A climate risk assessment of sovereign bonds' portfolios

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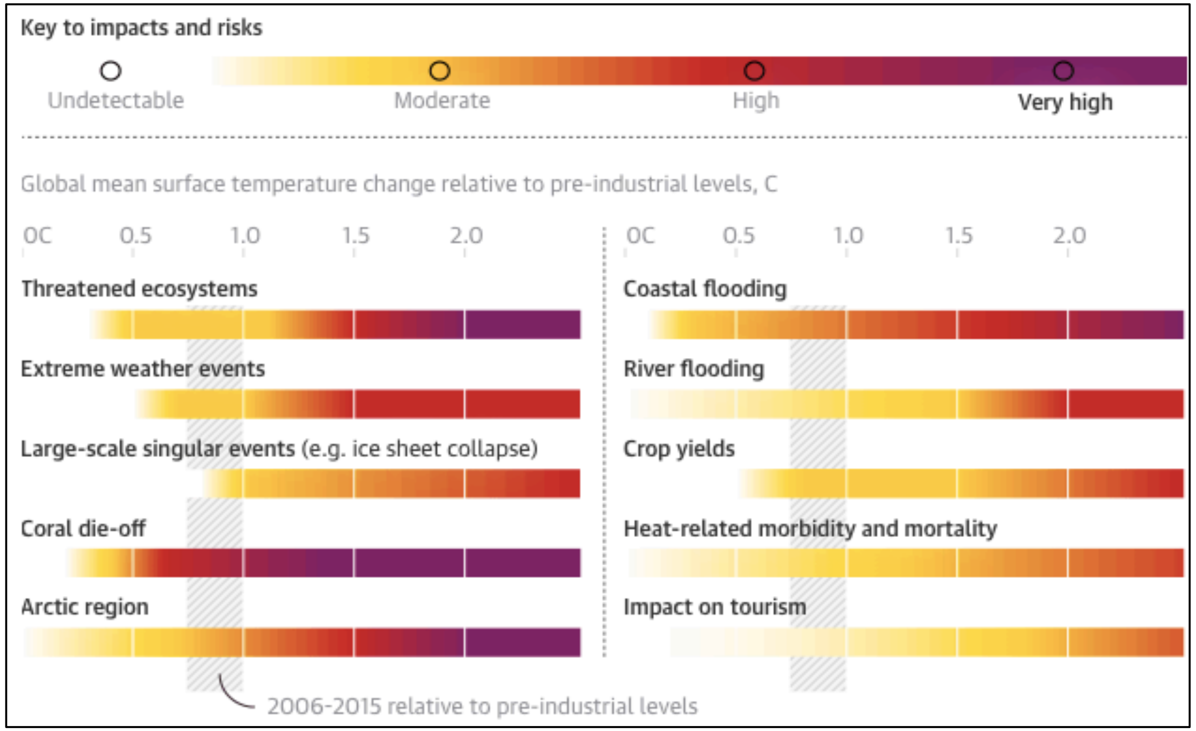
EFMD EQUIS ACCREDITED AACSB ACCREDITED ASSOCIATION AMBA ACCREDITED

The criticality of the next 10 years/1

- Limiting global warming to 1.5°C requires **drastic action now**: curb emissions by at least 49% of 2017 levels by 2030, carbon neutrality by 2050
- Most action from technological investments (decarbonize energy and transport)
- 0.5°C makes a big difference for socio-economic-envir. climate impacts



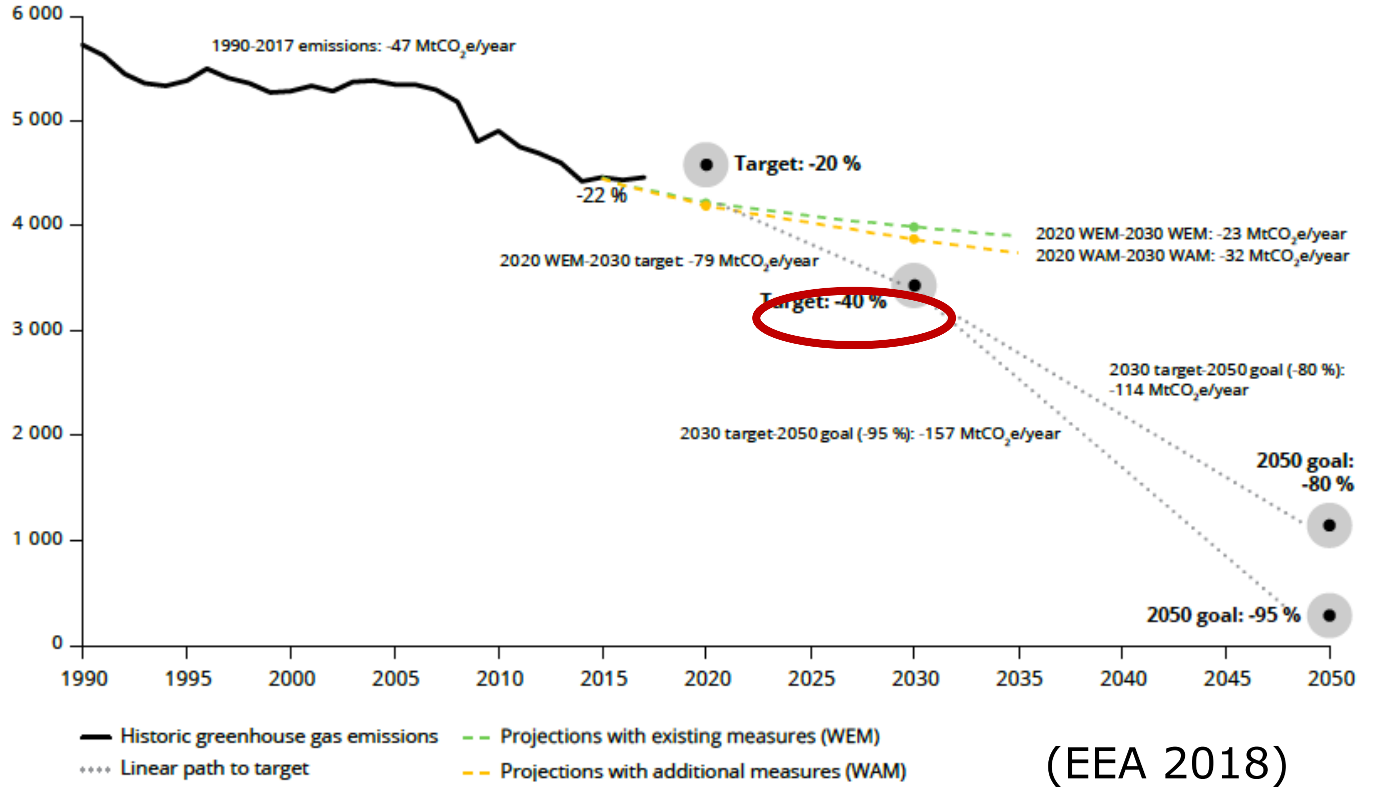
Source: IPCC 2018

Energy transition is crucial. But we are not getting there yet

- EU 2030 climate and energy targets for EU Member States (MS):
  - \- 40% in **greenhouse gas (GHG) emissions** (from 1990 levels)
  - 32% of **renewable energy**
  - 32.5% **energy efficiency**

- But MS' existing and additional measures aren't enough: in best scenario, -**32**% by 2030
- Limited contribution of additional planned measures (yellow dotted line)

GHG emission trends, EU projections and targets



(EEA 2018)

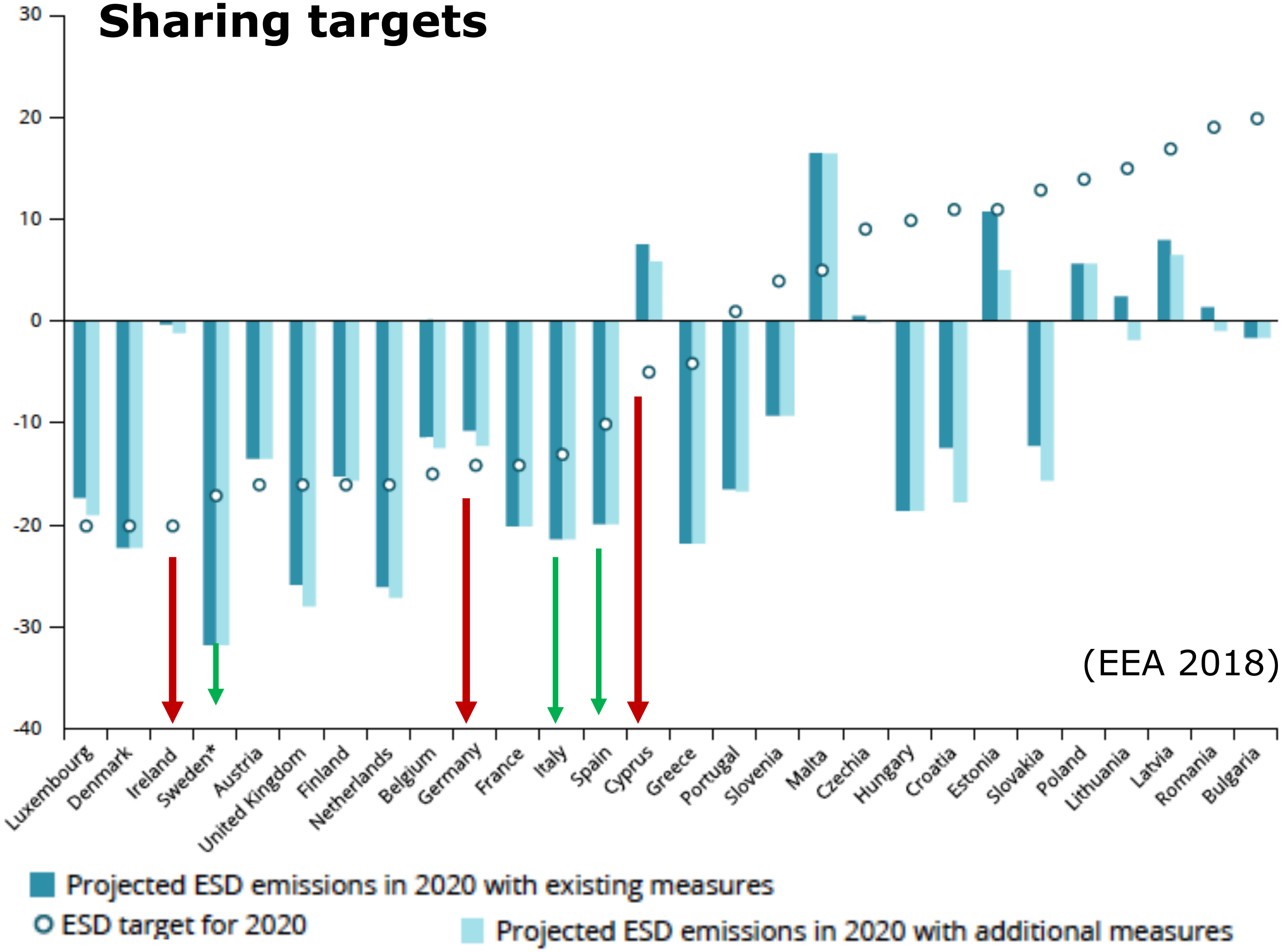
A price for countries' (and investors) misalignment?

