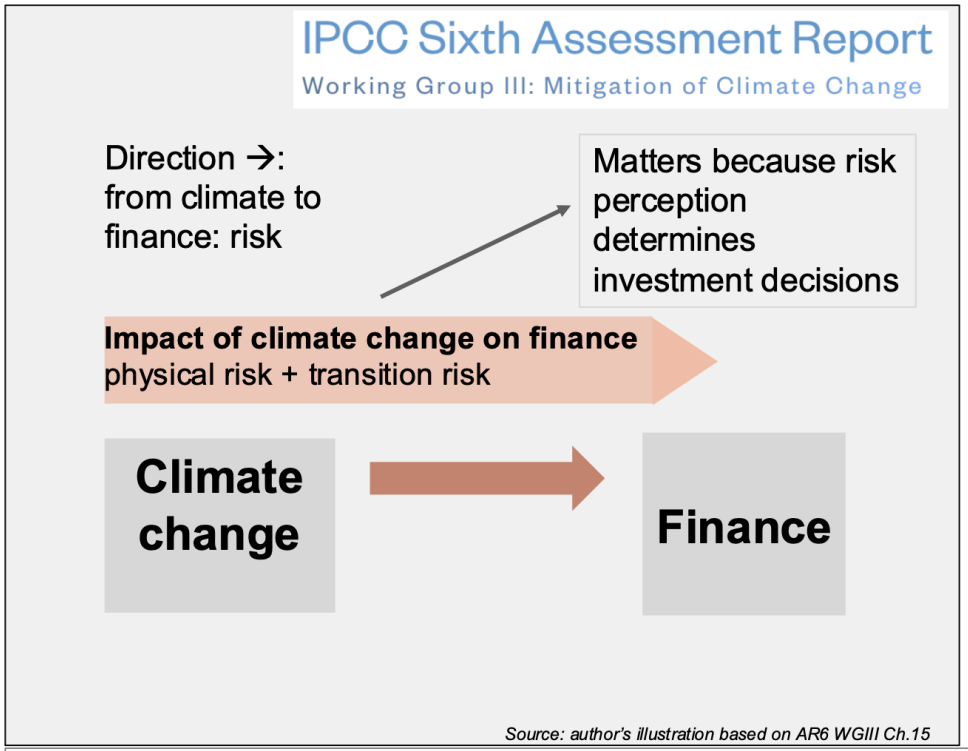
From academic research ...

- First science-based financial **Climate Stress-test** and Climate Policy Relevant Sectors (**CPRS**), classification of economic activities for transition risk (Battiston ea. 2017 Nature CC; 2021 Science; Roncoroni ea. 2021 JFS)
- European Taxonomy for sustainable investments: method to estimate **taxonomy-alignment of financial portfolios** (TAC & TEC) Alessi & Battiston 2022 Int.Rev.Fin.Anal

... to policy impact

- Users of CPRS and/or climate stress test method include: authorities ECB, EBA, EIOPA, ESMA, Swiss supervisor FINMA ...; industry: 100+ banks, insurance consultants, ...
- EU Commission, industry, data providers (e.g. S&P)

Climate stress tests for financial institutions



Impact of financial investments

- Firms make investment (CAPEX) decisions in high/low carbon equipment (e.g. wind vs coal power plants)
- Financial actors influence these decisions by making capital more/less expensive for firms

