Pricing forward-looking climate risks in investors' portfolios: the CLIMAFIN tool

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Irene Monasterolo
Vienna Univ. of Economics and Business (WU),
Boston Univ, CefES Milan Bicocca
irene.monasterolo@wu.ac.at

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Pricing forward-looking climate financial risks is key to signal the market. But challenging

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1. **Climate uncertainty** (Weitzman 2009), **non-linearity** (Ackerman 2017): historical values and benchmarks aren't good proxy of future risks

2. **Endogeneity of risk:** transition outcomes depend on gov. and firms' investment decisions:
   - Both decisions depend on agents' **risk perception**, but risks differ across the possible transition scenarios (Battiston ea. 2017)

3. **Financial risk:** interconnectedness and price of complexity (Battiston ea. 2016)

➢ **Standard approach to financial risk** analysis (i.e. computing expected values and risk based on historical values of market prices and volatility measures) **is not an adequate** for climate risk.

Climate transition risk can drive financial risk

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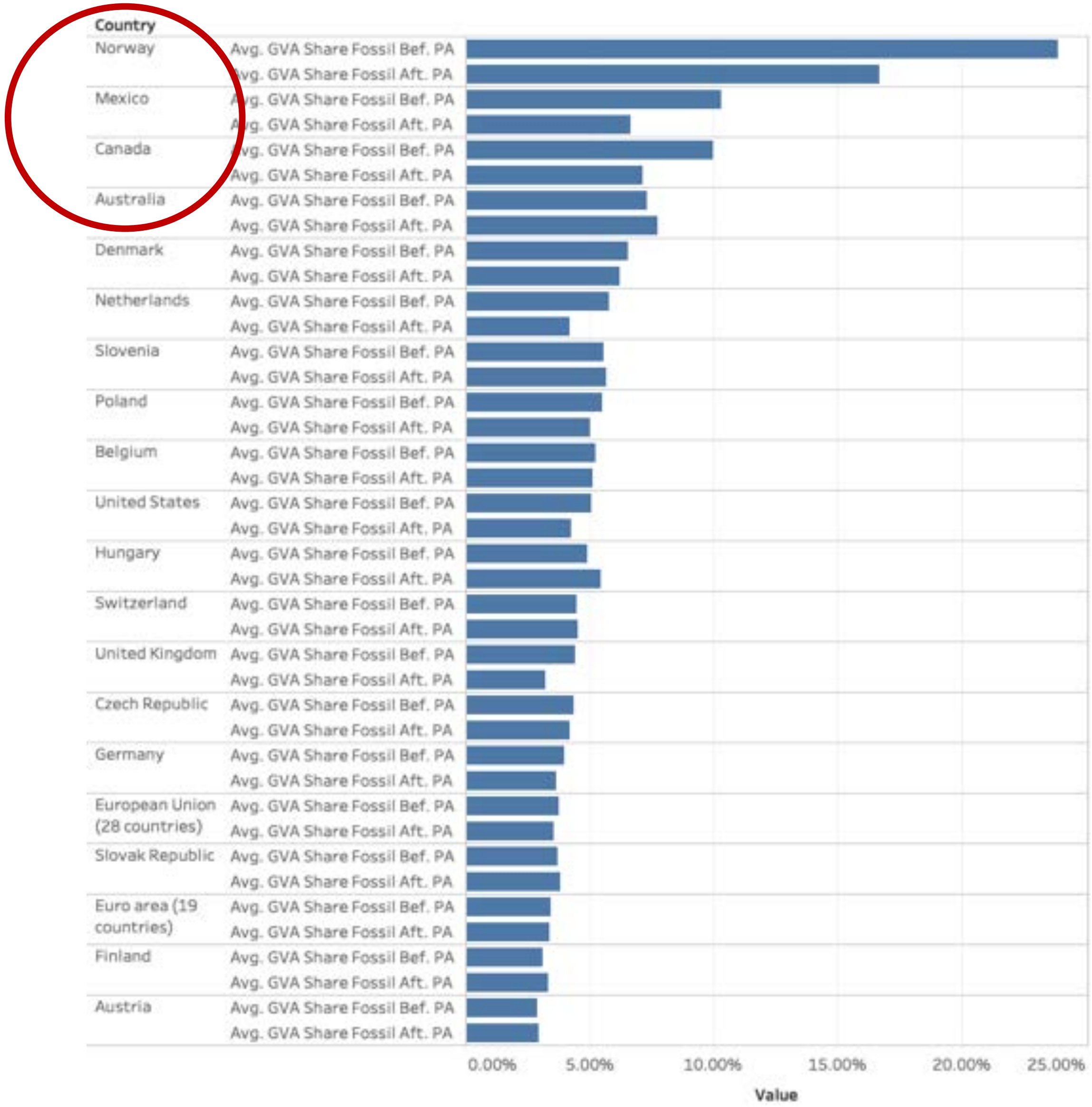

- Achieving the Paris Agreement’s climate targets requires to **decarbonize the economy** and massive investments into renewables (IPCC 2018). But…

- **Average share of fossil fuels on Gross Value Added (GVA) high:** in OECD country it reaches 18% after the Paris Agreement (Norway) and increasing (Australia) (OECD data).

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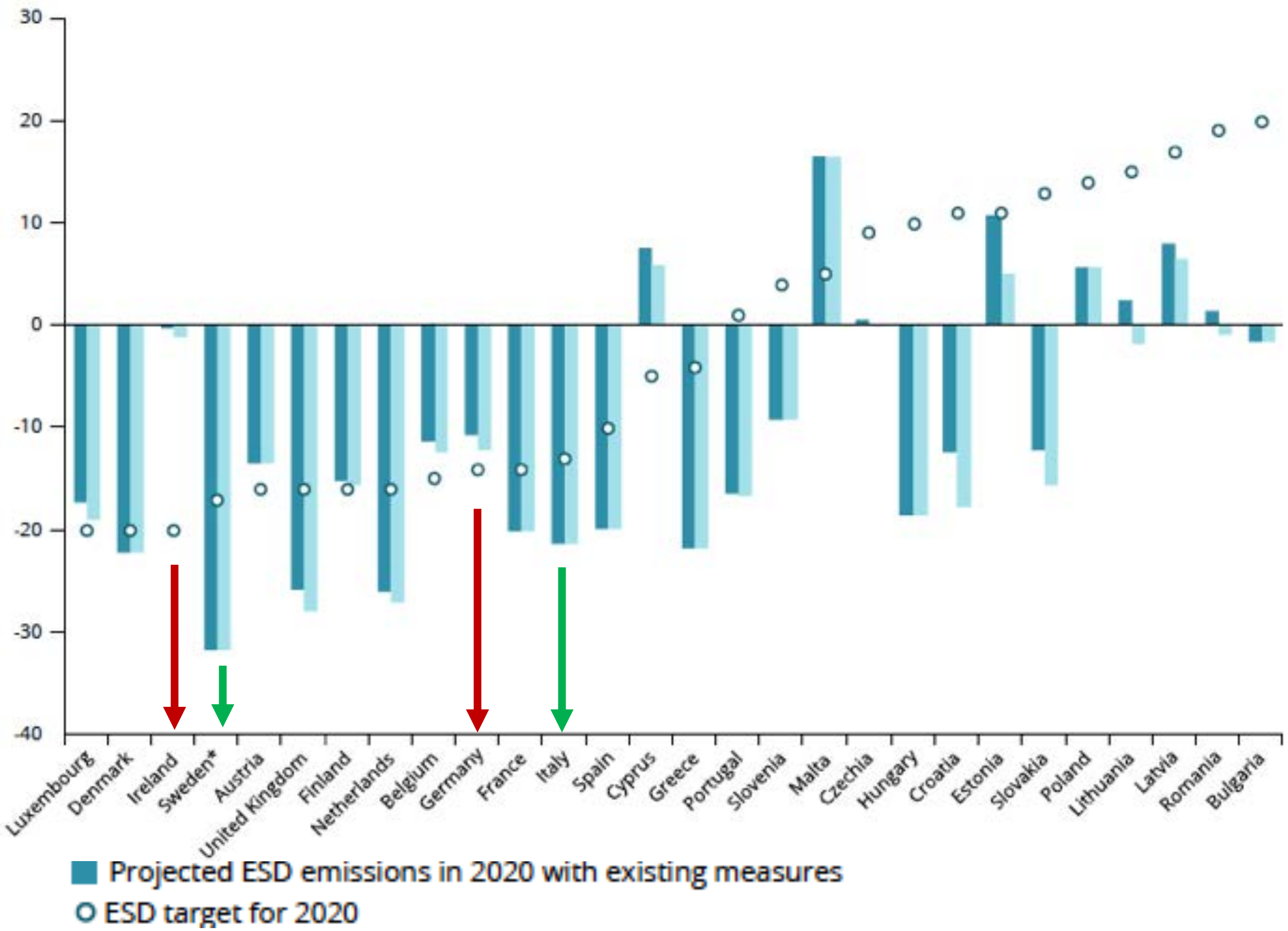
Indeed, most economies are misaligned to the climate targets

Projected EU member states' progress towards (unambitious) 2020 targets



- Heterogeneity in degree of alignment
- **Disorderly transition** (late introduction of policies/regulations that investors cannot fully anticipate and price) can lead to asset **price volatility** with **financial stability** implications (Battiston et al. 2017)
- **Countries** whose economies are **(mis)aligned** are more **exposed to climate transition risk**

Implications on sovereign’s fiscal and financial stability

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- **Climate financial risk pricing** can affect investors’ risk management strategies and financial regulation:

  - **Asset manager** who has to comply with **climate financial risk disclosure** (TCFD 2017) may revise its portfolio risk management:
  - ➢ Should I divest from bonds of misaligned (riskier) firms/countries?