- Austria, Belgium, Cyprus, Finland, Germany, Ireland, Luxembourg, Malta: projected emissions exceed their annual emission allocations by 2020

- *Can we assign a financial value and **price** misalignment of Ireland vs alignment of Italy?*

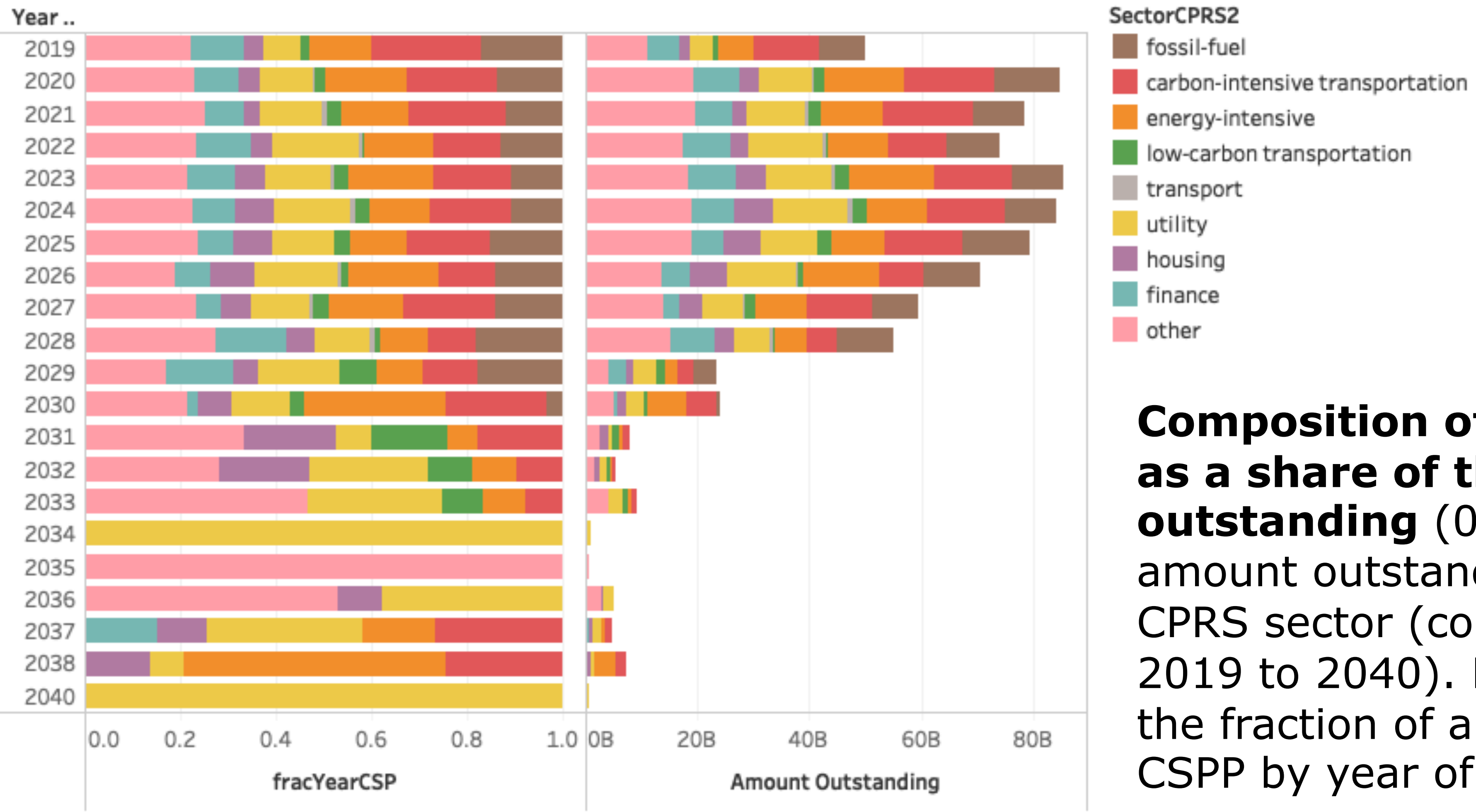
- *What the implications for **economic competitiveness and financial stability** at the MS and EU level?*

Projected MS progress towards 2020 Effort Sharing targets



(EEA 2018)

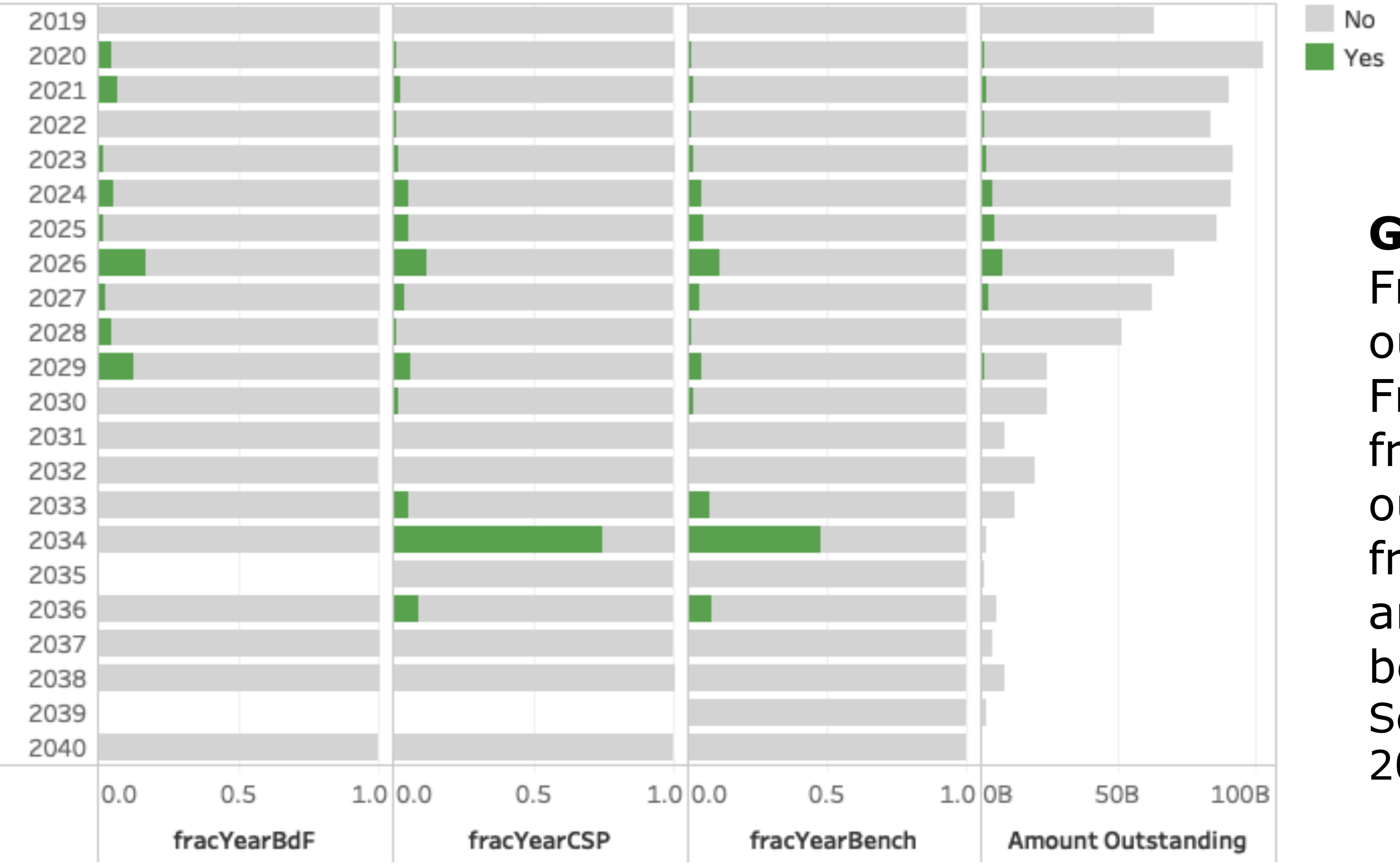
The criticality of the next 10 years/2
is brown here to stay? (look at the maturity)



Composition of ECB's CSPP portfolio as a share of the total amount outstanding (0.6=60%) (left) and by amount outstanding (in bn Eur, right), by CPRS sector (color) and maturity (from 2019 to 2040). FracYearCSP represents the fraction of amount outstanding of CSPP by year of maturity.

Battiston, S. and Monasterolo, I. (2019). *How could the ECB's monetary policy support the sustainable finance transition?* FINEXUS working paper https://www.finexus.uzh.ch/en/news/cspp_sustainable_finance.html

The criticality of the next 10 years/3 where is the green (bond)?



Green bonds in ECB's CSPP:

FracYearBdF: fraction of amount outstanding of Banque de France (BdF)

fracYearCSP: fraction of amount outstanding of CSPP

fracYearBench: fraction of amount outstanding of the benchmark.

Source: Battiston & Monasterolo 2019

A growing stream of research on climate risks and financial stability

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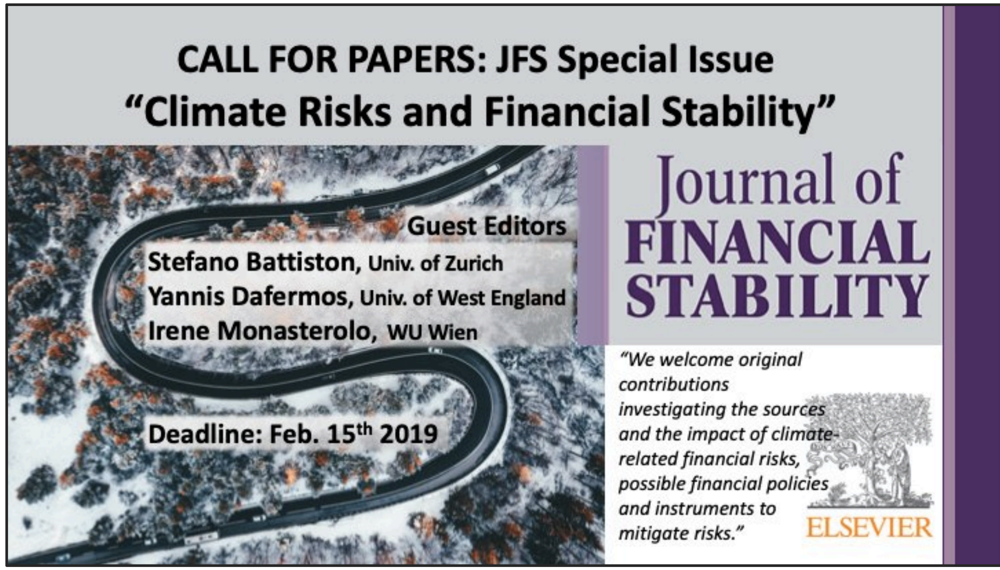
1. **Climate transition risk and climate stress-tests:**
    - **Climate stress-test** (equity): Battiston ea. 2017, *Nature Climate Change*
    - **Investors' exposure to climate risks**. Monasterolo ea. 2017, *Climatic Change*
    - China's **energy loans portfolio**. Monasterolo ea. 2018 *China and World Economy*
2. **Climate financial pricing models under deep uncertainty**
    - Battiston, Monasterolo 2019. This presentation
    - Battiston ea. 2019. Pricing climate risk in financial networks: insurance and systemic risk
3. **Financial macro-network model of climate policy:** Stolbova ea. 2018, *Ecological Economics*
4. **Mispricing of climate risk in financial markets:**
    - Monasterolo, de Angelis (2018). Blind to carbon risk? An Analysis of Stock Market's Reaction to the Paris Agreement (under review*)*

