Climate Risk and Financial Stability in the Network of Banks and Investment Funds

Stefano Battiston, FINEXUS Center, Dept. Banking & Finance, Univ. of Zurich
with A. Roncoroni (UZH), J.L. Escobar Farfan (Banco de Mexico), S. Martinez-Jaramillo (CEMLA and Banco de Mexico)

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Acknowledgments

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- NGFS - Network for Greening the Financial System: engaging stakeholders in framework for climate-related financial risk management under uncertainty
- EU FET CLIMEX: tool for practitioners to assess portfolio exposure climate-related financial risk

Previous grants

- SNF Professorship at Dpt. Banking and Finance, UZH: Financial Networks and Systemic risk
- EU FET **DOLFINS** 2015-2018, 14 partners: sustainable finance, policy evaluation, civic engagement.
- EU FET **SIMPOL** 2013-2016 Financial Systems and Policy Modeling: collaborations with central banks, ECB, DG-FISMA; complex derivatives, climate-finance, big-data, crowdsourcing policy maps.
- other EU projects: ISIGROWTH, SEIMETRICS, BIGDATAFINANCE

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Key messages

1. Growing concern for financial stability from climate inaction or late and sudden action
2. Stress-tests: primary tool to ensure orderly functioning and stability of financial markets
3. Challenges to go from stress-test to climate stress-tests: endogeneity of climate risk
4. First science-based Climate Stress-test of financial institutions: Battiston ea. 2017 (Nat Clim Change); applications at (ECB, EIOPA, and National Central Banks).
5. Roncoroni ea. 2019 (ssrn 3356459, RR on JFS): first climate stress-test combining: supervisory data (Banco de Mexico, as illustration for other LA countries), with network financial valuation (NEVA, Barucca ea. 2016) for banks and funds
6. Most parsimoniuos framework to conduct a science-based climate stress test

Stefano Battiston @zbattiz · Jan 17

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Motivation

1. In the aftermath of the Paris Agreement, growing awareness of need for a combination of climate policies in order reach 2C target.
2. NGFS and other platforms have raised concerns about
    1. unanticipated effect of introduction or implementation of climate policies
    2. disorderly transition to a low-carbon economy
3. The assessment of climate-related financial risks is currently a major dossier for most policy makers in EU, Asia and Latin America.
4. There is growing demand for an established approach to conduct climate stress-tests.

Challenge

1. Climate risk is endogenous: our perception of the risk feedback on the risk itself
   1. Multiple economic scenarios with unknown probability.
   2. Historical market information not sufficient to assess climate transition risk.
   3. Backward-looking materiality of risk is misleading.
2. Standard finance approaches (expected value) to risk assessment and contracts valuation are inadequate.
3. How can financial supervisors and financial institutions manage climate-related financial risk?

Research questions

- Q1 How do we build a **science-based climate stress-test** of the financial system?
- Q2 How do we translate **forward-looking** knowledge from climate science and climate economics into metrics of financial risk at the level of individual institutions and at system level?
- Q3 What are the policy insights that we can expect from a climate stress-test?

Methodology. Building on:

Climate stress-test (Battiston ea. 2017; Monasterolo ea. 2018):

- disorderly transition: temporary transition between equilibria of economic trajectories consistent with different climate policies
- shocks on financial assets: derived from shocks on GVA and revenues

Network financial valuation of claims (NEVA, Barucca ea. 2016) and (DebtRank, Battiston ea. 2012; 2016)

- standard finance valuation assumptions + fund contagion model

Data

- Economic trajectories from set of 6 climate economics models and 9 scenarios (IAM, LIMITS)
- **Supervisory data of Banco de Mexico** on bank and funds exposures to real economy

Contributions and Findings

C1 First combination of Climate Stress-test (Battiston ea. Nature Clim. Change 2017) with Network Valuation of Financial Assets (Barucca ea. 2016, RR Math Fin., interbank claims in network of obligations).

C2 **Analytical** and empirical relations on impact on financial stability from **interplay** btw 1) climate policy shocks and 2) financial market conditions including banks and funds.

F1 Policy implication I: in the face of possible disorderly transition financial institutions have incentive to engage earlier, under the same market conditions

F2 Policy implication II: possible to reach tighter climate policy target, at same level of risk if market conditions are strengthened enough.