  - **Financial supervisor** with financial stability mandate (EBA, ECB, EIOPA):
  - ➢ Increase capital req for investors exposed to climate relevant sectors?

- **If we consider sovereign bonds**: implications for country’s performance, refinancing conditions and solvability -> **climate Spread**

Central banks and financial supervisors started to worry about the climate…

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Mark Carney tells global banks they cannot ignore climate change dangers

Financial sector warned it risks losses from extreme weather and its stakes in polluting firms

Search **Bloomberg**

Climate Changed

ECB Says Mispricing Climate Change May Hurt Financial Stability

By Piotr Skolimowski
29 May 2019, 01:00 GMT-7

Italy central bank to spurn firms that don't go green

The Bank of Italy plans to adopt investment criteria which reward companies that take action on climate change, joining other central bank...

reuters.com

Network for Greening the Financial System
First comprehensive report

A call for action
Climate change as a source of financial risk

April 2019

3 research questions

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1. **What do we need to know to assess and manage climate transition risk in the value of financial contracts and portfolios?**
   - How climate policy shocks shift sov. bonds' default probability (PD)?
   - What is the price of climate risk (spread) for a country and investor?
   - To what extent the financial network could amplify losses (e.g. second round)?

2. **Do we have models to do it?**

   - Battiston, Mandel, Monasterolo 2019, CLIMAFIN Handbook: Pricing climate financial risk, Part 1 https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3476586

3. How can this info support **risk management and prudential regulation?**
   - Battiston, S., Jakubik, P., Monasterolo, I., Riahi, K. and van Ruijven, B. 2019. Climate risk assessment of the sovereign bond portfolio of European insurers. In: EIOPA Financial Stability Report, pp. 69-89

To address these questions we developed the CLIMAFIN tool

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- **Scientifically vetted** (interdisciplinary expertise in climate economics, systemic financial risk, climate policy, macroeconomics), **applied by leading decision makers**

- Supported by the **Network for Greening the Financial System** (NGFS) INSPIRE grant, by the **European Commission Innovation Launchpad**

- Applied to the portfolios of several financial institutions in collaboration with:
  - **central banks** (Austrian National Bank, Banco de Mexico)
  - **financial regulators** (European Insurance and Occupational Pension Authority (EIOPA), French Regulation Agency)
  - **development finance institutions** (World Bank, China Development Bank, Caribbean Dev. Bank).

Battiston, Mandel, Monasterolo 2019, CLIMAFIN Handbook: Pricing climate financial risk, Part 1
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3476586

CLIMAFIN's contribution

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- 1st transparent, science-based approach to combine:
  - **forward-looking climate transition** scenarios based on climate change and climate economic models (Integrated Assessment Models) reviewed by IPCC
  - with climate financial risk metrics **(Climate VaR)** and financial network models **(Climate Stress-test)** used by scholars and practitioners
- CLIMAFIN allows to **assess quantitatively** climate financial risks:
  1. Identify channels by which disorderly transition scenarios affects activities' Gross Value Added and issuer's **fiscal revenues**
  2. **Price** climate scenarios in financial contracts' **PD**, price and Spread
  3. Calculate climate scenarios-conditioned **Climate Value at Risk** and worst-case losses, considering second (and >) round losses: **Climate Stress-test**

Stream of literature and collaborations on climate financial risk assessment

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1. Battiston S., Mandel A, Monasterolo I., Schuetze F. & G. Visentin (2017). A Climate stress-test of the EU financial system. *Nature Climate Change*, 7, 283–288.
2. Monasterolo, I., ea. (2017). Vulnerable yet relevant: the two dimensions of climate-related financial disclosure. *Climatic Change*, *145*(3-4), 495-507.
3. Monasterolo, I., Jiani I. Zheng and Battiston, S. (2018). A carbon risk assessment of China's overseas energy portfolios. *China & World Economy 26*(6), 116–142. Input to the G20 Task Force "An International Financial Architecture for Stability and Development".
4. Battiston S., Mandel A, Monasterolo I. (2019). CLIMAFIN handbook: pricing forward-looking climate risks under uncertainty. Available at SSRN.
5. Battiston, S. and Monasterolo, I. (2019). A climate risk assessment of sovereign bonds' portfolio. Working paper forthcoming as OeNB financial stability report.
6. Battiston, S., Jakubik, P., Monasterolo, I., Riahi, K. and van Ruijven, B. 2019. Climate risk assessment of the sovereign bond portfolio of European insurers. EIOPA Financial Stability Report, pp. 69-89
7. Monasterolo, I., de Angelis, L. (2020). Blind to carbon risk? An analysis of stock market's reaction to the Paris Agreement. *Ecological Economics*, 170, 1-10

The CLIMAFIN approach

Battiston S., Mandel A., Monasterolo I. (2019). CLIMAFIN Handbook: Pricing climate financial risk Part 1 https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3476586

From Stress-test to Climate Stress-test

- **Classic stress-tests** consider scenarios where a shock consists in changes in macro-economic variables across two equilibrium states of the economy

- **Climate Stress-test**: we consider transition from a business-as-usual (*BAU*) to a policy (2°C target) trajectory (P): temporary out-of-equilibrium evolution

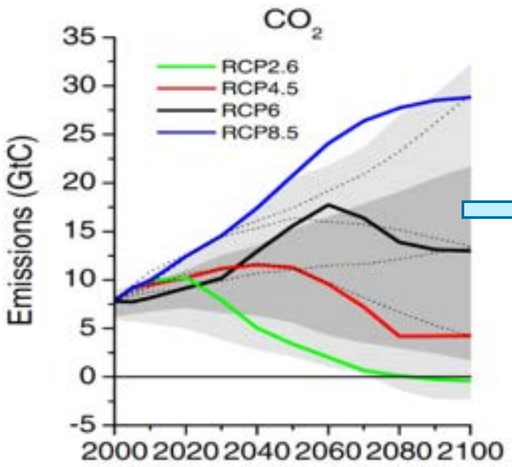
  - Shocks are obtained from differences in sectors' output between the two trajectories (*BAU* and *P*) for the same Integrated Assessment Model

  - Shocks shift the **Probability of Default** on financial contracts and revaluation of losses in investors' portfolios

  - Calculate **Climate Value at Risk** on portfolio and the worst-case losses, considering second (and >) round losses.