Barriers to mitigation

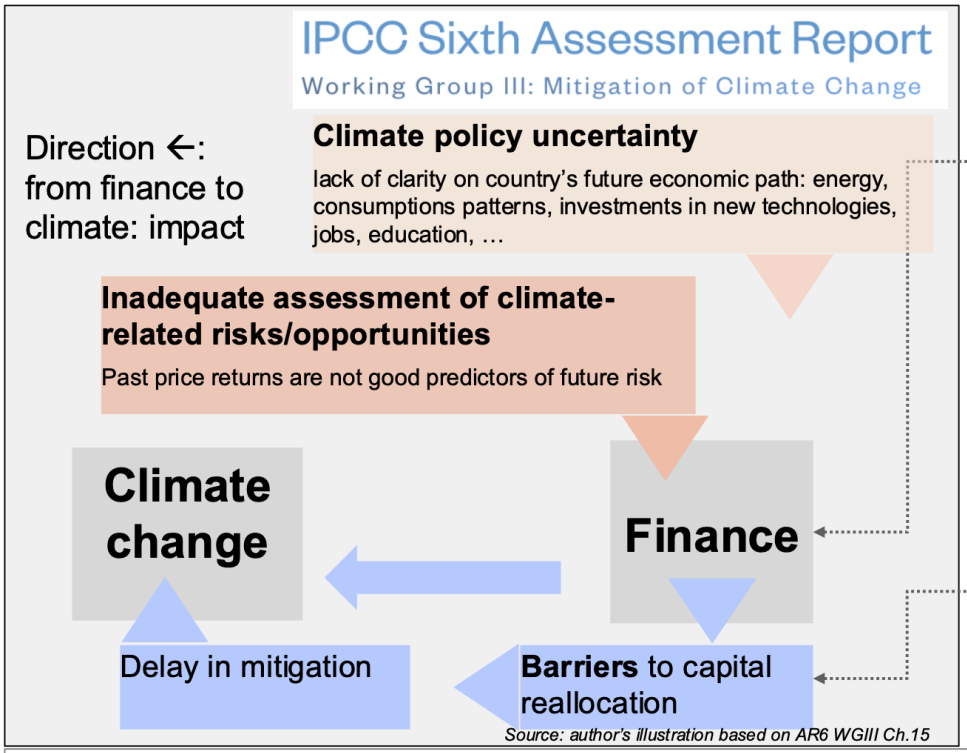
- Inadequate assessment of climate-related risks/opportunities
- When adequate, unattractive risk-return profiles because of national/regional conditions
- Weak regulatory environments, limited standardization (disclosure), lack of track record

Most barriers relate to **uncertainty** on decarbonization plans and transition risks for the private sector.

Source: Kreibiehl et al. Investment and Finance, Ch15 in IPCC *AR6 WGIII*

Kreibiehl, S., T. Yong Jung, S. Battiston, P. E. Carvajal, C. Clapp, D. Dasgupta, N. Dube, R. Jachnik, K. Morita, N. Samargandi, M. Williams, 2022: Investment and finance. In IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Working Group III to 6th Assessment Report of the Intergovernmental Panel on Climate Change

Climate stress tests for financial institutions



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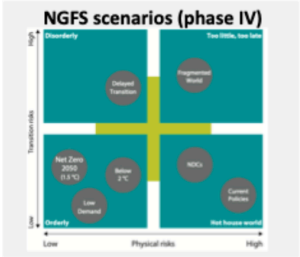
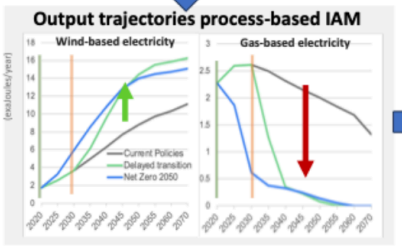
Climate stress tests for financial institutions

Adequate risk assessment:

- Forward-looking scenarios based on science and policy development
- Fundamental of firms
- Changes in **investors' expectations over future production trajectories** can translate in differences in future credit risk, depending on the technological profile of the firm

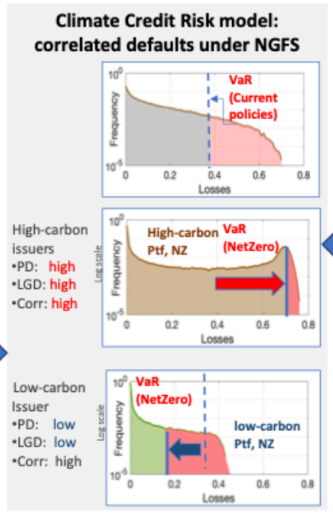
- Narrative and models: Battiston ea. 2017 *Nature Clim Ch.*; *Science* 2021; 2023 ssrn (Climacred); Bressan ea. 2024 *Nature Comm.*
- Policy applications: Battiston FSR BdF 2019; EIOPA Fin. Stab. Rep. 2019; FINMA Annual Report 2021; Roncoroni 2021 JFS; NGFS STS 2025

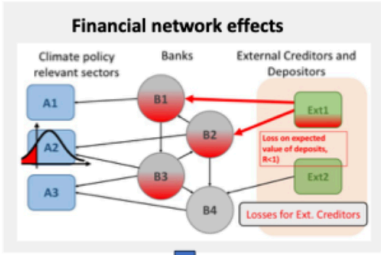




Climate-related financial data:

- Firms characteristics:
- emissions/tech
- Portfolios: holdings





- Climate scenarios (physical, transition risk)
- Estimates of sectors' production by energy technology, cash-flow streams of securities
- Scenario-contingent valuation adjustment of issuers' default probability, bond spread, credit risk etc. based on firms' exposure (asset-level) to climate risks
- Adjustment in financial risk measures (e.g. VaR) considering network effects

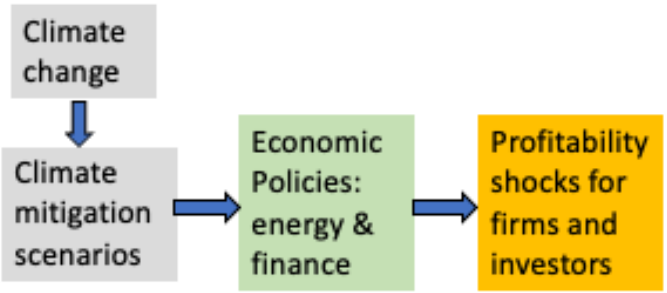
Climate financial risk Models

Adjustments to future cashflows
Adjustments to equity/bond valuation
Adjustment to risk measures for financial portfolios

What is the role of finance in the future of climate?

Macro-financial feedback loop from scenarios to investors' expectations

- **Climate risk** recognised by financial authorities as source of **financial risk** since 2019 (NGFS



Science

Battiston S., Monasterolo I., Riahi K., van Ruijven B.J., Accounting for finance is key for climate mitigation pathways, ***Science****, 28 May 2021. DOI: 10.1126/science.abf3877.*

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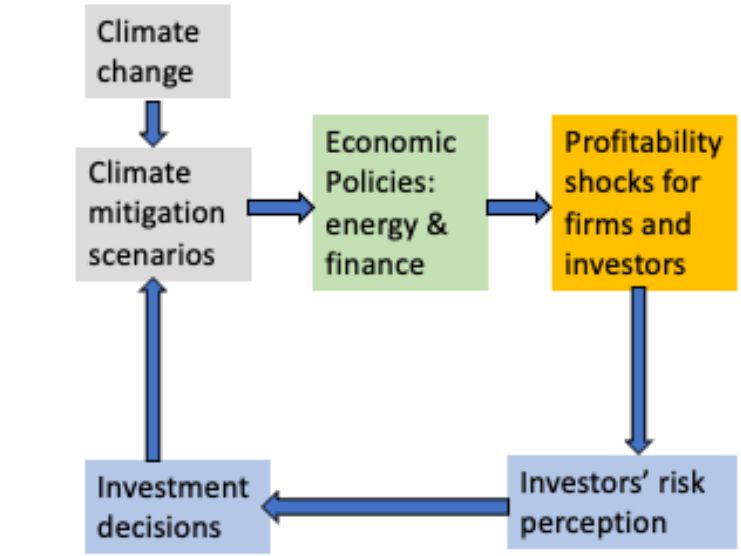
- Climate mitigation scenarios and policy credibility shape financial **investors' perception of risk** and thus investment decisions in low-carbon tech
- Yet current NGFS climate scenarios recommended by financial authorities do not account for impact of financial actors' looking at scenarios:
  - Missing feedback loop btw
    - Risk perception ←→ Scenarios



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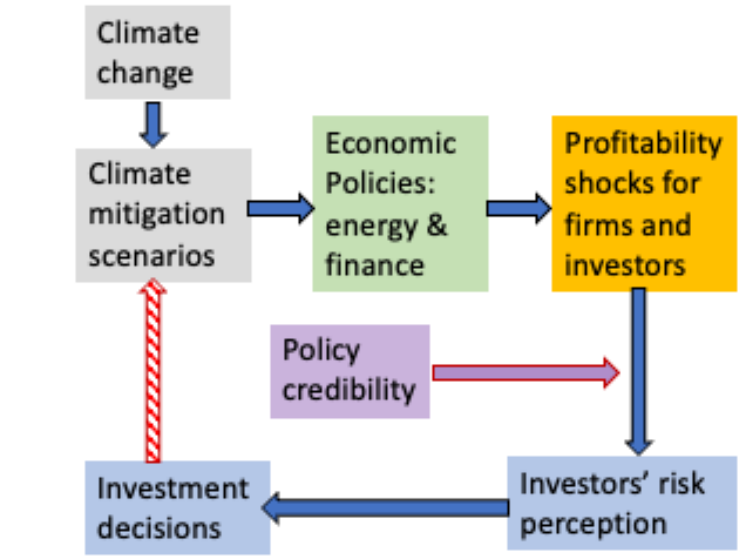
- Fixing the scenarios is key for the world to achieve the energy transition
- Modelling framework to generate new scenarios in Battiston ea. 2022 Science