THIS PRESENTATION

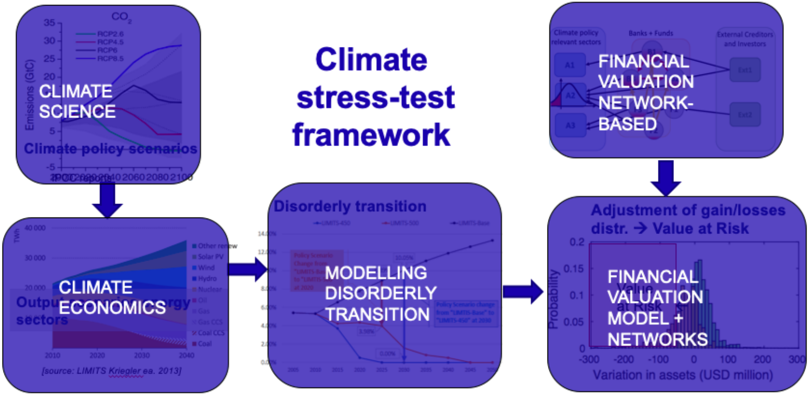
- Overview of climate risk issues that the framework addresses
- Visual illustration of components
- Appendix with formulas and more details

Framework

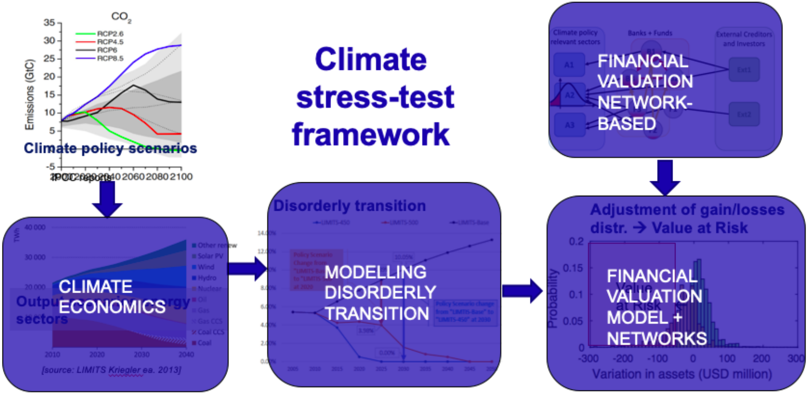
Framework

1. **Climate policy shocks:** Impact of a late and disorderly alignment to a climate policy scenario designed to meet a set of climate targets. Building on climate economics (e.g. LIMITS, CD-LINK)
2. **First round:** Losses suffered by banks and funds due to direct exposures to Climate Policy Relevant Sectors (CPRS) - supervisory data
3. **Second round:** Network valuation of intra-financial claims (NEVA Barucca ea. 2016, accounting for market volatility).
4. **Third round:** Banks' and funds' reaction to shock to get to initial risk management level which add further pressure on prices.
5. **Fourth round:** losses too large to be absorbed by banks' capital and are transmitted to external creditors (Roncoroni ea. 2019 ECB WP).

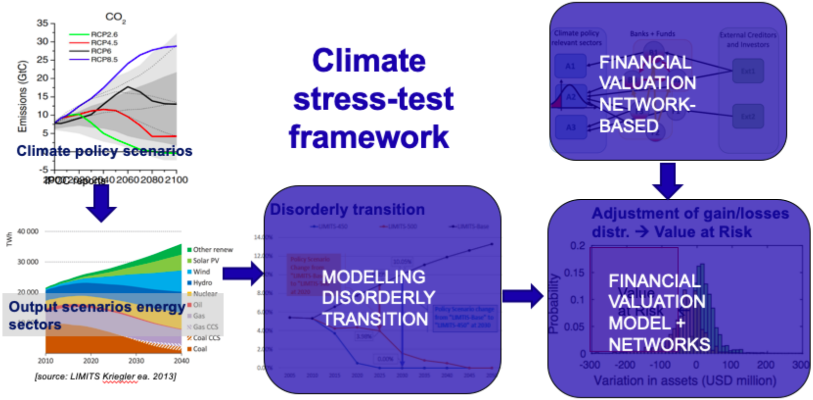
Climate stress test framework



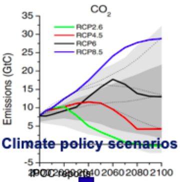
Climate stress test framework



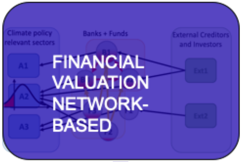
Climate stress test framework

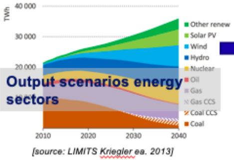


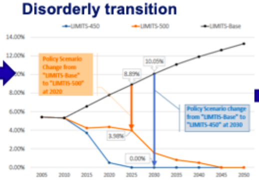
Climate stress test framework

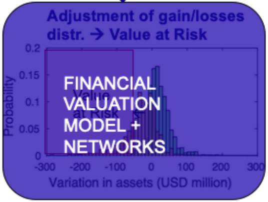


Climate stress-test framework

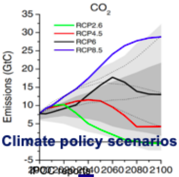


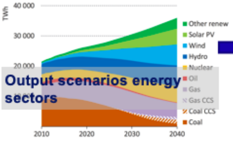






Climate stress test framework

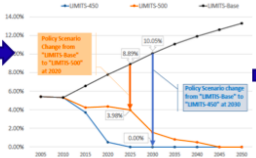


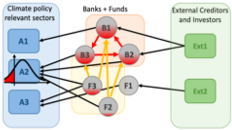


[source: LIMITS Kriegler ea. 2013]