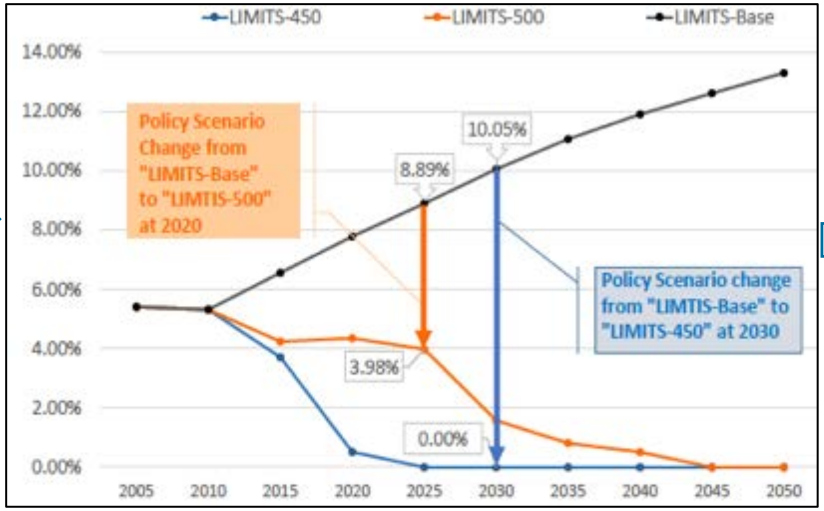
Climate risk assessment framework under uncertainty

CLIMATE SCENARIOS (EMISSIONS TARGETS)



(IPCC 2014)

SHOCKS ON SECTORS' FORWARD-LOOKING TRAJECTORIES (market shares, LIMITS)



SHOCK on FIRM'S CASH FLOWs and FISCAL REVENUES

Utility: 10TWh generation

3 TWh from coal

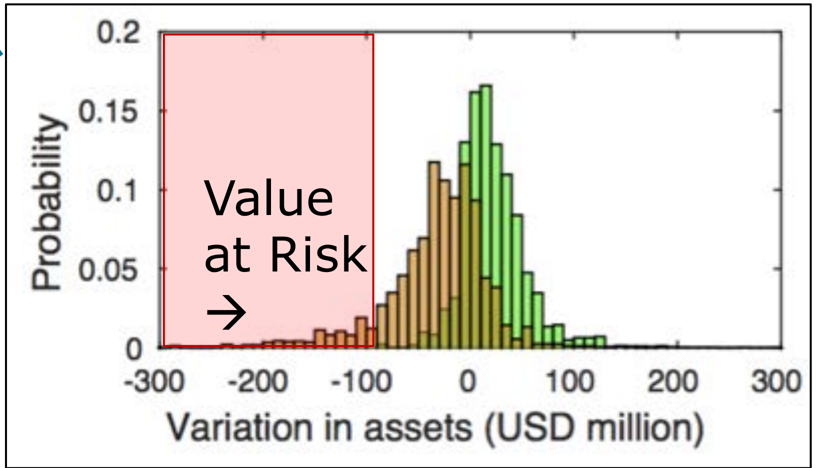
7 TWh from renewables

SHOCKS ON PD and PRICE OF FINANCIAL CONTRACTS

Country	WITCH: bond shock (%)	WITCH: yield shock (%)
Austria	1,3	-0,16
Australia	**-17,36**	**2,45**
Canada	-5,21	0,67
Norway	**-14,82**	**2,05**
Poland	**-12,85**	**1,75**

Sources: Battiston & Monasterolo 2019, Monasterolo ea 2018

CLIMATE VALUE AT RISK OF PORTFOLIO CONDITIONED TO CLIMATE SCENARIOS



FEEDBACK: **ECONOMIC STRUCTURE**

Assessing climate risks requires to rethink financial risk

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- Climate risk entails **new types of risks for finance**

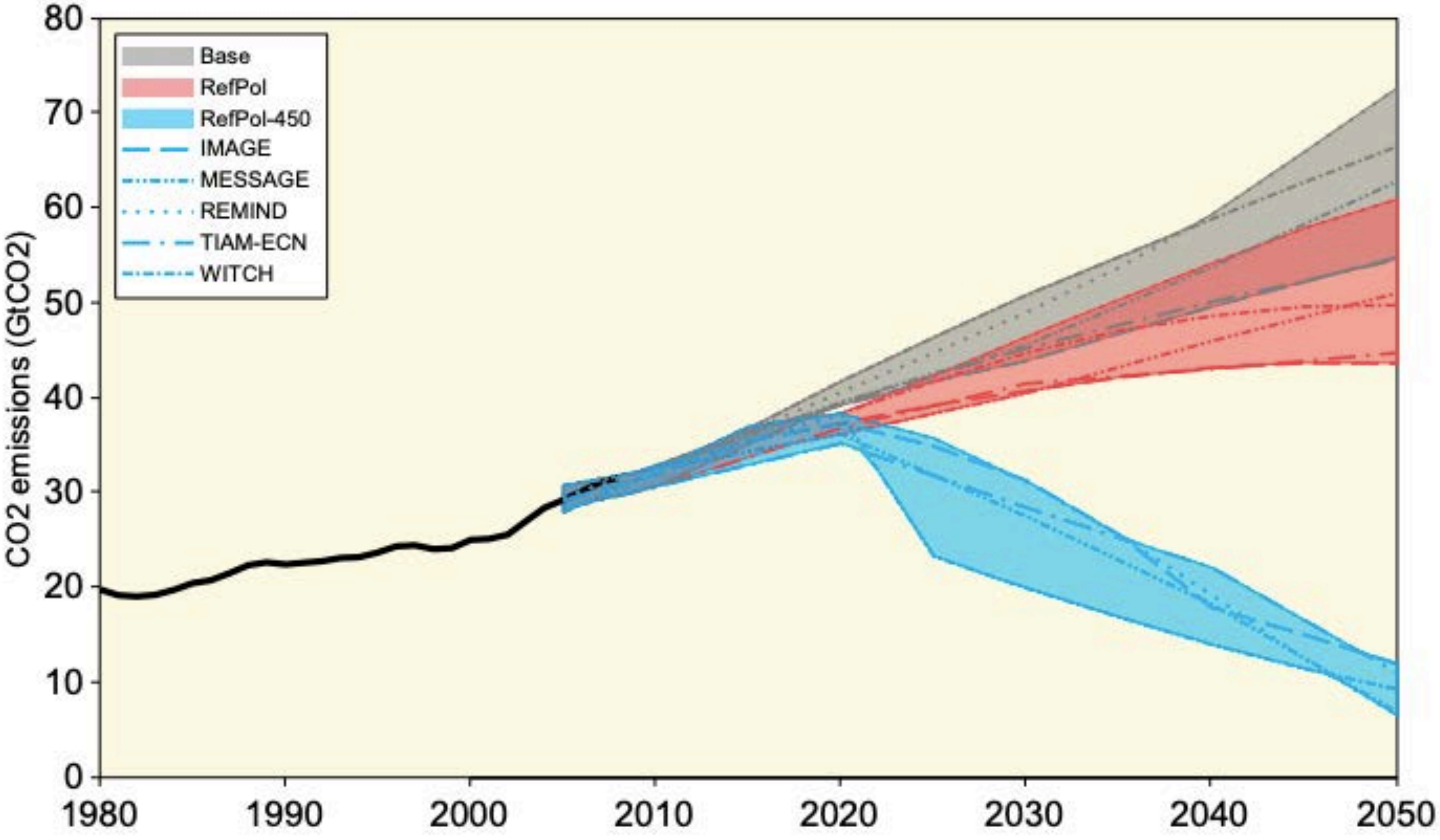
- Traditional approaches to financial pricing (e.g. used by rating agencies) and pure scenario-based stress-test are **inadequate to incorporate the nature of climate risks** and the associated **financial risks** (balance sheet interconnectedness, macro-financial feedbacks)

- Aligning finance to climate targets requires new, transparent methodologies to price **forward-looking** climate risks (opportunities) in financial contracts and in investors' portfolios

Battiston S, Monasterolo I. 2019. A climate risk assessment of sovereign bonds' portfolios. In collaboration with the Austrian National Bank (OeNB) working paper available at SSRN #3376218

Step 1: Identify the climate scenarios and define the climate transition risk trajectories