Climate Risks and Financial Stability

- **Special issue Climate risks and financial stability on Journal of Financial Stability (Battiston ea 2019)**
- Research/ central banks/policy engagement
  - **Joint events**: Austrian National Bank – WU - SUERF conference 2018, CEP-Bundesbank (2018), CREDIT conference (2019)
  - **Joint research work:**
    - Austrian National Bank (this presentation)
    - *China development Banks/G20 (Monasterolo ea. 2018)*.
    - Banco de Mexico - *Roncoroni, Battiston, Escobar, Jaramillo 2019*



Application 1: the Climate Stress-test of the financial system

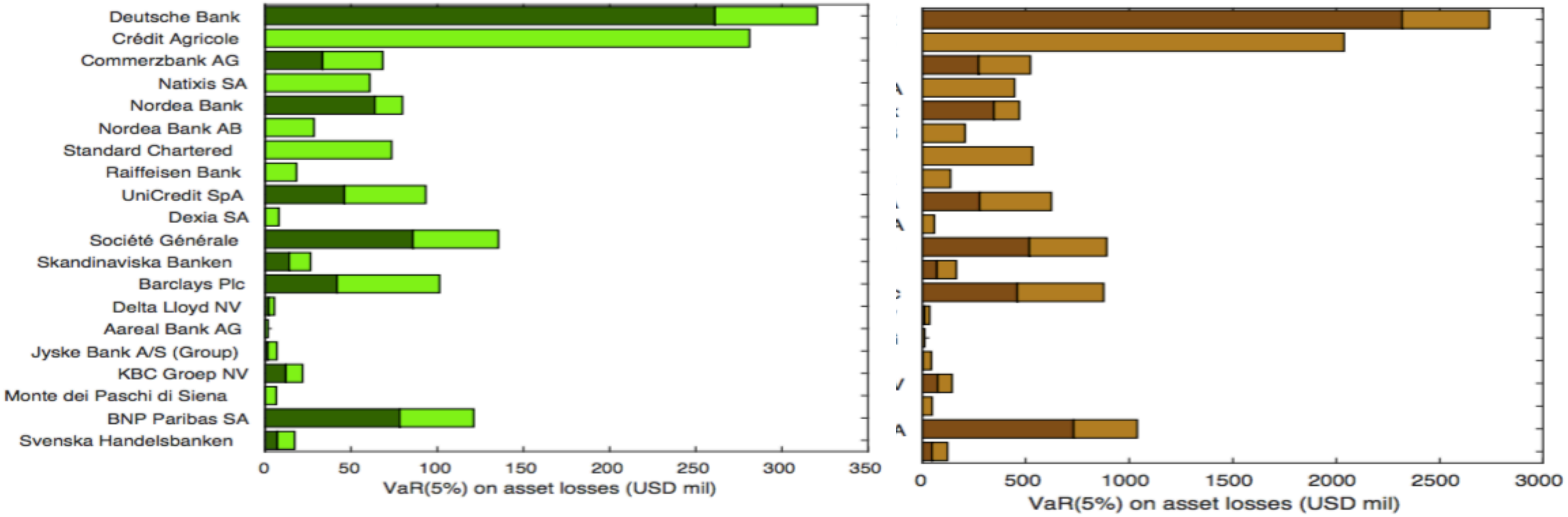
nature climate change

ARTICLES

PUBLISHED ONLINE: 27 MARCH 2017 | DOI: 10.1038/NCLIMATE3255

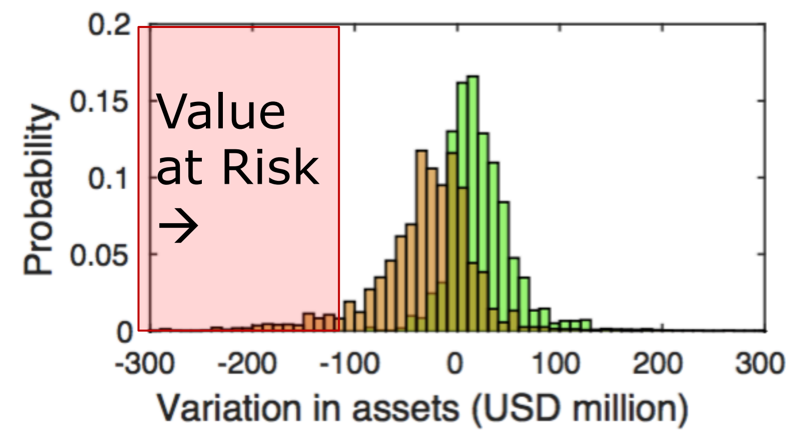
A climate stress-test of the financial system

Stefano Battiston[1]*, Antoine Mandel[2], Irene Monasterolo[3], Franziska Schütze[4] and Gabriele Visentin[1]



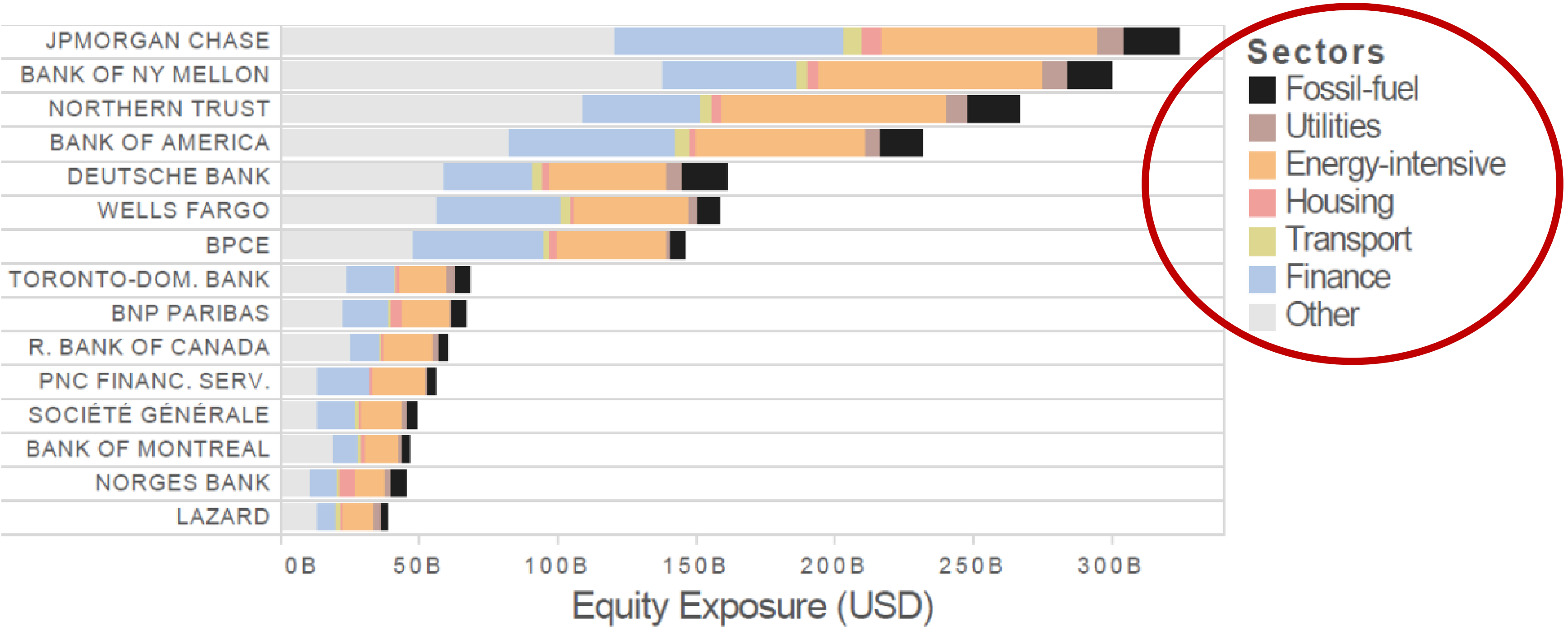
Value at Risk *(5% significance) on equity holdings of 20 most affected EU banks under scenario of green (brown) investment strategy. Dark/light colors: first/second round losses.*

Gain/losses probability distribution → Value at Risk



Investors’ exposure to climate policy relevant sectors (CPRS)

- EU and US pension funds and investment funds exposed for 45% of equity portfolio to climate policy relevant sectors (Battiston et al. 2017)
  - **Risk amplification** via reverberation and interconnectedness of financial contracts, with implications on systemic risk.



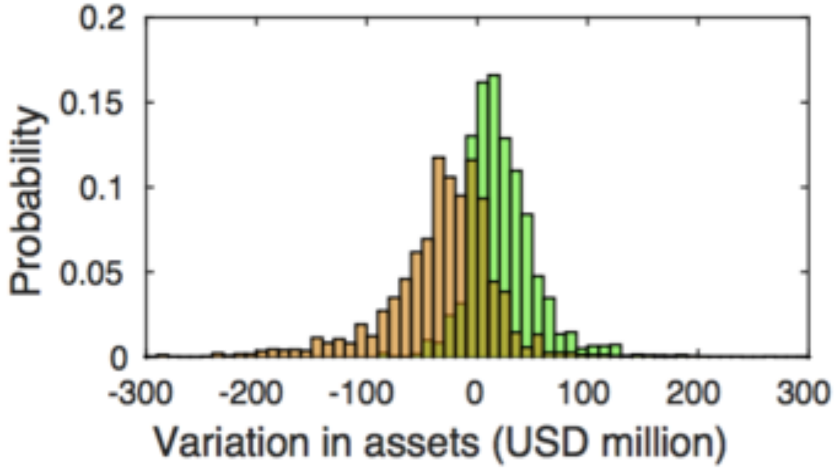
- CPRS (direct, induced emissions along the value chain, carbon leakage policy) represent important value of banks’ equity portfolios

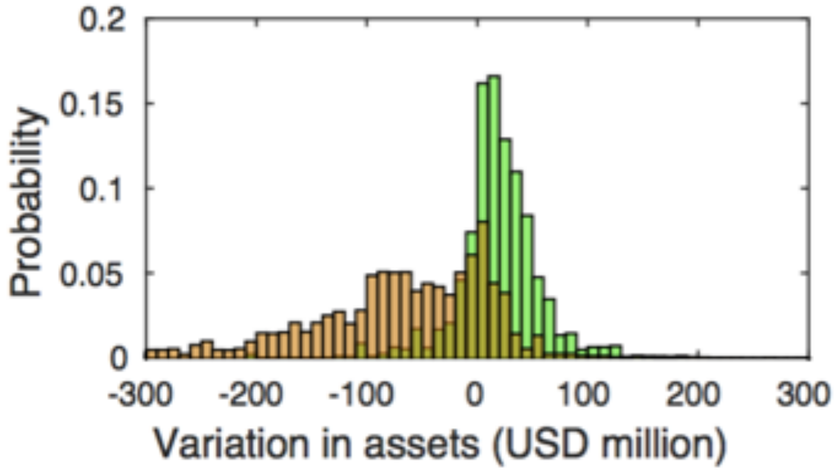
Battiston, S., Mandel, A., Monasterolo, I., Schütze, F., & Visentin, G. (2017). A climate stress-test of the financial system. *Nature Climate Change*, *7*(4), 283–288

A price for financial misalignment: climate Value at Risk

- **Climate stress-test:** top 20 Euro Area banks�much equity holdings under fossil/renewable investment strategy:
  - **1st round (top figure):** brown bank incurs more losses
  - **Adding 2nd round** effect (bottom figure) polarizes distribution of losses.