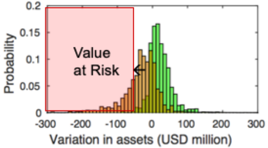
Climate stress-test framework

Disorderly transition

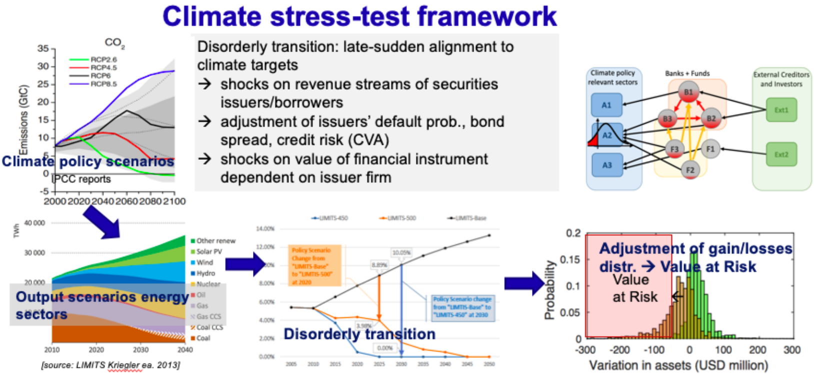




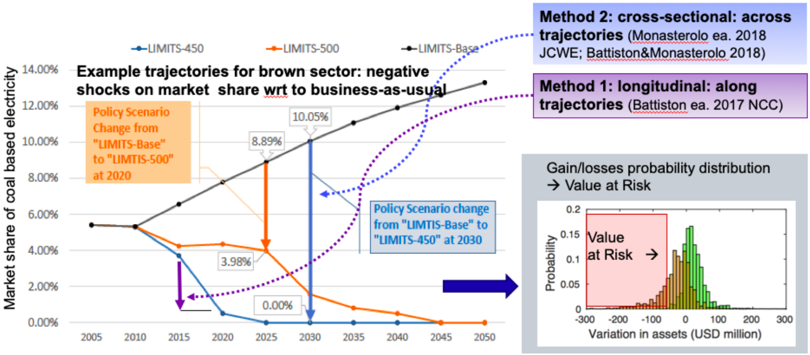
Adjustment of gain/losses distr. → Value at Risk



Climate stress test framework



Disorderly transition



Disorderly transition

NGFS
Central Banks and Supervisors
Network for Greening the Financial System

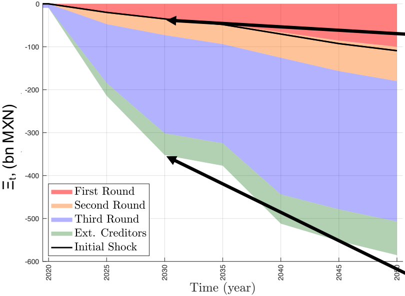
Transition pathway		Strength of response (based on whether climate targets are met): Met	Strength of response (based on whether climate targets are met): Not met
	Disorderly	**Disorderly** Sudden and unanticipated response is disruptive but sufficient enough to meet climate goals	**Too little, too late** We do not do enough to meet climate goals, the presence of physical risks spurs a disorderly transition
	Orderly	**Orderly** We start reducing emissions now in a measured way to meet climate goals	**Hot house world** We continue to increase emissions, doing very little, if anything, to avert the physical risks

Physical risks →

Transition risks ↑

(*)Source: NGFS 2019

Results - how to read



~40 bn of Mexican pesos

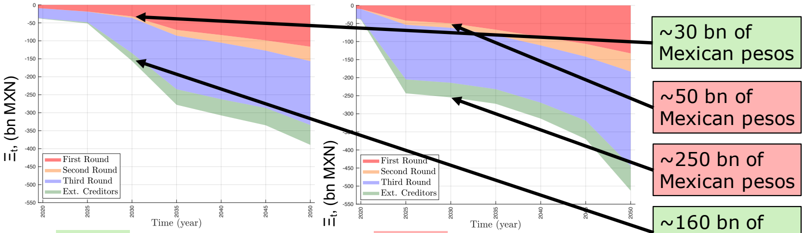
Black line: initial loss
Red: losses due to direct exposure
Orange: losses due to interbank contagion
Blue: losses due to common exposure contagion
Green: losses suffered by external creditors of banks

~360 bn of Mexican pesos

Shock (in mln of Mex. pesos) under a mild policy scenario [RefPol-500, GCAM, R=0.5, σ=1.0, α=ln(4/3), VaR=1%].