Climate policy scenarios



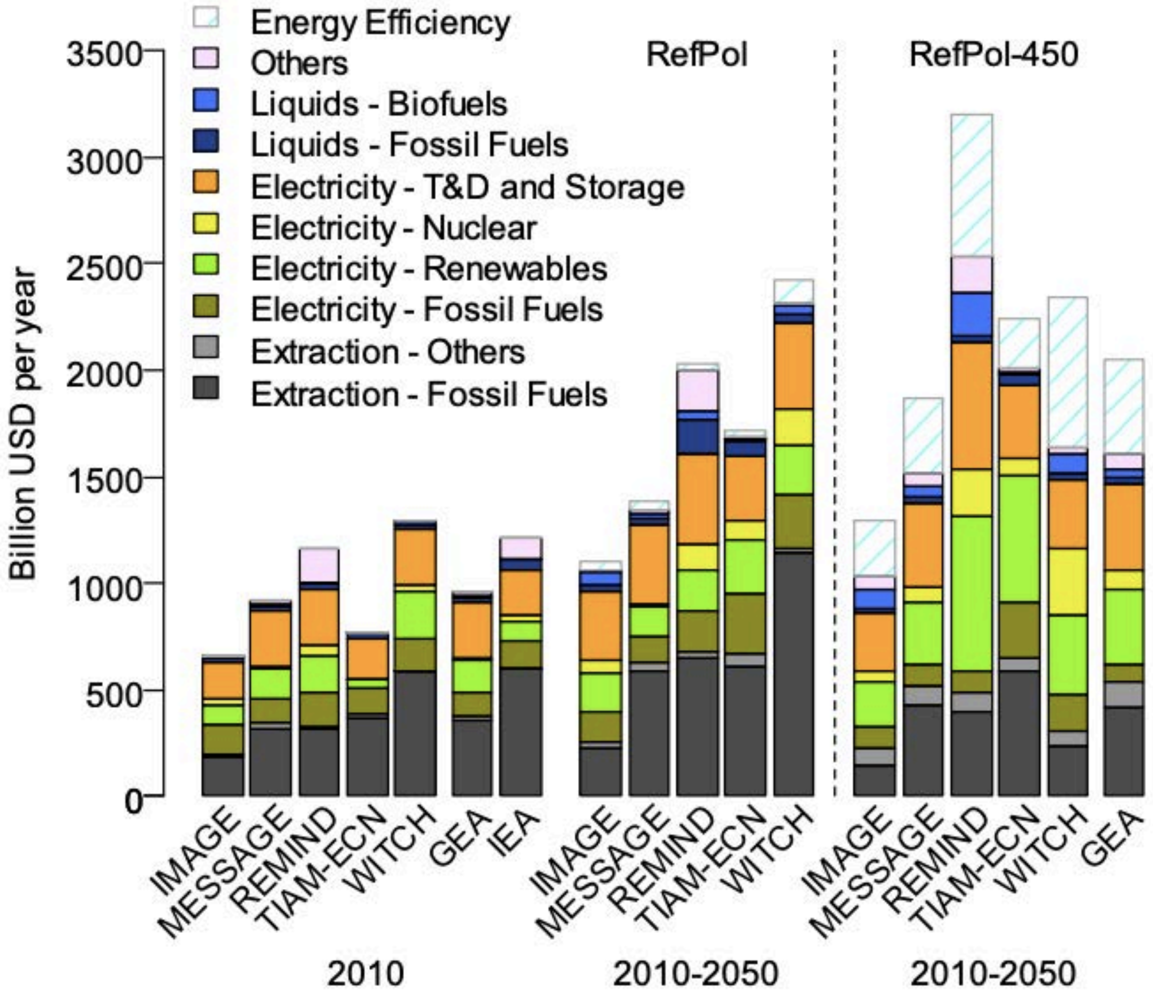
Example from LIMITS: Global CO2 emissions from fossil fuel combustion and industrial processes across the various models in the Base, RefPol, and RefPol-450 scenarios.

Several established models with different strengths/focus (e.g. land use/energy)

- e.g. AIM, REMIND, IMAGE, WITCH, GCAM. GLOBIOM, MESSAGE

Source of figure: D. McCollum, Y. Nagai, K. Riahi, G. Marangoni, K. Calvin, R. Pietzcker, J. van Vliet, B. van der Zwaan: Energy investments under climate policy: a comparison of global models (.pdf), Vol. 04/Issue 04, Climate Change Economics, World Scientific

Climate policy scenarios correspond to energy investment mix



From Mc Collum ea. 2014: Global annual energy investments (both supply- and demand-side) across models/sectors in RefPol and RefPol-450 scenarios. GEA = estimates from the International Energy Agency (IEA 2012b) and Global Energy Assessment (Riahi et al.

Most **model projections foresee substantial reduction** of investments in **fossil fuel sectors** wrt to Business as usual scenario

Source of figure: D. McCollum, Y. Nagai, K. Riahi, G. Marangoni, K. Calvin, R. Pietzcker, J. van Vliet, B. van der Zwaan: Energy investments under climate policy: a comparison of global models (.pdf), Vol. 04/Issue 04, Climate Change Economics, World Scientific

Climate transition trajectories

- LIMITS database of trajectories of low-carbon/high carbon economic activities consistent with 10 transition scenarios:
  - **Level of ambition** in emission reduction in near-term
  - Level of ambition in emission reduction in long-term (**450, 500 ppm**)
  - The level of **international cooperation** until 2020 and 2030

Scenario class	Scenario name	Scenario type	Level of ambition (near term)	Level of ambition (long term)	Level of international cooperation
No policy	Base	Baseline	None	N/A	None
Fragmented action	RefPol	Reference	Weak	2100	None
	StrPol	Reference	Stringent	2100	None
Immediate action	450	Benchmark	None	N/A	450 ppm
	500	Benchmark	None	N/A	500 ppm
Delayed Policy	RefPol-450	Climate Policy	Weak	2020	450 ppm
Delayed Policy	StrPol-450	Climate Policy	Stringent	2020	500 ppm
Delayed Policy	RefPol-500	Climate Policy	Weak	2020	500 ppm
Delayed Policy	StrPol-500	Climate Policy	Stringent	2020	500 ppm
Delayed Action	RefPol2030-500	Climate Policy	Weak	2030	501 ppm

Table based on: E. Kriegler, et al. 2013

Step 2: assess impacts of forward-looking climate shocks on economic activities

Building shock distributions on forward-looking trajectories (negative/positive)

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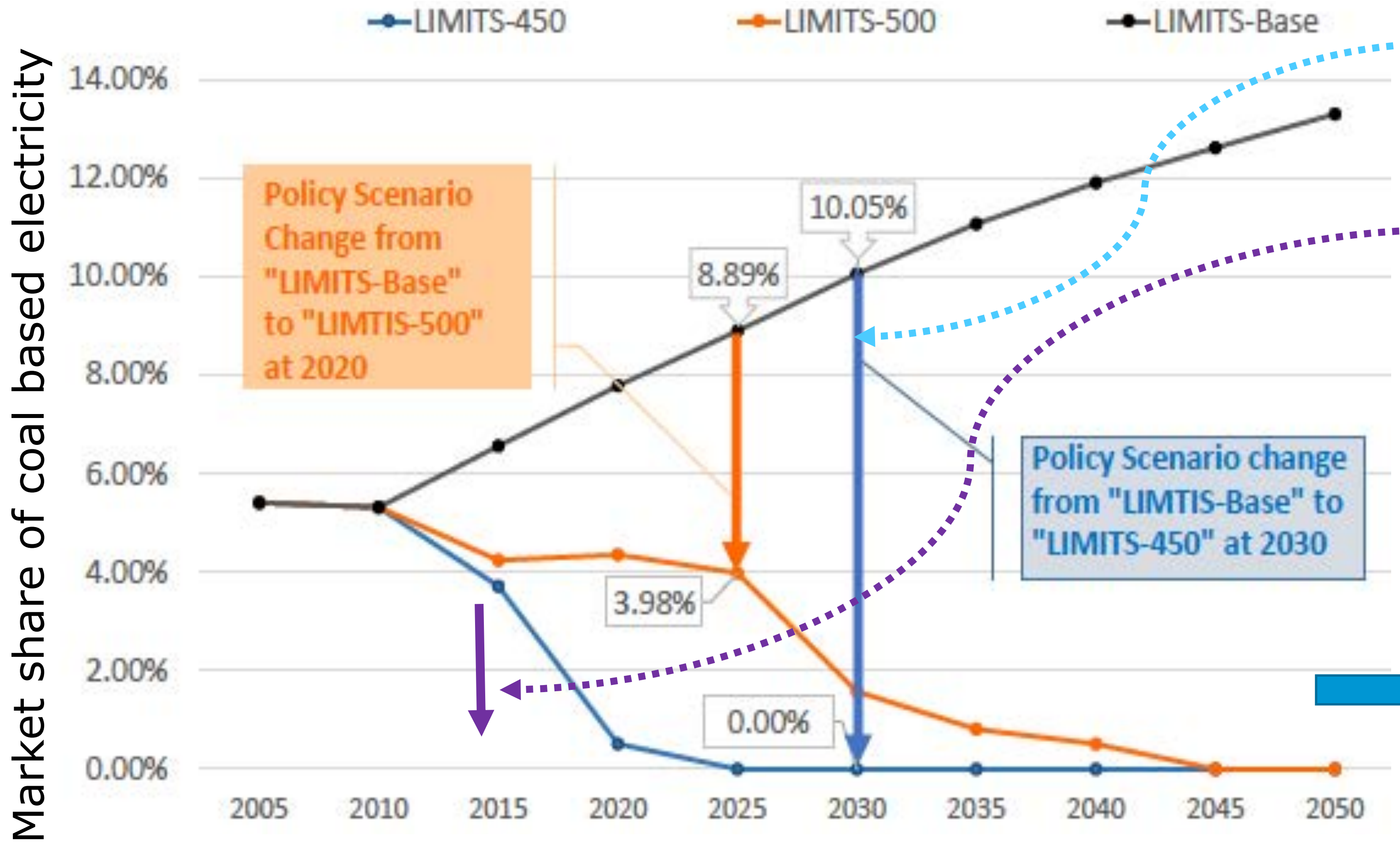
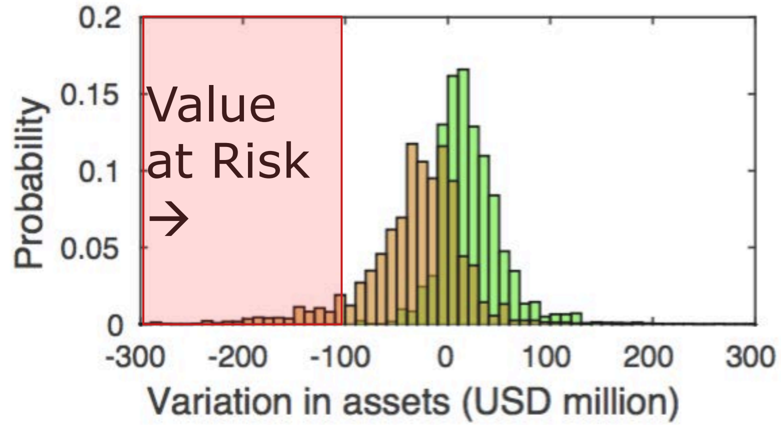