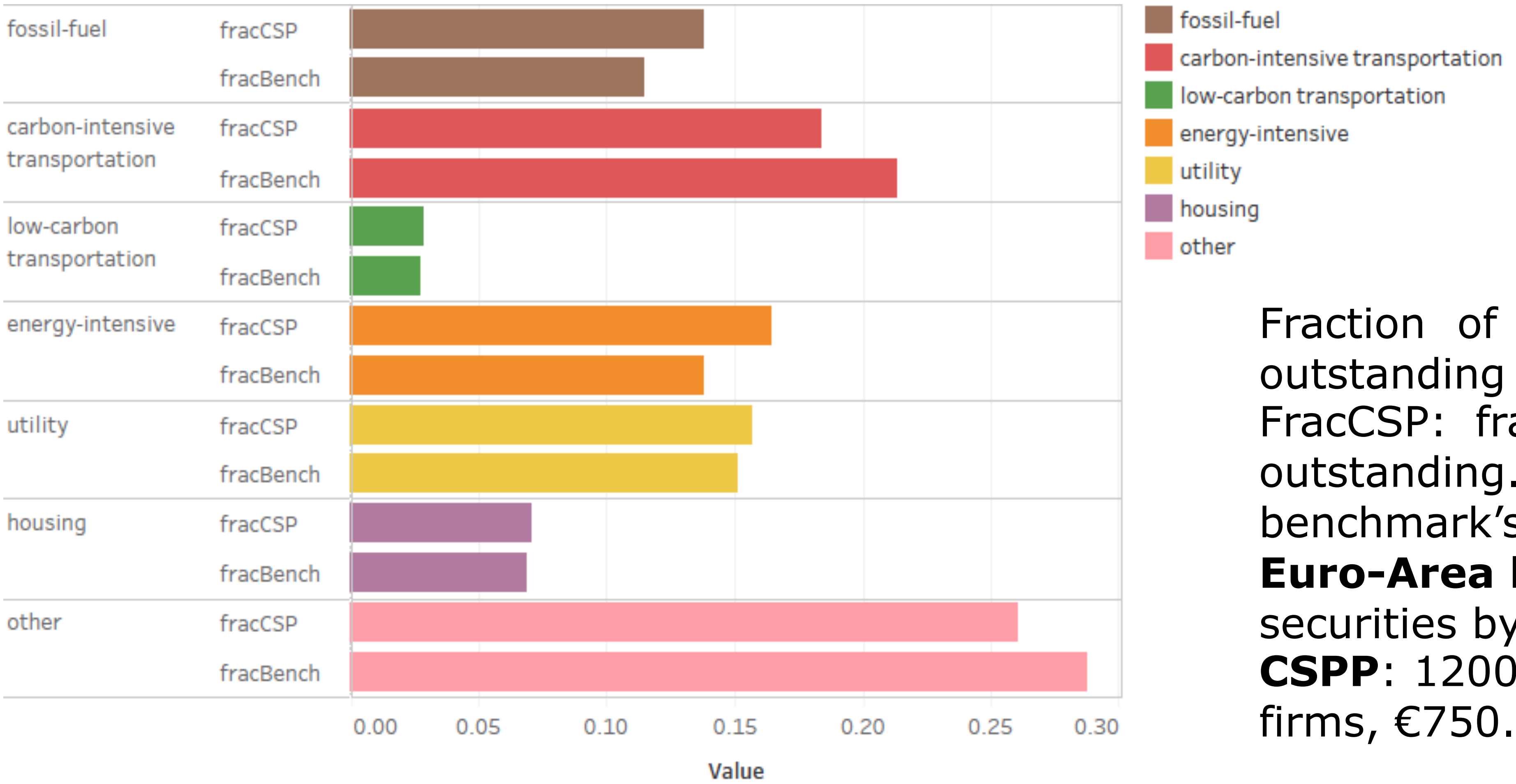
- **Climate stress-tests** can help central banks identify climate risks for financial stability and mitigation measures (e.g. macropru regulation)





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.

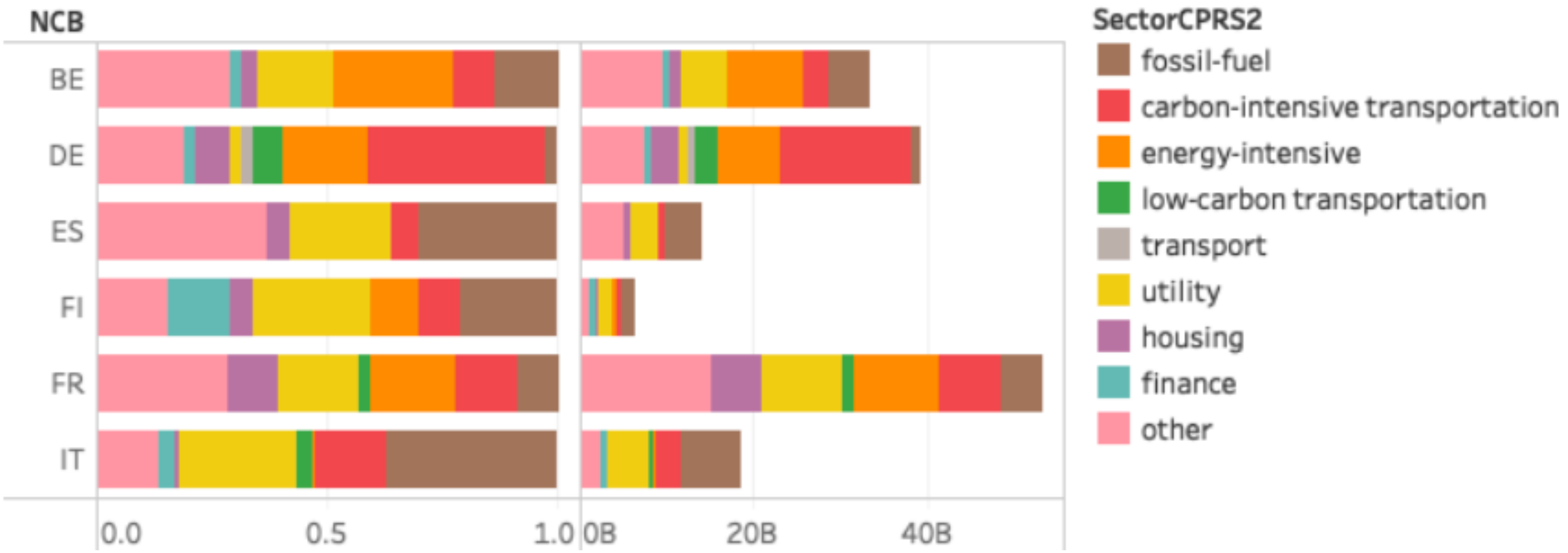
Application 2: ECB shopping list: CSPP Climate-Relevant-Sectors composition vs market benchmark



Fraction of bonds on total amount outstanding (0.2 = 20%). FracCSP: fraction of CSPP's amount outstanding. FracBench: fraction of benchmark's amount outstanding
Euro-Area benchmark: 1.557 securities by 282 firms, €809.859 bn
CSPP: 1200 securities by 237 firms, €750.278 bn.

Source: Battiston, S. and Monasterolo, I. (2019). *How could the ECB's monetary policy support the sustainable finance transition?* FINEXUS working paper (input to Positive Money and Veblen's report Aligning Aligning Monetary Policy with the EU's Climate Targets) https://www.finexus.uzh.ch/en/news/cspp_sustainable_finance.html

Different shades of brown: carbon exposure of CSPP by national central banks

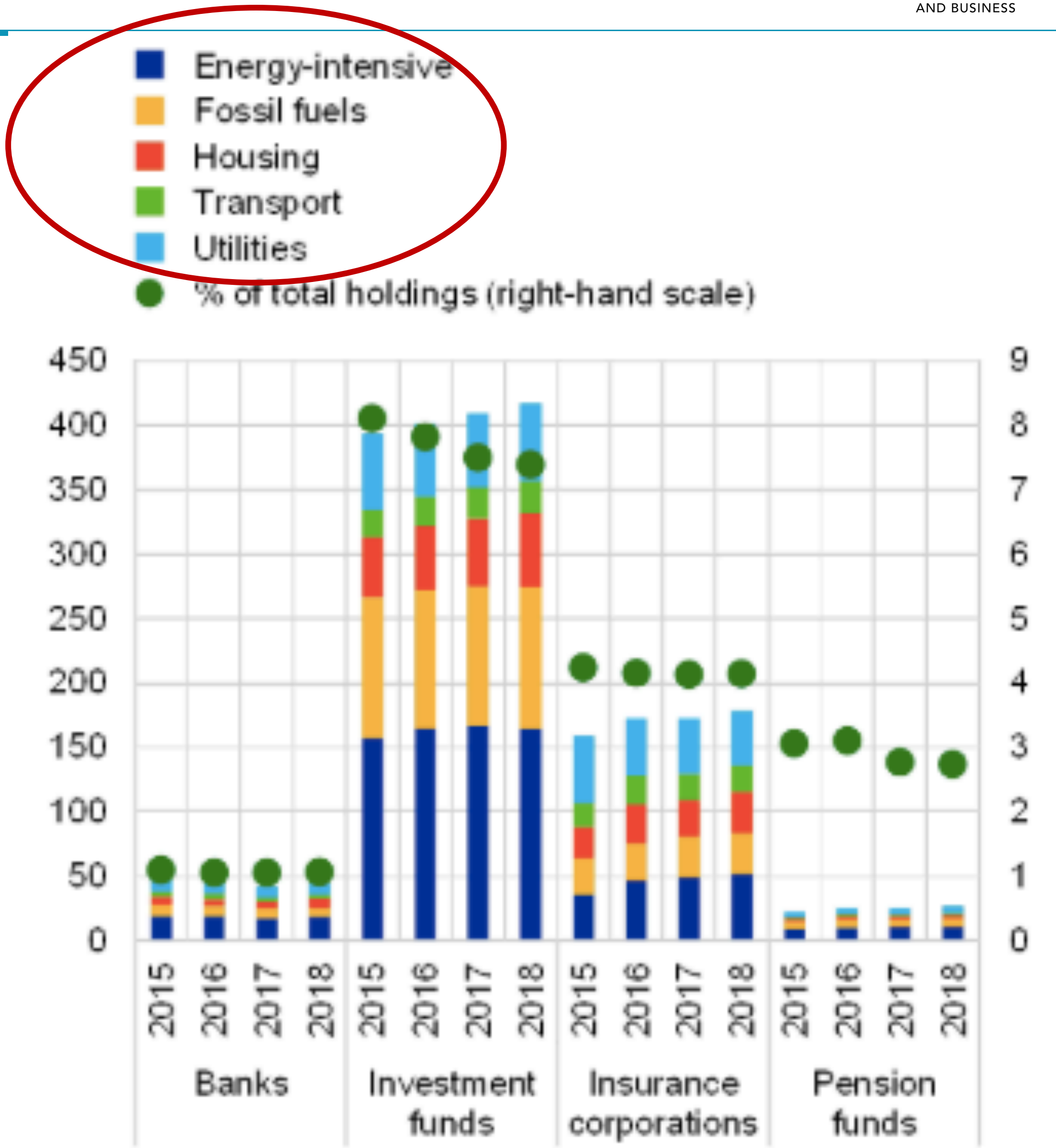


Composition of the six individual NCBs' CSPP portfolio by CPRS as a share of the total bonds' amount outstanding (0.5 =50%, left) and in value of amount outstanding in bn Eur (right).
Source: Battiston and Monasterolo 2019.