Roncoroni ea. 2019 - Climate risk and financial stability in the network of banks and investment funds

Results - Policy implication I



(a) StrPol-500, $R = 0.49334$, $\sigma = 0.90776$ (b) StrPol-450, $R = 0.50470$, $\sigma = 0.90235$

Under the same market conditions (R, σ), a stricter climate policy scenario triggers larger shocks for the financial system.

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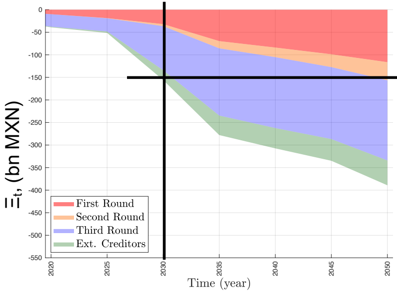
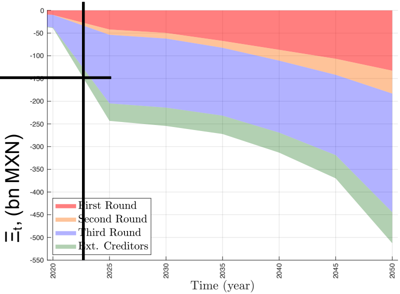
Results - Policy implication II



(a) StrPol-500, $R = 0.49334$, $\sigma = 0.90776$



(b) StrPol-450, $R = 0.50470$, $\sigma = 0.90235$

Under the same market conditions, the disorderly transition to a stricter scenario may lead to the same level of losses if the alignment occurs earlier.

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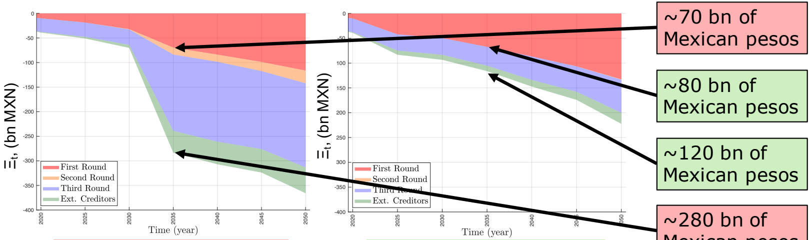
Results - Policy implication III



(a) StrPol-500, $R = 0.39607$, $\sigma = 0.80354$

(b) StrPol-450, $R = 0.78736$, $\sigma = 0.38525$

If market conditions (R, σ) are less risky, aligning to a more stringent climate policy scenario might lead to lower losses than aligning to a less stringent climate policy scenario.

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Illustration of climate distress propagation

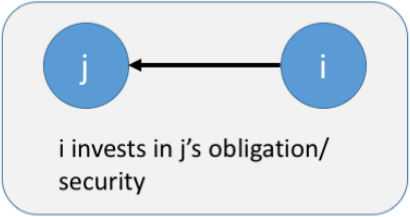
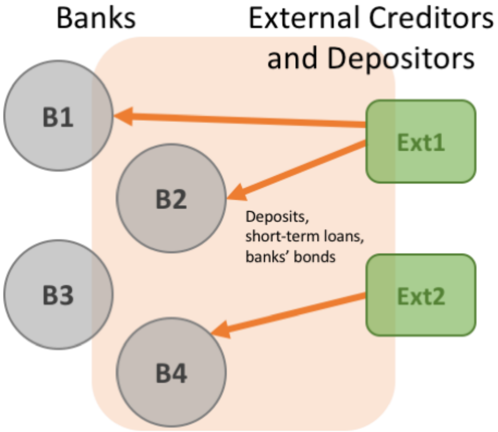


Illustration of climate distress propagation

Transmission channel via banks

Illustration of climate distress propagation



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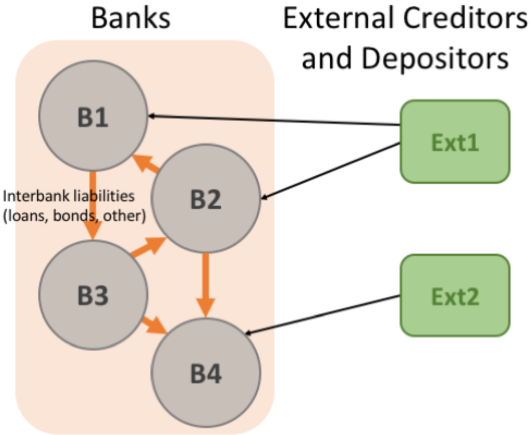

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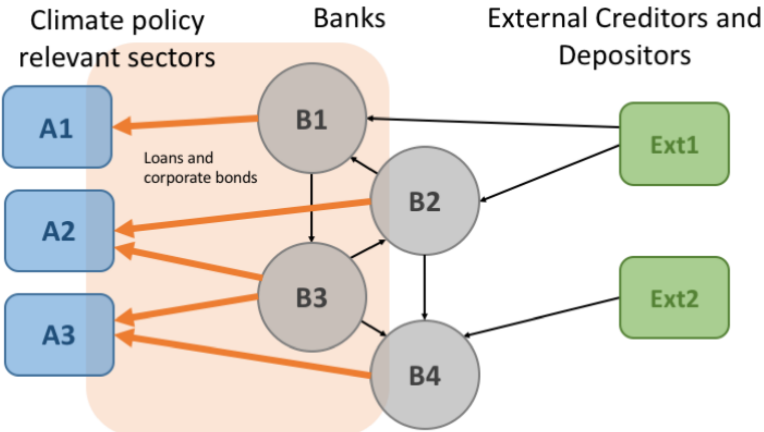