Cross-sectional: across climate trajectories (this presentation)

Longitudinal: along trajectories (every 5 y time step)

Gain/losses probability Distribution → Value at Risk



Trajectories for coal-based electricity sector: *market share under tight/mild policy scenarios (Monasterolo ea. 2018)*

Step 3: Pricing forward-looking climate risks in financial contracts

Define investor's risk management strategy under climate deep uncertainty

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1. Account for investor-specific **risk aversion** level (varying subsets of investor information set InfoSetClimRisk)
2. Account for **counterparty risk** adjusted for **climate policy shock** scenarios (e.g. probability of default PD, spread)
3. Account for metrics relevant for financial regulation e.g. *risk measure* such as **Value-at-Risk**

Climate VaR Mng Strategy

- Risk averse investor aims to minimize her Climate Value-at-Risk (*Climate VaR*) under investor information set *InfoSetClimRisk* (i.e. policy shocks, econ scenarios, climate models)
- **Climate VaR Management Strategy** aims to minimize the worst-case losses of the portfolio across the forward-looking Climate Policy Shock Scenarios:

$$\textbf{ClimVaRStr} = \min_{\text{Portfolios}} \{ \max_{\text{Shocks}} \{ \text{VaR}(\text{Ptfolio,Adj.PD} \,|\, \text{Policy Shock}) \} \}$$

Defaultable sovereign bonds

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Portfolio of zero-coupon defaultable sovereign bonds

- Risky (defaultable) bond of country j issued at t_0 with maturity T
- Bond value at T:

$$v_j(T) = \begin{cases} R = (1 - LGD) & \text{if j defaults (with prob. } q_j) \\ 1 & \text{else (with prob. } 1 - q_j) \end{cases}$$

  where $R < 1$ bond recovery rate, rLGD Loss-given-default (in %)
- Expected value of bond: $\mathbb{E}[v_j] = (1 - q_j) + q_j R_j = (1 - q_j(1 - R_j))$
- Discounted expected value of the bond, with: y_j bond j yield (under risk neutral measure) and y_f risk free rate

$$e^{-y_f T}\,\mathbb{E}[v_j] = e^{-y_f T}(1 - q_j(1 - R_j)) = e^{-y_j T}$$

- Bond spread defined as: $s_j = y_j - y_f$, with $e^{-s_j T} = 1 - q_j(1 - R_j)$
- Useful fact about spread, with rLGD = relative LGD:
  $s_j \approx \frac{1}{T} q_j(1 - R_j) = \frac{1}{T} q_j \, \text{rLGD}_j$ (for small s_j)

Sovereign default conditions

Sovereign fiscal revenues: shocks and default condition

- Sovereign i balance sheet: $A_j(t_0)$, $A_j(T)$ **net fiscal asset** at t_0 and maturity; $L_j(T)$ liability.
  - Default condition (e.g. Gray-Merton-Bodie 2007)

$$A_j(T) = A_j(t_0)(1 + \eta_j(T)) < L_j(T)$$

  - $\eta_j(T) \in \mathbb{R}$: **idiosyncratic shock** (e.g. aggregate productivity), $\phi(\eta_1, ..., \eta_j, \eta_n)$ **joint probability distribution** (possibly correlated)
- We add climate policy shock ξ_j on j's fiscal assets ("jump" up/down), assuming idiosyncratic shock η_j and policy shock ξ_j are **independent**
- New sovereign default condition:

$$A_j(T) = A_j(t_0)(1 + \eta_j(T) + \xi_j(P)) < L_j(T)$$

$$\iff \eta_j(T) \leq \theta_j(P) = L_j(T)/A_j(t_0) - 1 - \xi_j(T, P)$$

  - $\theta_j(P)$ default threshold under scenario P
  - $\xi_j(P)$ **climate policy shock** $B \to P$, positive/negative: $\xi_j(P) > -1$, possibly correlated across j

Change in sovereign bonds' PD due to Climate policy scenario

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Proposition. Δ default prob. with policy shock B→P

- Assuming
  - idiosynchratic shocks are **independent** from policy shock
  - policy shock on fiscal asset is proportional to shock on GVA via elasticity $\xi_j = \chi_j \, u_j^{GVA}(P)$
- The **change** $\Delta q_j(P)$ in default probability of sovereign j under Climate Policy Shock Scenario B→P
  - increases with GVA shock magnitude $|u_j^{GVA}(P)|$ if $u_j^{GVA}(P) < 0$, and decreases viceversa (under mild condition on ϕ)
  - is proportional to the GVA shocks on climate relevant sectors (in the limit of small Climate Policy Shock):

$$\Delta q_j(P) \approx - \chi_j \left(u_{j,PrFos}^{GVA} \, w_{j,PrFos}^{GVA} + u_{j,ElFos}^{GVA} \, w_{j,ElFos}^{GVA} + u_{j,ElRen}^{GVA} \, w_{j,ElRen}^{GVA} \right).$$

Sovereign bonds' value adjustment conditioned to climate policy scenarios

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Definition. Climate policy shock bond value adjustment

- **Climate policy shock bond value adjustment** Δv_j^* is defined as the change in the discounted expected value of the bond, v_j^*, conditional to a Climate Policy Shock Scenario $B \rightarrow P$

$$\Delta v_j^* = v_j^*(q_j(P) - v_j^*(q_j(B)) = -e^{-y_f T} \Delta q_j(P) \text{LGD}_j$$

Proposition. Bond value adjustment and climate policy shocks

- Conditional to policy shock scenario $B \rightarrow P$, and assuming everything else the same regarding the issuer's balance sheet, then the bond value adjustment $\Delta v_j^*(P)$:
  - is negative and increases with magnitude of policy shock $|\xi_j(P)|$ if $\xi_j(P) < 0$
  - is positive and increases with magnitude of policy shock if $\xi_j(P) > 0$, with the constraint $v_j^* \leq 1$

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Sovereign bonds' value and spread conditioned to climate policy scenarios

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Definition. Climate policy shock bond value adjustment

- **Climate policy shock bond value adjustment** Δv_j^* is defined as the change in the discounted expected value of the bond, v_j^*, conditional to a Climate Policy Shock Scenario $B \to P$

$$\Delta v_j^* = v_j^*(q_j(P) - v_j^*(q_j(B)) = -e^{-y_f T} \Delta q_j(P) \mathrm{LGD}_j$$

Definition. Climate spread on sovereign bonds

- **Climate spread** Δs_j is defined as the change in the spread s_j, conditional to Climate Policy Shock Scenario $B \to P$

$$\Delta s_j = s_j(q_j(P) - s_j(q_j(B))$$

Climate policy shock on OECD sovereign bonds

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- Disorderly transition scenario: policy shock in **2030** (mild/tight 2C-aligned climate policy scenarios based on carbon pricing of LIMITS IAMs)
- Affects yield of 10-years, zero coupon sovereign bonds

Geo region	Models' region	WITCH: bond shock (%)	WITCH: yield shock (%)	GCAM: bond shock (%)	GCAM: yield shock (%)
AUSTRIA	EUROPE	1,3	-0,16	0,13	-0,02
AUSTRALIA	REST_WORLD	**-17,36**	**2,45**	n.a.	n.a.
BELGIUM	EUROPE	0,84	-0,1	0,03	0
CANADA	PAC_OECD	-5,21	0,67	-18,29	2,61
POLAND	EUROPE	**-12,85**	**1,75**	-2,49	0,32

- Large **shocks on sovereign bonds' value and spread for countries where fossil fuels play big role on fiscal revenues** (E.g. -12,85%/ 1,75 for Poland).