The ECB's view: climate risk exposure could drive financial risk

- **European Central Bank (ECB)'s last** Financial Stability Review includes its first **climate change and financial stability report** (May 2019): large exposures of euro area banks to climate-sensitive assets (by issuer sector) could drive financial risk.
- Sectors based on **Battiston et al. 2017's CPRS classification (Climate Stress-test** methodology)

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



Application 3: energy infrastructure loans of Chinese Development Banks

China & World Economy

Original Article

Climate Transition Risk and Development Finance: A Carbon Risk Assessment of China's Overseas Energy Portfolios

Irene Monasterolo, Jiani I. Zheng, Stefano Battiston

model	scenario	minshock	maxShock	totNegShock	totPosShock	totRelNegShock	projectVaR
GCAM	LIMITS-RefPol-450	-1582	6500	-12176	22338	-0.05	-830
WITCH	LIMITS-RefPol-450	-3965	6500	-50778	42809	-0.22	-3878
GCAM	LIMITS-RefPol-500	-1180	6500	-9484	21957	-0.04	-711
WITCH	LIMITS-RefPol-500	-3503	6500	-31343	46723	-0.14	-2710

- **High losses on tot. loans' portfolio value:** ¼ of portfolio
- **Given bank leverage, even an avg shock can lead to financial distress**
- Climate VaR ranges between - $3878 mln/- USD 711 mln (*factor close to 5).*

Why climate matters for investors, central banks and regulators?

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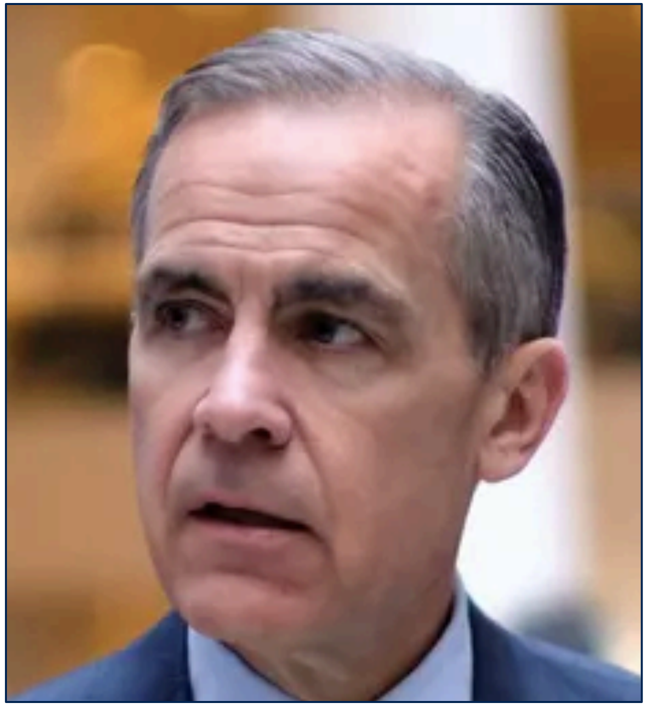
- **Climate risks in the economy and finance can be material and can change investors and governments' financial risk position**
  - Losses on assets can lead to a revaluation of financial contracts and price volatility if large asset classes involved, with implications on financial instability and systemic risk (Gros ea 2016, Battiston ea 2017, Monasterolo ea. 2017)
- Thus they can't be ignored by financial **supervisors** (whose mandate is financial stability), **investors** (those with fiduciary duty), **governments** (fiscal policy, Maastricht criteria)
- Central banks' mandate is preserving price and financial stability. Thus, **assessing and monitor investors' exposure to climate risks is crucial to deliver on their mandate** (Battiston and Monasterolo 2019)

Indeed, what do they have in common?



Mark Carney
Governor of the Bank of England

François Villeroy de Galhau
Governor of the Banque de France

Ma Jun
Chief Economist at The People's Bank of China

They are concerned by the impact of climate risk on financial stability

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

Network for Greening the Financial System
First comprehensive report

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

April 2019

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

Addressing investments' misalignment requires to price climate risks in portfolios

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- Including the characteristics of climate and financial risks in contracts and assets and portfolio's evaluation:
  - **Climate**: uncertainty, non-linearity, tipping points, time-mismatch (financial market's short-term horizon vs. long-term climate impacts)
  - **Finance**: in *interconnected* business-financial sectors, *risk propagates* upward from the economic activity in which capital is allocated to investors, and can be *amplified* across chains of financial contracts
- Beyond sector-based approaches to financial risk assessment, embracing interdisciplinarity and **complexity** (Monasterolo ea. 2019 for a review)
- **Thus, climate finance is not traditional finance + *g* factor**

Monasterolo, I., Roventini, A., and Foxon, T. (2019). Uncertainty of climate policies and implications for economics and finance: an evolutionary economics approach. *Ecological Economics*, 163, 1-10

An approach for climate-financial risk assessment and management under uncertainty(*)

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- We develop an approach to climate financial risk assessment and management under uncertainty
- **Interdisciplinary, science-based** methodology integrating climate economic models' trajectories (IAM), financial pricing models, climate stress-testing.
- Considers sources of **uncertainty** related to climate and climate policies, **complexity** of financial sector, institutions' business model and **mandate**.
- **Goal**: price forward-looking climate risks and opportunities in investors' portfolios,
    - conditions for onset of systemic risk and mitigation at portfolio level

(*) Battiston and Monasterolo 2019. A climate risk assessment of sovereign bonds' portfolios. Forthcoming as OeNB working paper, see SSRN #3376218

3 Pillars

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1. **Understanding risk**: **"this time it is different!"**
   - *Non-linearity, uncertainty* and *endogeneity*: policy makers' decision about climate policies and investors' reaction can lead to multiple equilibria
   - *Amplification* of risk: macro-financial shocks can be reinforcing
2. **Assessing risks/opportunities under incomplete information**:
   - Need to *assess investors' exposure* to climate risks (first/second round)
   - Need to *price climate risk* into financial contracts (climate spread)
3. **Informing risk mitigation**: portfolio's rebalancing to avoid massive losses and achieve gains

(*) Battiston and Monasterolo 2019. A climate risk assessment of sovereign bonds' portfolios. Forthcoming as OeNB working paper, see SSRN #3376218

3 Research questions

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1. **Can we measure individual sovereign exposure to climate transition risk?**

2. **Can we price climate risks/opportunities in the value of individual contracts?**
   - How future climate policy shocks shift my default probability?
   - What’s the price of climate risk (spread) for a country and investor?
   - If I were an investor, should I keep my exposure to Polish bonds?

3. **What implications for central banks and regulators?**

A modular and tailored approach

What	**Portfolio breakdown** by instrument (equity, bonds, loans, etc.)	Contracts classification in **climate policy relevant sectors (CPRS)**	Identification of relevant **climate scenarios** (physical, transition) by 2030/50	Climate shocks on green/brown energy firms' **market share**	Shock to profitability and **assets prices** (e.g. climate spread)	Portfolios' losses/gain, **default** probability (investor, country)
How	Financial macro-network analysis, exposure analysis		Scientific reports (IPCC, IEA)	Climate econ. models (IAM, SFC)	Climate financial pricing model	Climate Value at Risk (VaR)
	Risk identification and monitoring			**Risk assessment and management**		
Data & source	Firm financial (Orbis, TR), climate-relevant data (Scope123, Capex, etc.)		GHG emissions, temperature	Value of fossil/renew. investments	Battiston & Monasterolo 2019	Battiston ea. 2017

4 Take home messages

1. We develop an approach to climate financial risk assessment and management under uncertainty
   - **Rooted on interdisciplinary complementary knowledge** (climate economics models, financial networks, financial pricing models)

2. We **price** countries' misalignment to the climate targets in the value of **sovereign bonds** across feasible **climate policy scenarios**
   - Channels of risk transmission: from disordered climate transition to shocks on sectors' market share, asset's revaluation (+/-) and change in portfolio's value

3. **Include climate in sovereign financial risk metrics** (climate spread):
   - (Mis)alignment to 2°C target improves (worsens) fiscal/financial position (yield)

4. We find that climate can change the **financial risk position** of countries and investors: relevant for **central banks' financial stability mandate**

A climate risk assessment of sovereign bonds' portfolio

Step 1: understanding risk

Climate change and financial stability: where risk comes from?

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- **2 main channels of risk transmission**:
  - **Physical** risk: impact of extreme weather events on firms' production and profitability (physical *stranded assets*), could lead to financial losses for
    - Insurance, banks: losses on value of financial contracts owned and traded
    - Government: lower GDP growth thus lower fiscal revenue with negative impact on budget balance and economic competitiveness
  - **Transition** risk: disordered policy and technological transition that cannot be anticipated by financial actors leads to assets' revaluation for companies whose revenues depend on fossil fuels (renewable energy)
    - Losses on investors' portfolios with implications on price volatility
    - Cascading effect on their investors in the financial network

Why climate changes financial risk assessment

- **Risk**: *range* of events that may happen with a known probability distribution

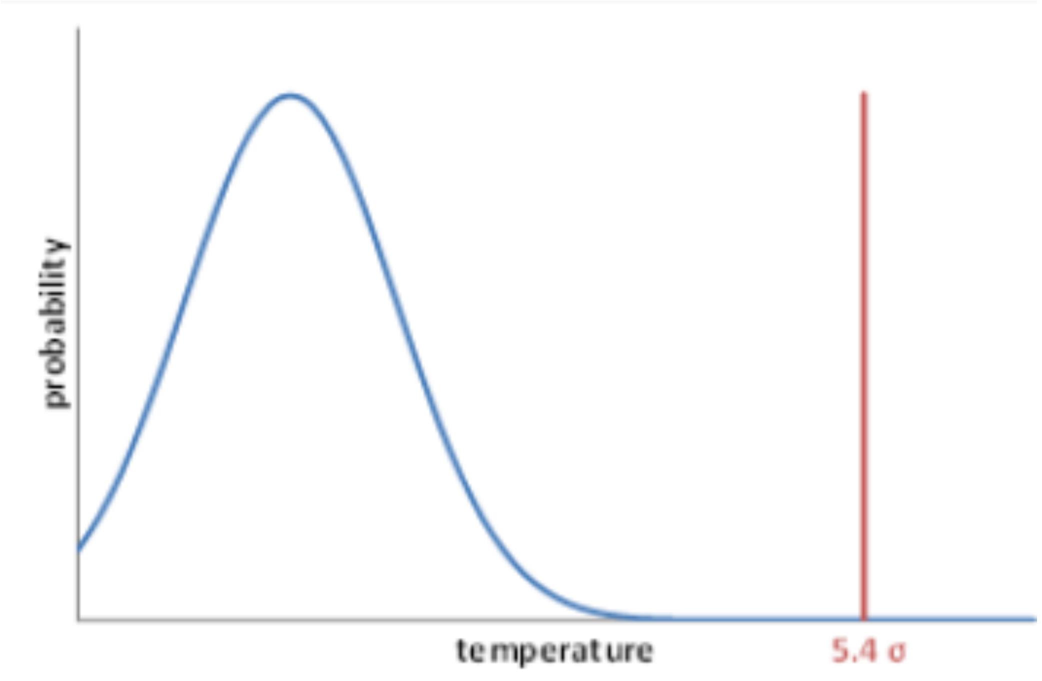
- **Traditional risk assessment** requires to:
  - Identify your **goal and the type** of risk
  - Price the **risk-free** term and define your **risk tolerance**
  - Identify relevant **scenarios** and assign them **probabilities**