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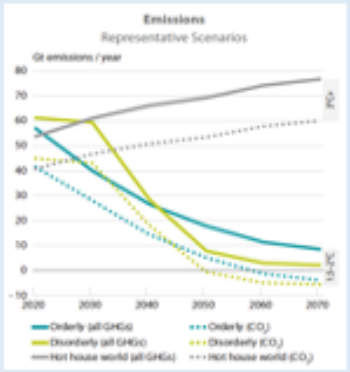
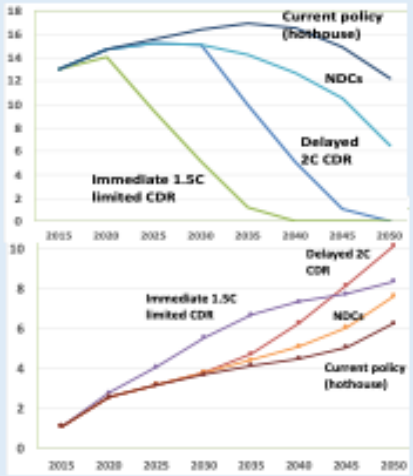
What is the role of finance in the future of climate?

Macro-financial feedback loop is missing

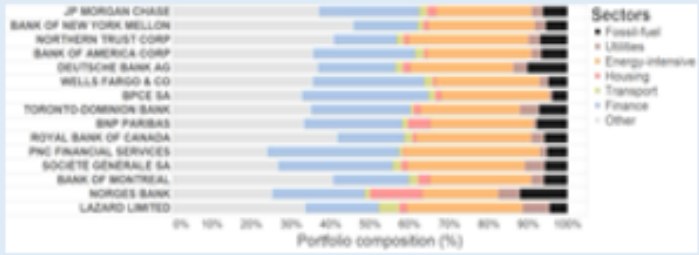
Climate scenarios' (IPCC, NGFS)



Economic scenarios (sector output, IAM)



Climate risk exposures *(disclosure)*



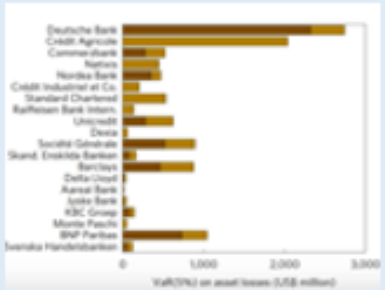
Battiston ea (2017)

Missing!

New investments and capital reallocation

Missing!

Climate-adjusted risk and asset *valuation (climate stress-test)*



Battiston ea (2017)

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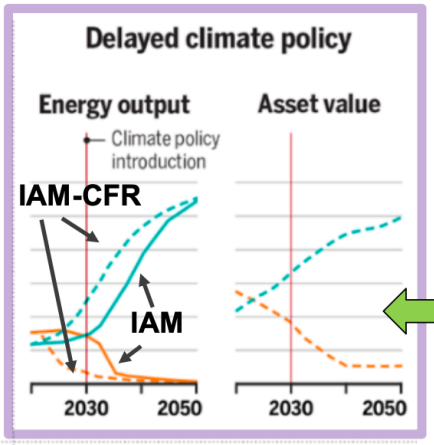

Science

Accounting for finance is key for climate mitigation pathways

> SCIENCE > VOL. 372, NO. 6545 >

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Enabling role of finance: investors' perception: high physical risk, **credible climate policies,** high transition risk (but opportunities from successful transition)

→ They reallocate capital into low-carbon investments early and gradually and anticipate policy impact

Hampering role of finance: investors' perception: low physical risk, **climate policies not credible,** high-carbon firms as risk low-carbon.

→Capital reallocation insufficient to fund investments required for 2C scenario. Transition either failed or more costly for society due to abrupt reallocations of capital and price adjustments.

Low-risk perception makes scenario unfeasible (self-defeating prophecy)

Legend

Trajectories from IAM scenarios — Renewable energy — Coal

Trajectories from IAM-CFR framework - - Renewable energy - - Coal

IAM: Integrate Assessment Model
CFR: Climate Financial Risk

Conclusions

What did I bring with me from SG Chair?

- passion for scientific endevour
- attention to added value of network models and complexity
- attention to implications for science and society

Huge legacy: thank you Frank!