Tight policy scenario (RefPol450 ppm) computed with GCAM and WITCH. 2,45=245 basis points
Source: Battiston & Monasterolo (2019).

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R1: climate risk assessment of OeNB's portfolio

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Model	Policy Scenario	Country	Region	Portfolio Shock
WITCH	LIMITS-RefPol-450	Country 1	REST_WORLD	-0.367%
WITCH	LIMITS-RefPol-450	Country 2	REST_WORLD	-0.350%
WITCH	LIMITS-RefPol-450	Country 3	PAC_OECD	-0.329%
WITCH	LIMITS-RefPol-450	Country 4	NORTH_AM	-0.110%
WITCH	LIMITS-RefPol-450	Country 5	EUROPE	-0.078%
WITCH	LIMITS-RefPol-450	Aggregate	Aggregate	-1.234%
WITCH	LIMITS-RefPol-450	Country 6	EUROPE	0.005%
WITCH	LIMITS-RefPol-450	Country 7	EUROPE	0.016%
WITCH	LIMITS-RefPol-450	Country 8	EUROPE	0.018%
WITCH	LIMITS-RefPol-450	Country 9	EUROPE	0.021%
WITCH	LIMITS-RefPol-450	Country 10	EUROPE	0.083%
WITCH	LIMITS-RefPol-450	Aggregate	Aggregate	0.143%

- -0,367: negative shock (%) on the value of OECD sovereign bonds **weighted** for the role of the country issuing it on OeNB's portfolio.
- **Total negative shocks** = 1,234% of OeNB portfolio
- Shocks can be also positive where renewables grow

EUROPE includes different countries (disclosure issues).
Battiston & Monasterolo (2019)

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You think shocks are small?

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- Consider that:
  - For leveraged institutions (leverage = 30), shock of 1% = 1/3 losses
  - Countries are not aligning to pledges thus tighter policy scenarios may be considered
  - IAMs' policy scenarios before the Paris Agreement (now SSPs)
  - Even few decimal points of GDP growth change could impact yields due to expectations (IT)
- ***Thus, our shocks results are conservative***

R2: Climate risk assessment of sovereign bond portfolio of European insurers

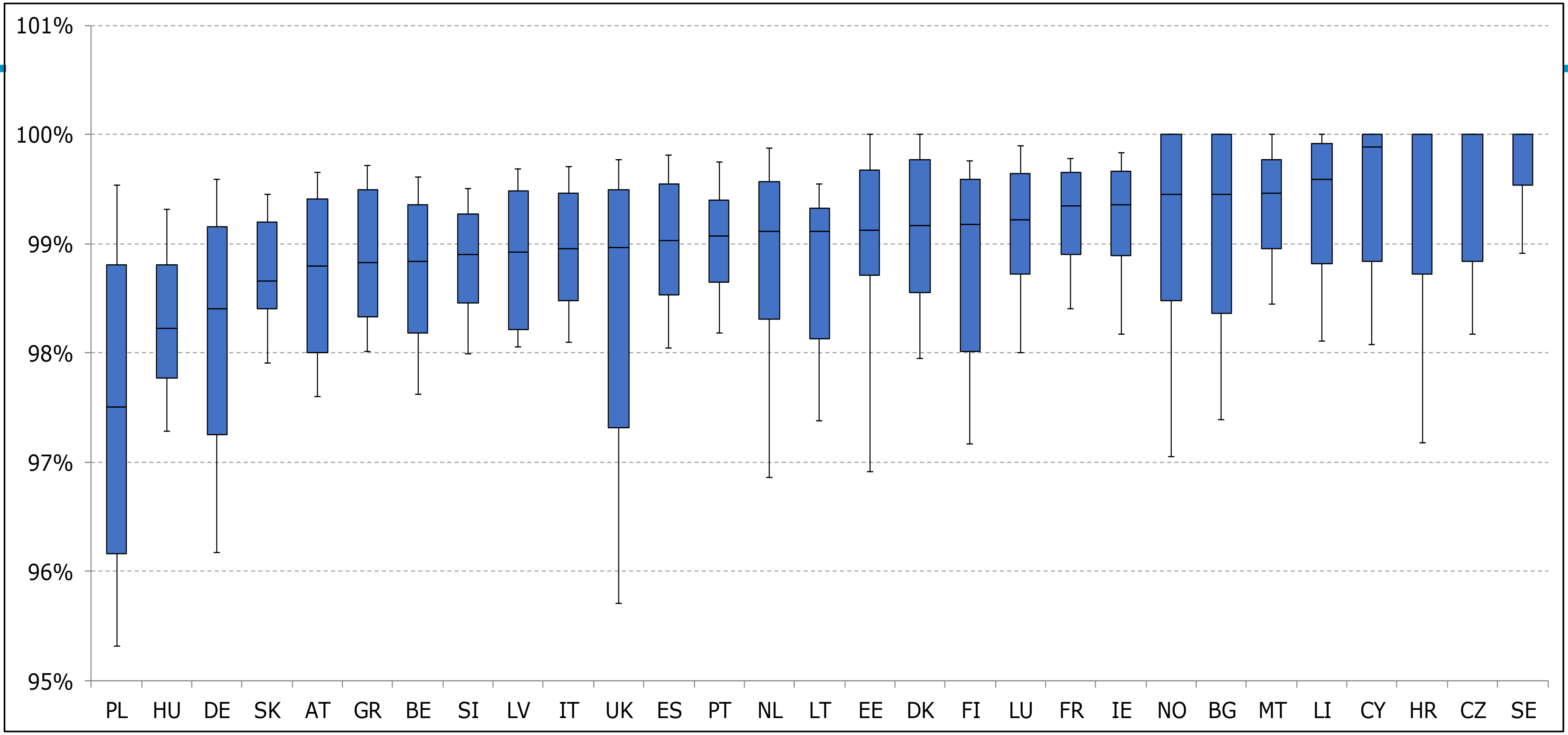
- 1st collaboration btw. climate economists (IIASA), climate finance risk experts (WU, UZH), EU financial regulator (European Insurance and Occupational Pension Fund Authority (EIOPA):

- For each mild/tight scenario (LGD and *χj)* and IAM, we compute the shock on the value of each sov. Bond and the *portfolio impact*

- **3 drivers of the magnitude of the portfolio impact:**
  - For each sov. bond, negative shocks (e.g. on primary energy fossil) can be compensated by positive shocks (e.g. electricity based on renewable sources)
  - Negative aggregate shocks from a less climate-aligned sovereign can be compensated by positive shocks from more climate-aligned sovereign
  - This application does not consider macroeconomic reverberations of a shock

Battiston, S., Jakubik, P., Monasterolo, I., Riahi, K. and van Ruijven, B. 2019. Climate risk assessment of the sovereign bond portfolio of European insurers. In: EIOPA Financial Stability Report, pp. 69-89

Results

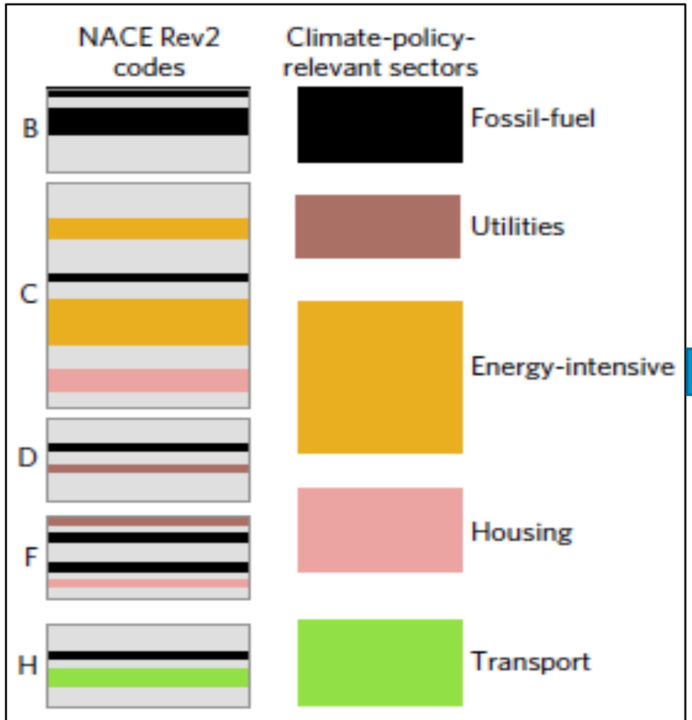


- *Distribution of impact on sovereign holdings of European insurers across climate policy scenarios and* ***adverse*** *market conditions (100% = 0% impact, 97% = drop by 3%)*
- *Potential impacts on insurers' portfolios is moderate but non-negligible and heterogenous across countries*