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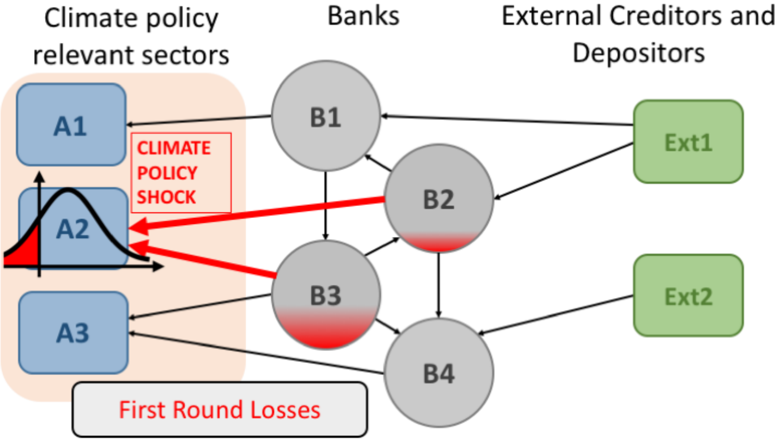

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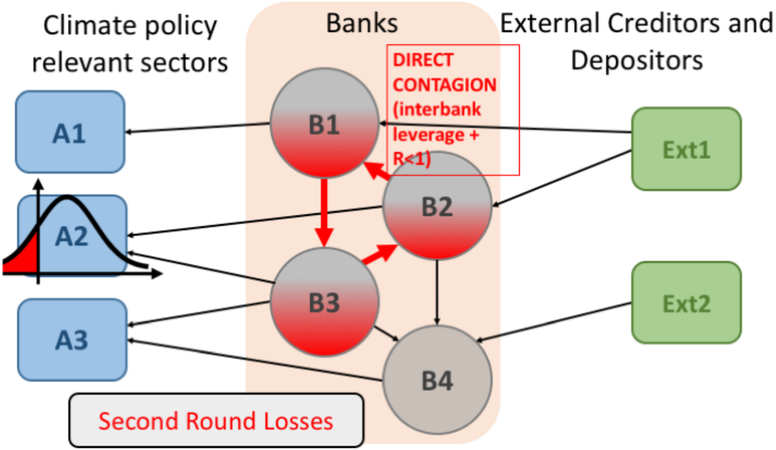

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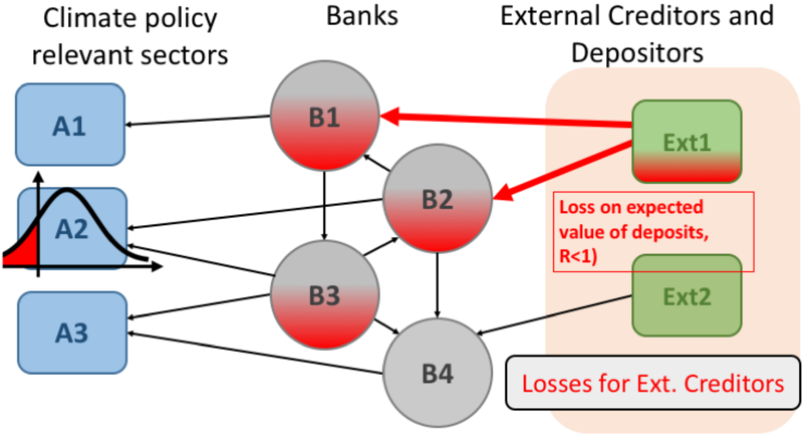

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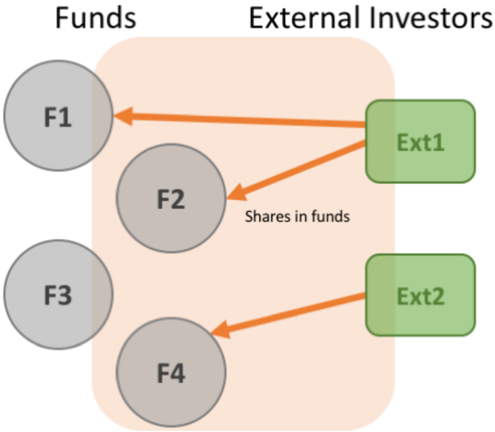