- How does **climate** affects **financial risk assessment** and management?
  - Non-linearity, reinforcing feedbacks, domino effects: **fat-tail risk**
  - **Uncertainty:** we cannot assign probability distributions

- Climate makes **past data and lessons less useful for risk assessment**

Non-normal climate data evidence

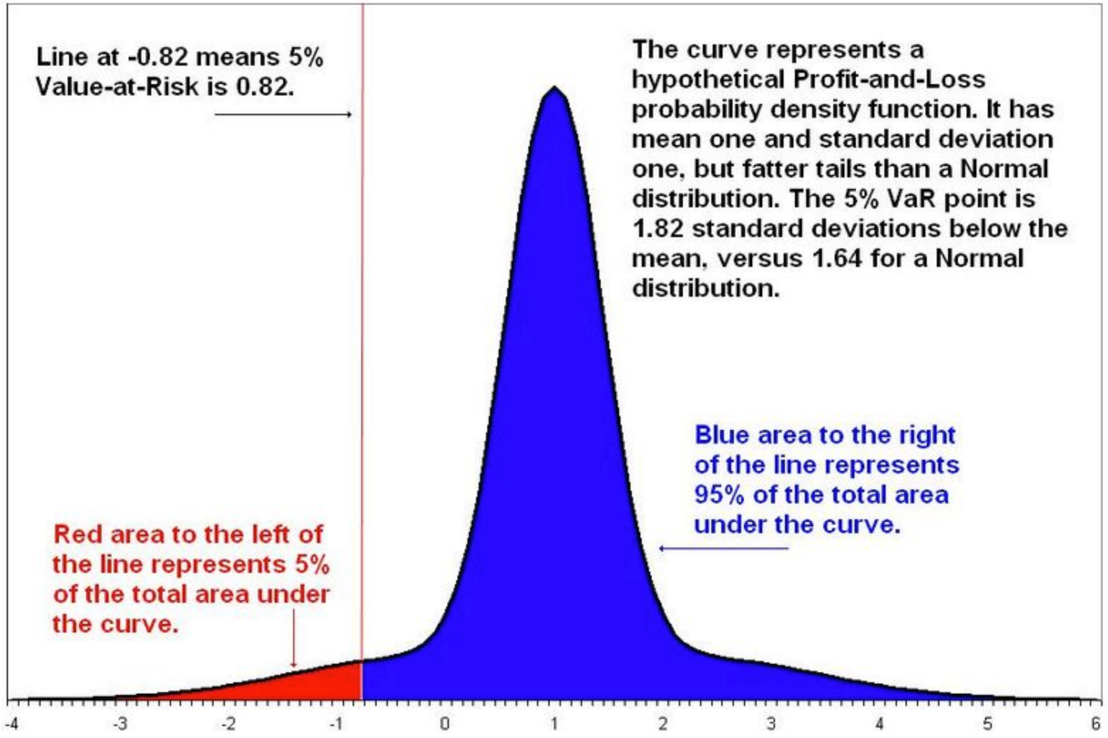
- Western European summer 2003 was 5.4σ above mean temperature for 1864-2000
  - With normal distribution, 5.4σ summer would occur once every 30 mil. years
  - But Eastern Europe had similar heat wave in 2010: if such events happen every 7 years, **temperatures are not normally distributed**
  - Heat wave in the EU right now (you might have felt it…)



Source: Ackerman 2017

Risk type 1: if we know what we don't know

- Value-at-Risk (VaR) used by central bankers to set capital requirements: value to keep aside to avoid massive losses in 95% of cases
- Stands on normal distribution of shocks
- But in presence of fat tails, we can't assume normality: thus, we can't compute a traditional VaR
- But models ignore this assuming a linear shock transmission from climate to prices

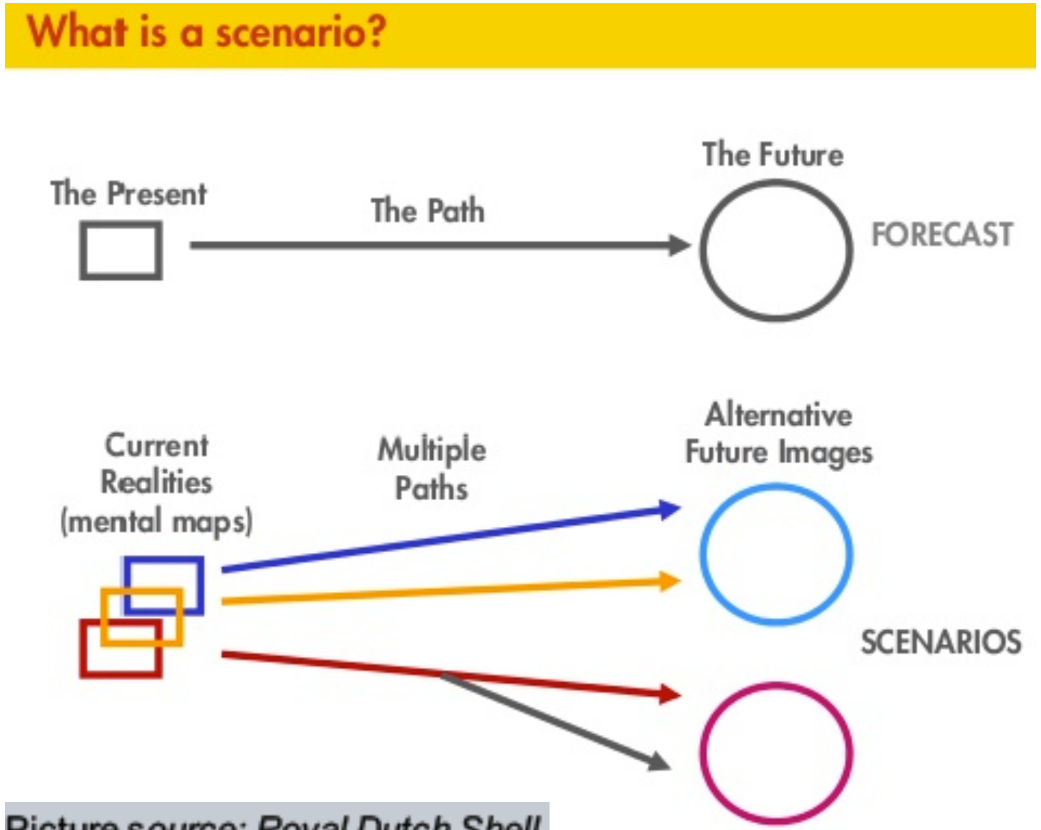


Picture source: wikipedia

Risk type 2: if we don’t know what we don’t know

- Several situations in which we don’t know the distribution of shocks, thus we need to work with *scenarios*

- Scenario analysis can help (doesn’t rely on probability distribution):
  - Decide what extreme climate scenarios could be feasible and relevant for you business
  - Compute losses conditioned to each scenario
  - Identify portfolios’ rebalancing strategies (mitigate risk/ overperformance) under each scenario



Picture source: *Royal Dutch Shell*

Step 2: identify relevant and feasible shocks' scenarios

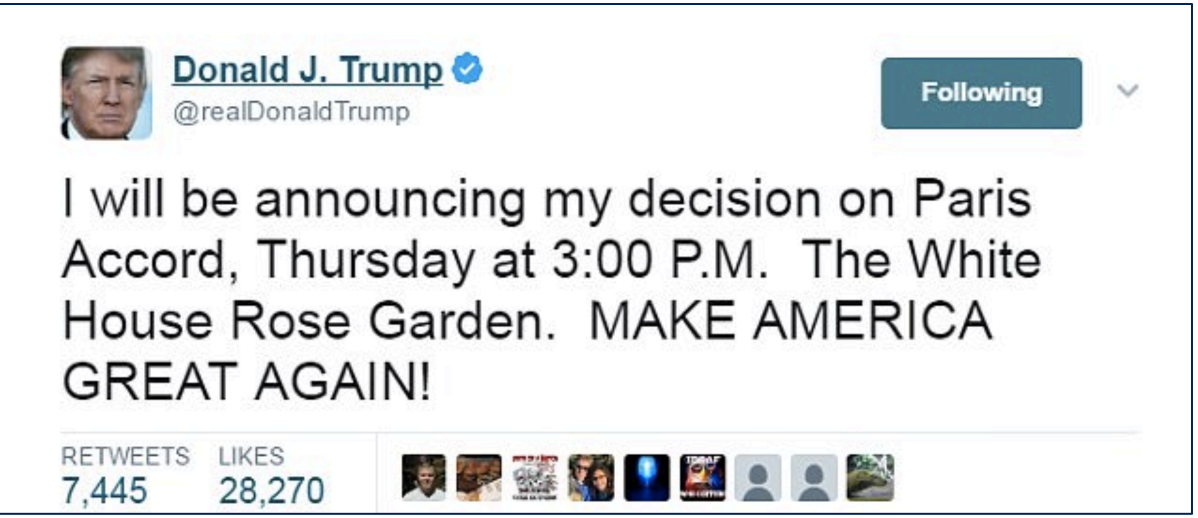
Unanticipated technological shocks

- Example: a fast decrease in renewable energy production costs can destroy value in the fossil fuels (create value in renewable energy) sector (Unruh 2000, Foxon 2016).
- Most investors didn't discount correctly future value of investments in the assets having fossil/ renewable tech. as underlying

Unanticipated climate policy shocks

- The success in reaching an agreement at COP21 came as a surprise to many

- The 2017 position of the US administration towards climate change would have not been correctly predicted by most observers in 2016.