Step 4: Climate financial risk assessment: climate Value at Risk and Climate Stress-test

Classify investors’ exposure to Climate Policy Relevant Sectors (CPRS)

- NACE no proxy of risk: no technology risk, car companies classified as **financial** (FIAT)
- We developed **5 Climate Policy Relevant Sectors (CPRS)** classification:
  - Direct/indirect/induced contribution to emissions (scope)
  - Relevance for climate policy (carbon leakage)
  - Firm business model and technology mix (CAPEX)



CPRS 1	CPRS Rev 2
1-fossil	1-fossil|coal
	1-fossil|oil
	1-fossil|gas
2-utility	2-utility|electricity|coal
	2-utility|electricity|gas
	2-utility|electricity|solar
	2-utility|electricity|wind
	2-utility|electricity|biomass
	2-utility|electricity|marine
	2-utility|electricity|nuclear
	2-utility|other
	2-utility|water&sewerage
	2-utility|waste

Battiston et al. (2017), Nature Climate Change

Assess direct and indirect investors' exposures to CPRS

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Direct exposures: through assets of the market player

$$A_i = \left(\sum_{S \in S} \sum_{j \in S} \alpha_{ij}^{Equity} + \alpha_{ij}^{Bonds} + \alpha_{ij}^{Loans} \right) + R_i$$

S - Set of climate-relevant sectors

A_i - Total assets of the financial actor *i*

α_{ij} - Monetary value of exposure of *i* to *j*

$A_{FS} = \sum_{i \in F} \alpha_{iS}$ - Exposure of institution *F* to a given climate sector

Indirect exposures: through interlinckages of the market player with its couterparties

$$A_i = \left(\sum_{j \in F} \alpha_{ij}^{Equity}(A_j) + \alpha_{ij}^{Bonds}(A_j) + \alpha_{ij}^{Loans}(A_j) \right) + \left(\sum_{k \in A/F} \alpha_{ik}^{Equity} + \alpha_{ik}^{Bonds} + \alpha_{ik}^{Loans} \right) + R_i$$

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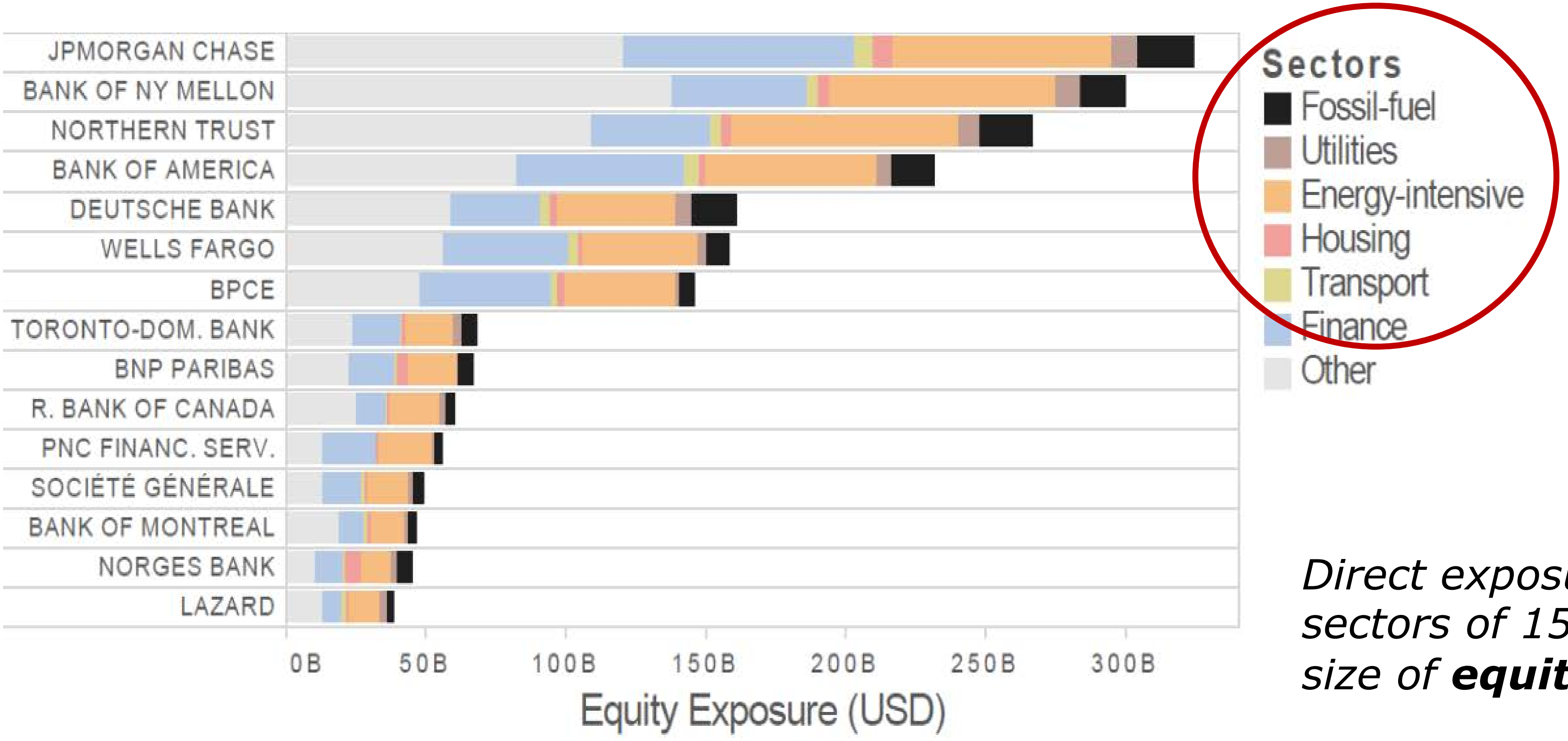
Banks' direct exposure to Climate Policy Relevant Sectors (CPRS)

- CPRS represent important value of world top banks' equity portfolios



*Direct exposures to climate-relevant sectors of 15 top banks worldwide by size of **equity** portfolio*