Illustration of climate distress propagation

Transmission channel via funds

Illustration of climate distress propagation

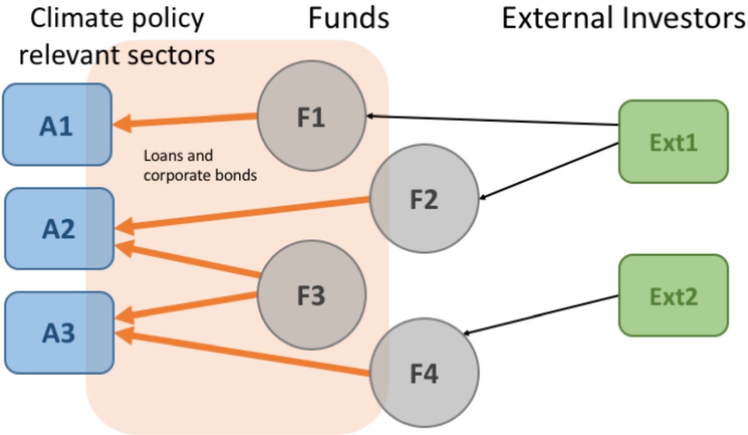
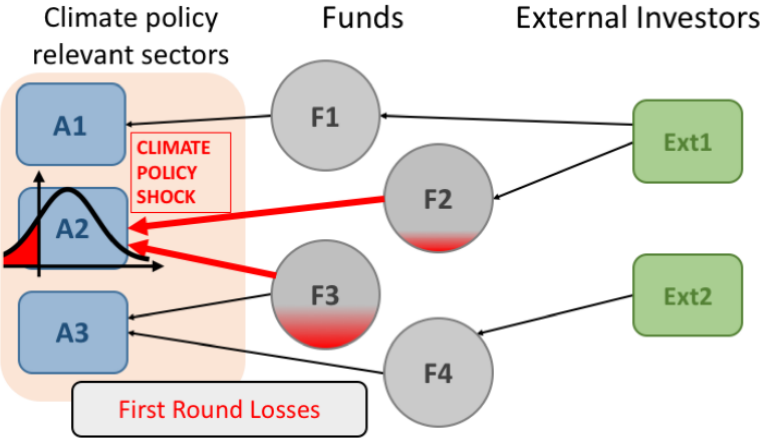


Illustration of climate distress propagation



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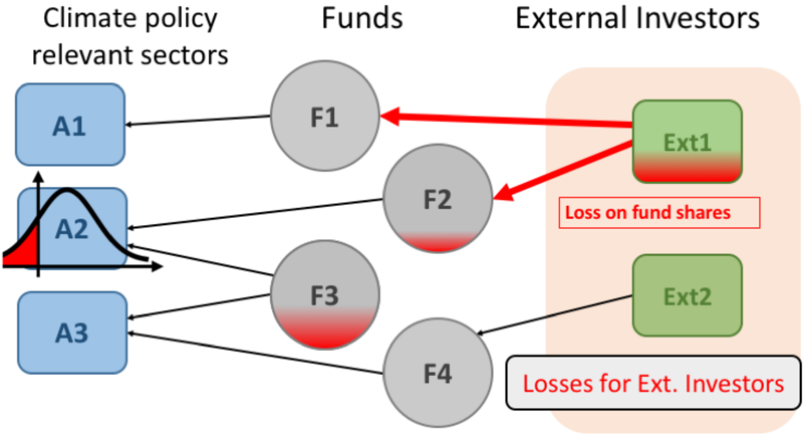
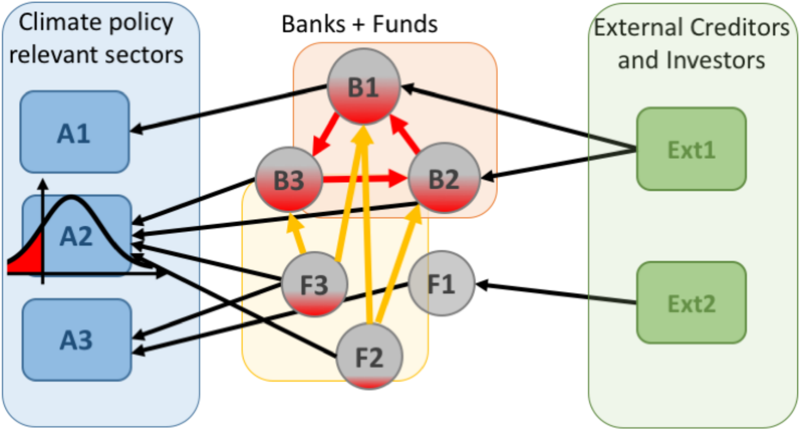


Illustration of climate distress propagation

Transmission channel via
bank AND funds

Illustration of climate distress propagation



Conclusions and key messages - I

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4. Most parsimoniuos framework to conduct a science-based climate stress test

Conclusions and key messages - II

- C1 First combination of **Climate Stress-test** (Battiston ea. Nature Clim. Change 2017) with **Network Valuation of Financial Assets** (Barucca ea. 2016, RR Math Fin., interbank claims in network of obligations).
- C2 **Analytical** and empirical relations on impact on financial stability from **interplay** btw 1) climate policy shocks and 2) financial market conditions including banks and funds.
- F1 Policy insight I: in the face of possible disorderly transition, **incentive** of financial institutions to engage earlier, under the same market conditions. Assess its **magnitude** in terms of Value at Risk reduction.
- F2 Policy implication II: possible to reach tighter climate policy target, at same level of risk if market conditions are strengthened enough.