Investors did not price correctly the future value of investments in the assets that have fossil fuels/renewable plants as underlying

Climate transition risk: scenarios

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- We consider a country's transition to the low-carbon economy to achieve the Paris Agreement (PA). It can occur either:
  - **Orderly:** government introduces timely policies; investors *can* anticipate the policy and price it in portfolio's strategy (e.g. increase (decrease) exposure to bonds of climate-aligned (brown) countries)
  - **Disorderly:** government delays the policy's introduction; investors cannot anticipate the climate policy's introduction and thus cannot price it in.
- Evidence that countries aren't aligning to their PA pledges (UNEP 2018) and investors not pricing risk in (Monasterolo and de Angelis 2018).
- Thus, we consider a **scenario of disorderly transition**

Step 3: metrics to assess risks (and opportunities)

Combining climate stress-test with financial decision making under uncertainty

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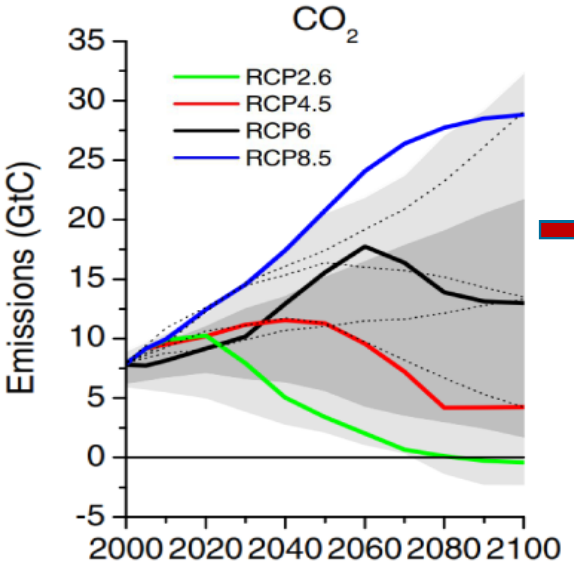
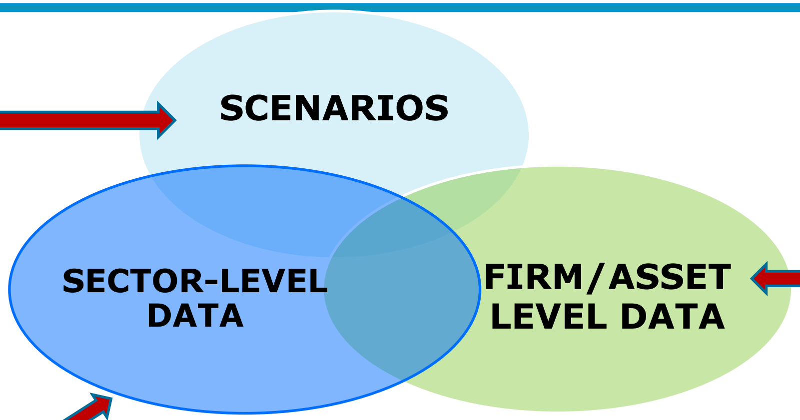
- Modular approach, uses micro-level **firms and assets data, combining financial and climate-relevant data**:

1. **Classify** the contracts into climate-policy relevant sectors (CPRS)
2. Compute **portfolio's exposure to CPRS** by individual contracts
3. Calculate impact of **forward-looking climate shocks** on market share of low/high-carbon firms sectors under 2ºC scenarios by 2030
4. **Price climate risk** in the value of assets and default probability with climate-enhanced pricing models
   - *climate spread* to factor climate in bonds' yields and valuation
5. Assess the **largest gains/losses** on portfolio's value:
   - *climate VaR* to assess largest losses on portfolios

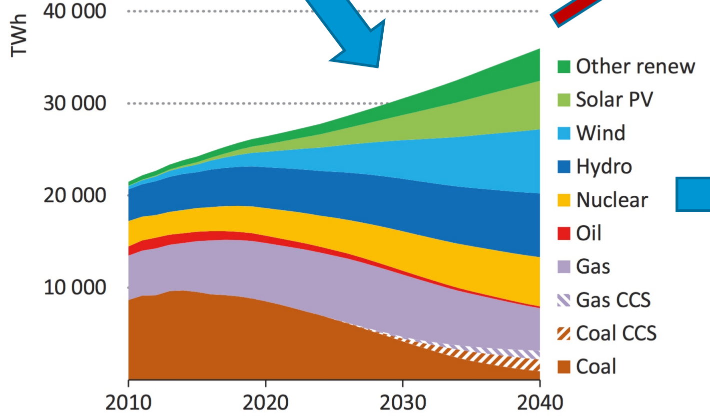
An integrated micro and systemic perspective





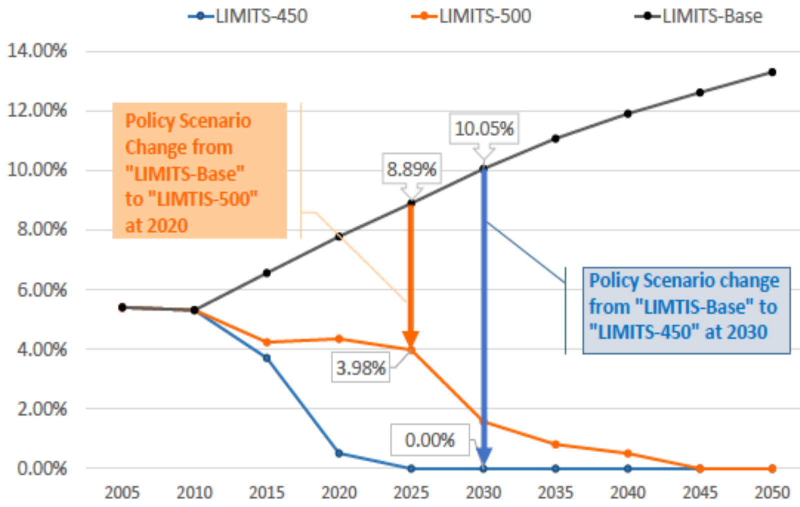
Utility : 10TWh generation

3 TWh from coal	7 TWh from renewables

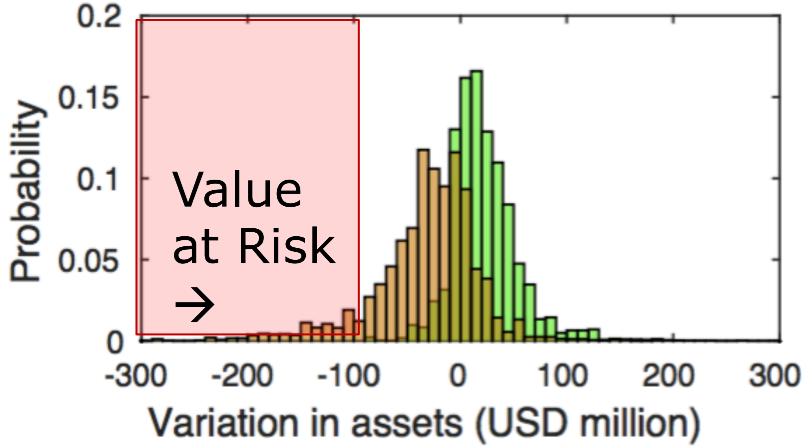


Forward looking trajectories of energy sectors market share [LIMITS, CD Links]

Shock on sector market share
(region/sector – specific, pos/neg)



Translated in financial metrics: Value at Risk



3 channels of climate impacts on financial stability considered

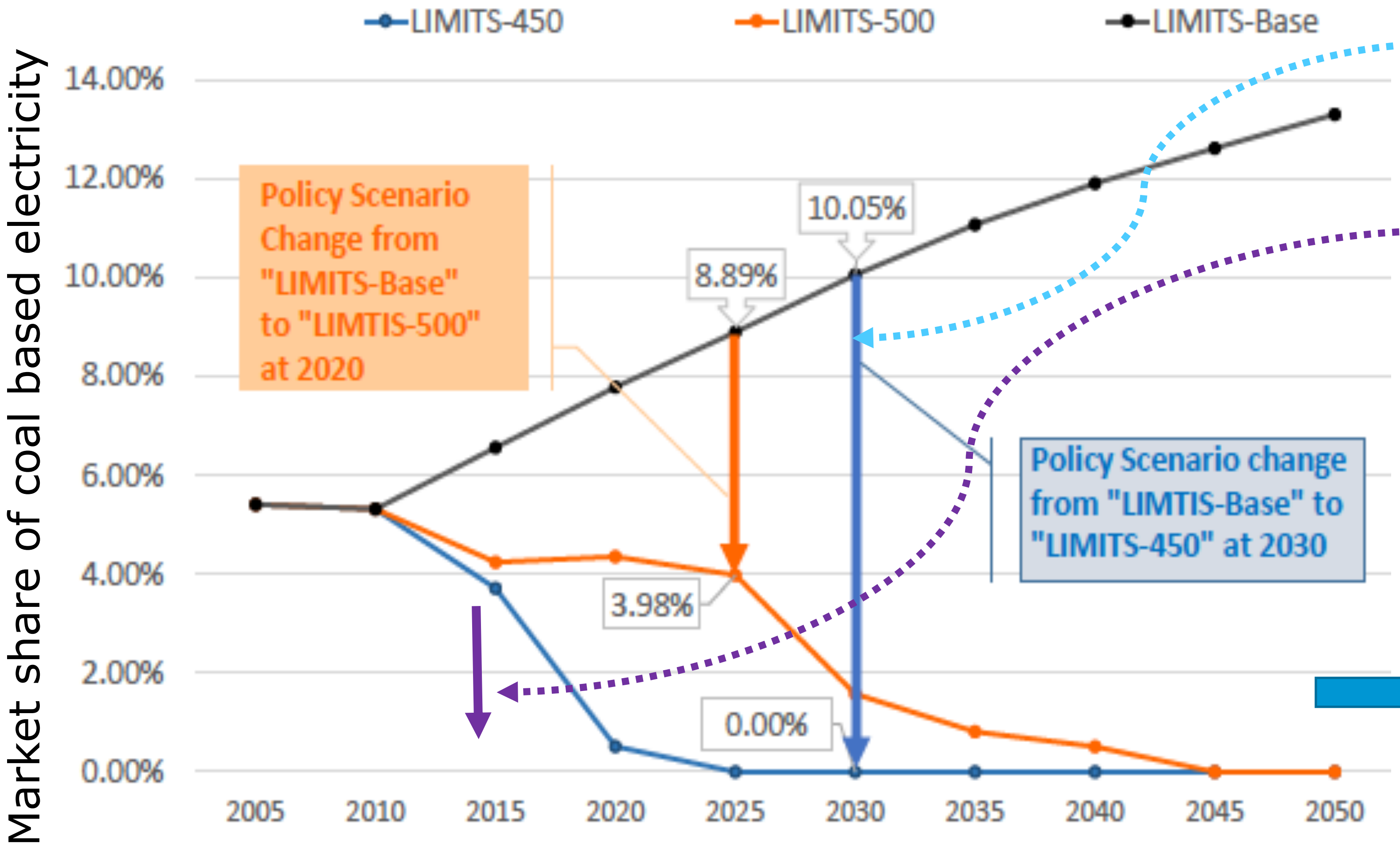
1. **Direct/indirect exposure of investors' portfolios to climate physical and transition risks** via firms and sectors of economic activity
(Battiston et al. 2017, Monasterolo et al. 2018, Roncoroni et al. 2019)

2. **Interconnectedness**: *risk propagates* upward from the economic activity in which capital is allocated to investors, and can be *amplified* by reverberation in chains of financial contracts

3. **Mispricing of climate risks** in the value of financial contracts (Monasterolo & de Angelis 2018) means that investors accumulate and trade exposures to risk and dismiss opportunities for returns

Monasterolo, I., de Angelis, L. (2018). Blind to carbon risk? An Analysis of Stock Market's Reaction to the Paris Agreement. https://ssrn.com/abstract=3298298

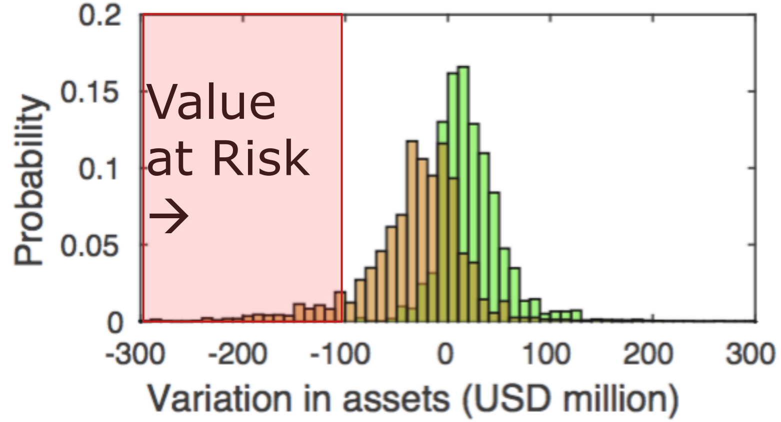
Building shock distributions on forward-looking trajectories (negative/positive)



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)*

Compute the Climate Value at Risk (considering mixed firms and portfolios)

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Utility company A: larger portion of electricity generated from renewable sources in portfolio.