Source: Battiston ea. 2017

CPRS used by ECB in its climate risk and financial stability considerations

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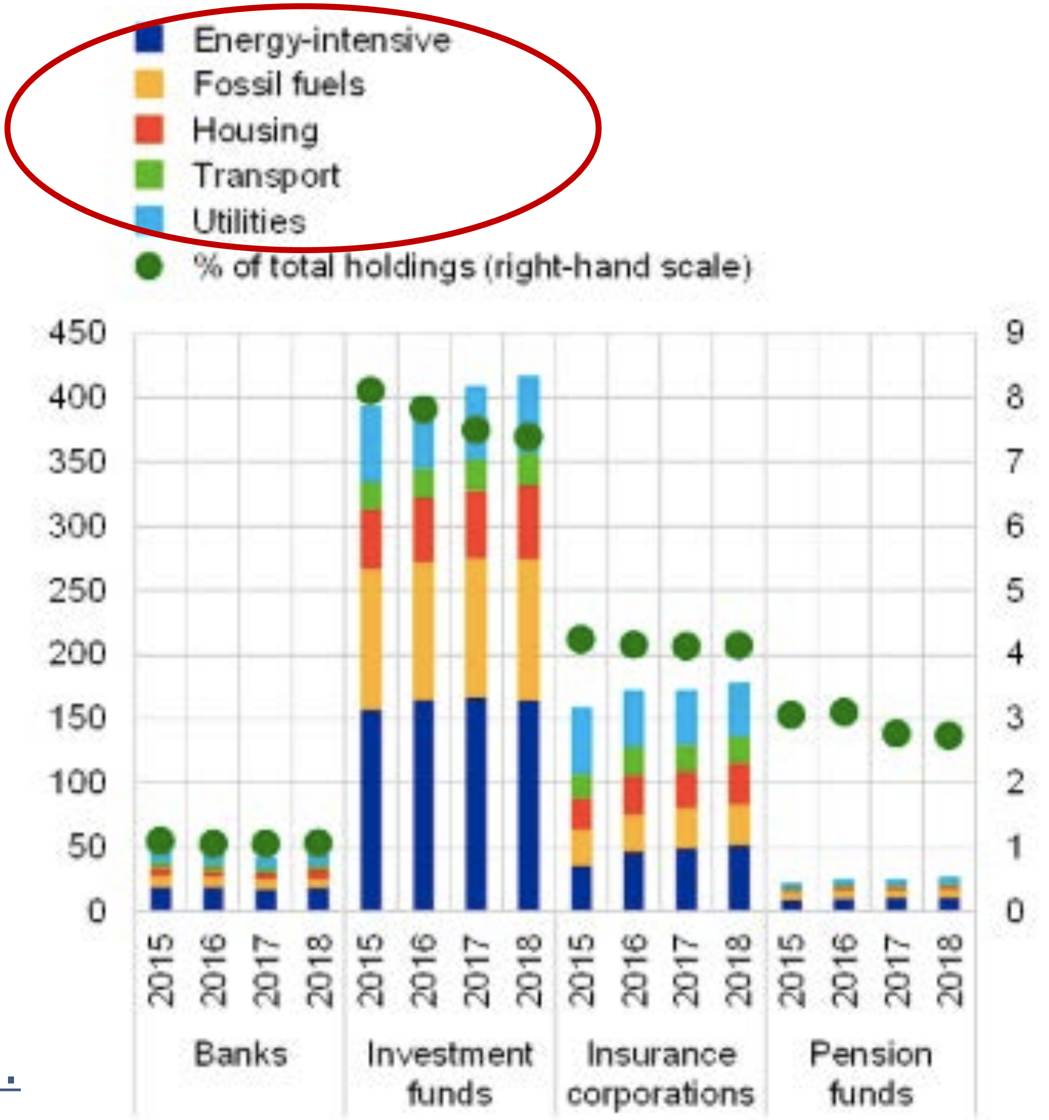
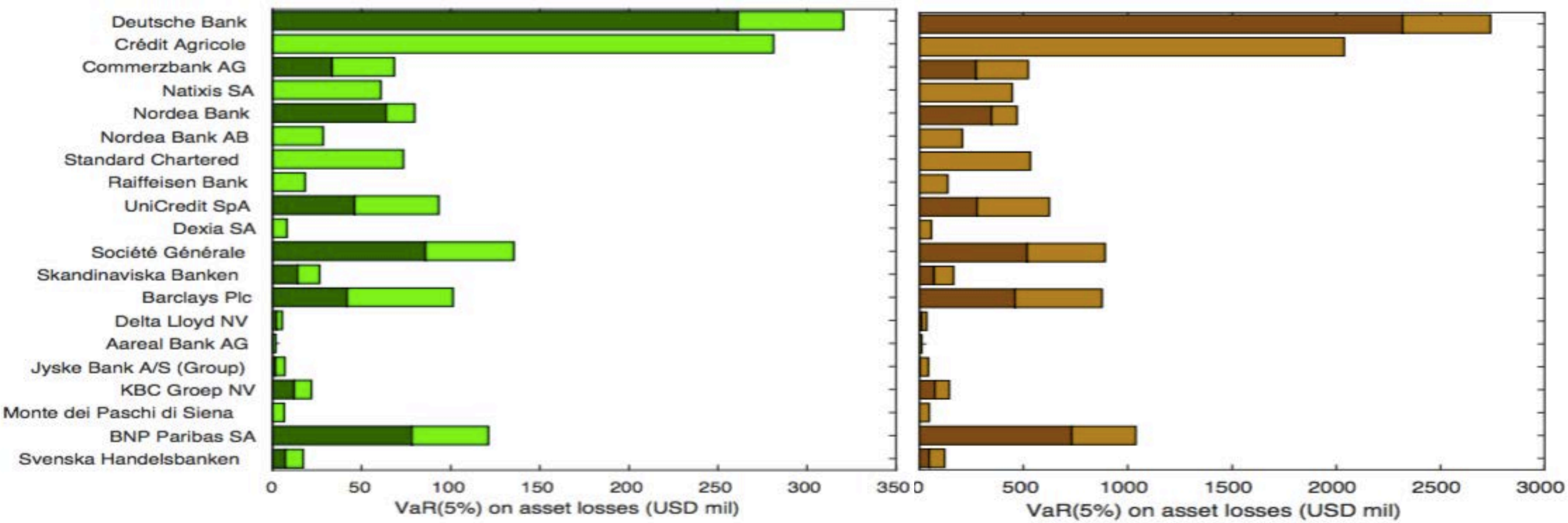
- **European Central Bank** (2019)'s **"Climate change and financial stability"** (in Financial Stability Review (May 2019):
  - Euro area financial institutions' exposures to transition risk based on CPRS classification by Battiston et al. 2017



https://www.ecb.europa.eu/pub/financial-stability/fsr/special/html/ecb.fsrart201905_1~47cf778cc1.en.html

Climate VaR conditioned to climate transition scenarios (equity)



Value at Risk *(5% significance) on equity holdings of 20 most affected EU banks under scenario of green (brown) investment strategy. Dark/light colors: first/second round losses. Battiston ea. 2017*

Climate Stress-test of top 20 Euro Area banks under green/brown investment strategy

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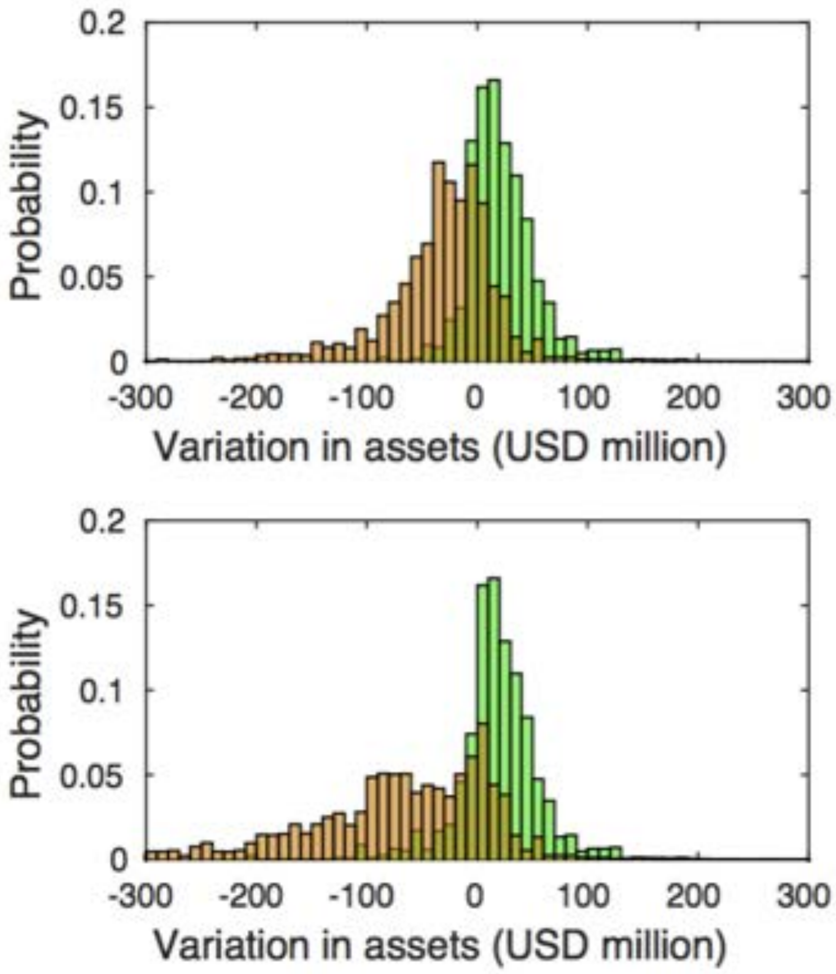
- **1st round (top figure):** a bank with brown investment strategy incurs more losses than a bank with green strategy

- Losses are small in comparison to bank's total assets ($ 604 bn), *but equity holdings represent only 3.8% of EU banks total assets*
- *-> our results are conservative*

- **Adding 2nd round** effects (bottom figure) further polarizes distribution of losses for the brown bank



Battiston S., Mandel A, Monasterolo I., Schuetze F. & G. Visentin (2017). A Climate stress-test of the EU financial system. *Nature Climate Change*, 7, 283–288.

Conclusions

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1. We developed the CLIMAFIN tool to inform decision making under climate deep uncertainty

2. It embes climate considerations in investors' risk management strategy and supervisory tools, and can integrated dynamic macro-financial feedbacks (e.g. from Stock-Flow Consistent ABM, Monasterolo and Raberto 2018)

3. Our results show that climate transition risk could change country's financial risk position via the carbon intensity of the economy and investments

4. Climate Stress-test: banks' exposure to fossil sector alone is small but combined exposures to CPRS is large and amplified by interconnectedness

5. Given the large exposure of investors to climate risks, transparent and science-based risk assessment should be considered as a **public good**

Climate Risks and Financial Stability: special issue on JFS forthcoming