APPENDIX

First round

Losses due to direct exposure

- Trajectories of market shares of economic (sub-)sectors under various climate policy scenarios (e.g. LIMITS, Kriegler ea. 2013).
- Relative difference in market share of sector c at time t btw scenario S (model m, policy p) wrt Business-As-Usual (BAU).
- Shock on value of security c (e.g. bond)

$$\Delta A_c = f(\psi_c, F_c, r_c, YTM_c, T_c)$$

  where A expected value, F par value, r_c recovery rate of bond, YTM_c yield to maturity, T_c maturity.
- Very simplified case: expected value $\Delta A_{ic} \approx F_{ic}(1 - r_c)\chi\psi_c$ where F face value, χ elasticity of profitability. [Monasterolo ea. 2018].
- Both for banks and funds, first round shock Ξ_i^{1st} thus is

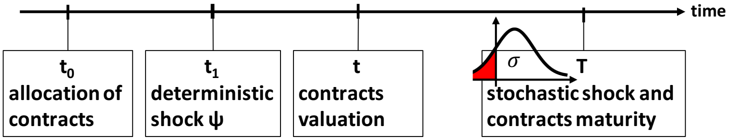
$$\Xi_i^{1st} = \sum_c \min\{0\,,\ \Delta A_c\} \cdot A_{ic} = \sum_c \min\{0\,,\ \psi_c\} \cdot A_{ic}.$$

Network Valuation of Financial Assets (NEVA)

- Ex-ante financial valuation [Barucca et al., 2016] of banks' obligations carried out at t , consistent with
  1. network of contracts with maturity T
  2. uncertainty on external assets σ
  3. endogenous recovery rate, with recovery rate coefficient R

$$E_i(t,T) = A_i^e(t,T) + \sum_{j=1}^{N} A_{ij}^b \cdot V_{ij}(E_j(t,T), A_j^e(t,T), \sigma, R) - L_i \Big|_{\text{shock at } t=0}$$

- $A_i^e(t,T)$ is valuation at t of bank i's external assets at time T;
- $V_{ij}(\dots)$ is valuation at t of i's interbank assets towards j



Network Valuation of Financial Assets (NEVA)

Endogenous recovery rate

- Under assumptions of limited liabilities, absolute priority and proportionality [Eisenberg and Noe, 2001]: interbank contract pays 1 if $E_j \geq 0$, and pays

$$R \cdot \left(\frac{E_j + \bar{p}_j}{\bar{p}_j} \right)^+$$

if $E_j < 0$, with $\bar{p}_j$ aggregate interbank debt of bank j.

Local information

- Valuation of financial contract i, j carried out based on j's equity, assets volatility σ:

$$V_{ij}(E_j) = 1 - p_j^D(E_j) + R \cdot \rho_j(E_j)$$

- with $p_j^D(E_j)$ endogenous default probability of j, $\rho_j(E_j)$ endogenous recovery rate of j.

Network Valuation of Financial Assets (NEVA)

Definition 1: Feasible valuation function

Given an integer $q \leq n$, a function $\mathbb{V} : \mathbb{R}^q \to [0, 1]$ is called feasible valuation function if and only if:

1. it is non-decreasing: $\mathbf{E} \leq \mathbf{E'} \Rightarrow \mathbb{V}(\mathbf{E}) \leq \mathbb{V}(\mathbf{E'}), \forall \mathbf{E}, \mathbf{E'} \in \mathbb{R}^q$,
2. it is continuous from above.

Theorem 1: Existence of solution

The set of solutions is a complete lattice, i.e. it exists E^- and E^+.

Theorem 2: Convergence to E^+

1. the sequence $E^{(k)}$ is monotonic non-increasing: $\forall k \geq 0,\ E^{(k+1)} \leq E^{(k)}$,
2. the sequence $E^{(k)}$ is convergent: $\lim_{k\to\infty} E^k = E^\infty$,
3. E^∞ is a solution and $E^\infty = E^+$.

Common Asset Contagion - Banks' asset liquidation

Banks' target leverage strategy

- If negative shock on asset is absorbed by equity $\rightarrow$ leverage $(\Lambda_i = \frac{A_i}{E_i})$ increases.
- After first (Ξ_i^{1st}) and second (Ξ_i^{2nd}) round shocks bank i leverage is:

$$\Lambda_i^{2nd} = \frac{A_i^{2nd}}{E_i^{2nd}} = \frac{A_i^0 + \Xi_i^{1st} + \Xi_i^{2nd}}{E_i^0 + \Xi_i^{1st} + \Xi_i^{2nd}} \geq \frac{A_i^0}{E_i^0} = \Lambda_i^0.$$

- Bank i recovers initial level of leverage by liquidating a fraction k_i of its assets, such that:

$$\Lambda_i^{3rd} = \frac{(1 - k_i)\left(A_i^0 + \Xi_i^{1st} + \Xi_i^{2nd}\right)}{E_i^0 + \Xi_i^{1st} + \Xi_i^{2nd} + k_i\left(A_i^0 + \Xi_i^{1st} + \Xi_i^{2nd}\right)} = \Lambda_i^0 = \frac{A_i^0}{E_i^0}.$$

Common Asset Contagion - Funds' asset liquidation

Funds' target VaR strategy

- First (Ξ_i^{1st}) and second (Ξ_i^{2nd}) round shocks shift asset risk profile towards the left $\rightarrow VaR_i$ increases.
- Initial relative VaR is $\overline{\mathrm{VaR}}_i = \frac{\mathrm{VaR}_i^0}{A_i^0}$.
- After first (Ξ_{it}^{1st}) and second (Ξ_{it}^{2nd}) round shocks fund i VaR is:

$$\mathrm{VaR}_i^{2nd} = (A_i^0 + \Xi_i^{1st} + \Xi_i^{2nd}) \cdot \overline{\mathrm{VaR}}_i - \Xi_i^{1st} - \Xi_i^{2nd} \geq A_i^0 \cdot \overline{\mathrm{VaR}}_i = \mathrm{VaR}_i^0$$

- Fund i recovers initial level of VaR by liquidating a fraction k_i of its assets, such that:

$$\mathrm{VaR}_i^{3rd} = (1 - k_i) \cdot (A_i^0 + \Xi_i^{1st} + \Xi_i^{2nd}) \cdot \overline{\mathrm{VaR}}_i - \Xi_i^{1st} - \Xi_i^{2nd} = \mathrm{VaR}_i^0.$$

Common Asset Contagion - negative pressure on asset price

Common Asset Contagion - negative pressure on asset price

- Banks' and funds' sudden liquidation adds further negative pressure on asset prices.
- We assume an exponential impact of liquidation on asset prices [Cifuentes ea. 2005]. The price of asset class c thus is

$$p_c^{\text{after}} = p_c^{\text{before}} \cdot e^{-\alpha \frac{\sum_i A_{ic}^0 (1-\psi_c) k_i}{\sum_i A_{ic}^0 (1-\psi_c)}} = p_c^{\text{before}} \cdot e^{-\alpha K_c},$$

  where $-\alpha$ is the market liquidity.
- The value of bank's and fund's assets decreases.
- Third round shock thus writes

$$\Xi_i^{3rd} = -\sum_c (1-\psi_c) \cdot A_{ic}^0 \cdot (1-k_i) \cdot \left(1 - \frac{p_c^{\text{after}}}{p_c^{\text{before}}}\right).$$

Climate VaR and Climate Policy Shocks

Definition. Portfolio Climate VaR conditional to shock B→ P

- **Portfolio Climate VaR** is defined as the Value-at-Risk of the portfolio of the investor, conditional to Climate Policy Shock Scenario $B \rightarrow P$, with π portfolio return, $\psi_P(\pi)$ distribution of returns conditional to shock B→ P:

$$\text{ClimateVaR}(P) = \int_{\inf(\pi)}^{\text{ClimateVaR}} \pi\, \psi_P(\pi)\, d\pi = C^{VaR}$$

  - with *portfolio rate of return* π_i at T, with W_{ij} amount (numeraire) of j's bond purchased by i, investor i's *portfolio value* z_i, $z_i(T) = \sum_j W_{ij} v_j(T)$, $\qquad \pi_i = \frac{z_i(T) - z_i(t_0)}{z_i(t_0)}$.

Proposition. Climate VaR and policy shock

- Conditional to policy shock scenario $B \rightarrow P$, the ClimateVaR(P):
  - increases with magnitude of policy shock $|\xi_j(P)|$ if $\xi_j(P) < 0$
  - decreases with magnitude of policy shock if $\xi_j(P) > 0$
  - increases with marginal default probability adjustment $\Delta q_j(P)$ of bond j

Properties - contagion

Properties - direct contagion

- Second round losses non-decreasing for negative shock magnitude $(-\psi)$.
- Second round losses are non-decreasing in market volatility (σ).
- Second round losses are non-increasing in recovery rate (R).

Properties - common asset contagion

- Third round losses are non-decreasing for negative shock magnitude $(-\psi)$.
- Third round losses are non-decreasing in second round losses.
- Third round losses are non-increasing in market liquidity $(-\alpha)$.

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