Electricity generation 10TWh

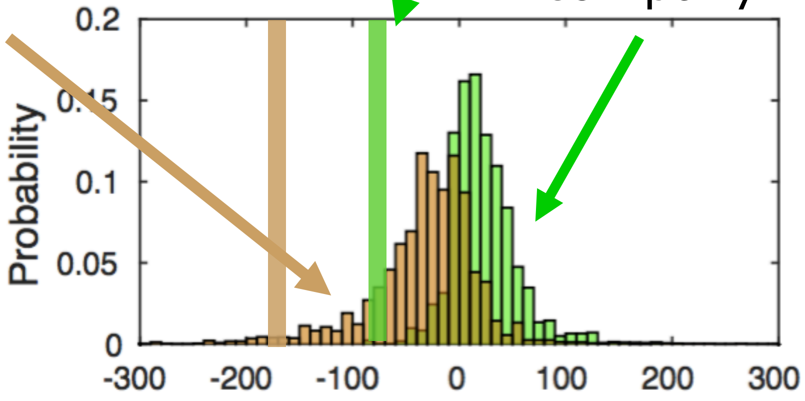
3 TWh from coal | 7 TWh from renewables

Under range of policy scenarios

Utility company B: larger portion of electricity generated from fossil fuels.

Electricity generation 10TWh

7 TWh from coal | 3 TWh from renewable



Firm-level gains/losses

In a 2°C transition scenario, company A has larger gains and smaller losses than company B. Hence a smaller Climate VaR

Climate financial pricing model: investor's information set

- The investor has **incomplete information** (Greenwald and Stiglitz 1986)
  - She doesn't know timing and distribution of climate policy shocks, thus she cannot compute a traditional VaR
  - She knows the magnitude of climate policy shocks (computed with IAM)
  - She doesn't know her (nor competitors') portfolio's exposure to climate risks
  - Historic values of data on financial performance of firms and sectors known

- The **market might not be efficient nor frictionless**:
  - Evidence that climate risk is not reflected in valuation of contracts (deGreiff ea 2018, Monasterolo and DeAngelis 2018, Morana & Sbrana 2019)
  - Complexity of financial contract can lead to mispricing of financial risk (even without considering climate, Battiston ea. 2016)

Estimating climate shocks on the value of sovereign bonds

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- We want to model **climate shock transmission** from fiscal revenues to sovereign bond's value in a market that is non necessarily efficient (Gray ea. 2007)
- We assume that sovereign bonds are not risk-free but **defaultable** (Duffie and Singleton 1999, Duffie ea. 2003)
- Payoff of defaultable bond is dependent on sovereign ability to **repay the debt out of its fiscal revenues** accrued until maturity (Gray ea. 2007)
- **Sovereign default conditions**: value of net fiscal assets at maturity T being smaller than liabilities:
  - $A_J(T) < L_J$ (1)

EFMD EQUIS ACCREDITED AACSB ACCREDITED ASSOCIATION AMBA ACCREDITED

Assumptions

- Asset value is observable only at investment time t_0 and maturity T_j
- Value of liabilities at T_j is known
- Asset value at maturity differs due to *idiosyncratic, climate policy* shock
  - *I.*: distribution at T_j known but individual shocks can't be anticipated
  - *CP.:* magnitude is known, computed with IAM but probability distribution is unknown, individual shocks can't be anticipated
- The two shocks are considered as independent (no empirical evidence of the contrary)
- In a disorderly transition, the value of economic activities in brown (green) sectors is subject to unanticipated negative (positive) shocks

Investor's risk management strategy under uncertainty

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- Risk averse investor aims to assess climate risk of her sovereign bonds' portfolio under incomplete information and uncertainty
- Future asset prices are subject to shocks depending on:
  - sovereign future performance, risk premia demanded by the market, climate policy introduction, outcome of countries' energy transition
- Risk management strategy based on Value at Risk (VaR)
- Considers **a set of feasible scenarios** that portfolio should withstand and compute **VaR conditional to those scenarios**
- Trajectories of future values of economic sectors' market share comes from Integrated Assessment Models (IAM) (other options available)

Battiston and Monasterolo 2019. A climate risk assessment of sovereign bonds' portfolios. Forthcoming as OeNB working paper, see SSRN #3376218

Climate policy shock's transmission on sectors' market share

- **2 sectors: fossil/renewable energy**, composed of one firm each
  - In most EU countries, a major energy firm (OMV in Austria) and one utility.
- Performance of sector S is linked to the change in its market share and sales as a result of a disorderly transition (P)
- P leads to decrease (increase) in tax revenues that issuer j collects from the firms operating in S
- We consider 2 countries j_1, j_2 with utility sectors S_{j1}, S_{j2}
  - Utility S_{j1}: larger share of generation from renewable compared to S_{j2}

Climate policy shock's transmission to firm profitability

- Shock results in jumping from a Business as usual (*B*) sector's economic trajectory of no climate policy to a sector's mild (StrPol500) or tight (RefPol 450) climate policy scenario P

- Lower profits of fossil-based line $\pi Fos(S_j, P) < \pi Fos(S_j, B)$

- *higher profits for renewables* $\pi Ren(S_j, P) > \pi Ren(S_j, B)$

- Net effect of the change in energy mix on *S*'s profit depends on pre-shock and post-shock energy mix (everything else equal)

Climate shock's impact on sectors' fiscal assets

- *Climate policy shock P* shifts the distribution of idiosyncratic shock depending on the composition of country's Gross Value Added (green/brown sector)
- Relative change in sector *S'* market share in country *j* implies a change in the net fiscal assets of issuer *j* from *S*
- Shock to *S* under scenario *P*, estimated on IAM *M*, denoted as $u_j(S, P, M)$:
- $u_j(S, P, M) = \frac{m_j(S,P,M) - m_j(S,B,M)}{m_j(S,B,M)}$ (2)
- Impact of P on fiscal assets of *S* are defined as $\Delta A_j(S, P, M)$:
- $\Delta A_j(S, P, M) = \chi_S \, u_j(S, P, M)$ (3)

χ_S: elasticity of profitability with respect to the market share

Why χ (elasticity) matters

- χ_S: elasticity of profitability with respect to the market share
- Would be tempting (and in economic tradition) to have a proportional shock shock transmission from sector's market share to firm profitability
- But investors have different business models, mandate, benchmark and time-horizon
- Thus, here the shock transmission from sector's market share to firm's discount value of cash flow, firm's profitability and then value of assets is based on the value of elasticity χ
- χ calibrated on **literature**, empirical analyses on firm's **characteristics** (i.e. business model, type of financial contract, type of shock)

Joint idiosyncratic and policy shocks

- Joint effect of idiosyncratic shock and shock associated to a policy scenario P
- Idiosyncratic and policy shock considered here as independent at this stage (no evidence yet from disasters losses databases on the contrary)
- Agent models the assets $A_j(T_j)$ of issuer j at the maturity T_j as a stochastic variable:

- $A_j(T_j) = A_j(t_0) + \xi_j(T_j, P) + \eta j((T_j)$ (4)

where $A_j(t_0)$: asset value at t_0; $\xi_j(T_j$, P): policy shock observable at T_j, $\eta((T_j)$ idiosyncratic shock observable at T_j

Sovereign default conditions

- Issuer defaults at T_j if her assets are lower than liabilities as result of both idiosyncratic and climate policy shocks

$$A_j(t_0) + \xi_j(T_j, P) + \eta j(T_j) < L_j \tag{5}$$

- *j*'s conditioned default probability is the probability that idiosyncratic shock η_j at T_j is smaller than a threshold value $\theta_j(P)$

- $\theta_j(P)$ *depends on* j's liability, initial asset value, magnitude of the climate policy shock j on the asset side

- Default conditions: $\eta_j(P) < \theta_j(P) = - \xi_j(T_j, P) - A_j(t_0) + L_j$ (6)

Result1: shock on security's revenue stream of OECD sovereign bonds

- Shock on the value and spread of 10 year, zero coupon sovereign bonds
- Positive shocks on yield correspond to negative shocks on bond's value

Geo region	Models' region	WITCH: bond shock (%)	WITCH: yield shock (%)	GCAM: bond shock (%)	GCAM: yield shock (%)
EU	EUROPE	1,3	-0,16	0,13	-0,02
Pacific	REST_WORLD	**-17,36**	**2,45**	n.a.	n.a.
EU	EUROPE	0,84	-0,1	0,03	0
North America	PAC_OECD	-5,21	0,67	-18,29	2,61
Scandinavian	REST_WORLD	**-14,82**	**2,05**	n.a.	n.a.
EU	EUROPE	**-12,85**	**1,75**	-2,49	0,32

Shock on bonds' value in a 2°C-aligned climate policy scenario (RefPol-450). Source: Battiston&Monasterolo (2019)

- **Largest negative shocks** on Australia, Norway, Poland's bonds (highest yields i.e. climate spread)
- Shocks led by i) large contribution to GVA and GDP of fossil fuel-based energy, ii) IAMs' forecast of the market share of specific sectors (e.g. nuclear)
- **Positive shocks** led by growing shares of renewables (Italy)

Result2: impact of climate policy shock on OeNB' portfolio

Model	Scenario	Region	Asset Shock (%)
WITCH	LIMITS-RefPol-450	REST_WORLD	-0,367
WITCH	LIMITS-RefPol-450	REST_WORLD	-0,350
WITCH	LIMITS-RefPol-450	PAC_OECD	-0,329
WITCH	LIMITS-RefPol-450	NORTH_AM	-0,110
WITCH	LIMITS-RefPol-450	EUROPE	-0,078
WITCH	LIMITS-RefPol-450	EUROPE	0,005
WITCH	LIMITS-RefPol-450	EUROPE	0,016
WITCH	LIMITS-RefPol-450	EUROPE	0,018
WITCH	LIMITS-RefPol-450	EUROPE	0,021
WITCH	LIMITS-RefPol-450	EUROPE	0,083

Climate policy shock (tight scenario) on OeNB's portfolio in percentage points (i.e. 1=1%), WITCH. EUROPE includes different countries (disclosure issues). Battiston & Monasterolo (2019)

You think shocks are small?

- Tighter policy scenarios may be considered (emissions increasing)
- IAMs' policy scenarios before the Paris Agreement (IIASA to integrate SSPs)
- Even few decimal points of GDP growth change could impact yields due to expectations (IT)

Thus, conservative result

Conclusions

1. **We develop a climate-financial risk assessment approach to decision making under uncertainty**

2. **Climate risk could change individual financial risk position:**
   - high-carbon (low-carbon) intensity of firms and assets can negatively (positively) affect climate alignment and financial risk of investor's portfolio

3. **Our Climate risk assessment allows to mainstream climate risk considerations in portfolio's management strategy:**
   - Assess portfolio's alignment to climate targets by individual asset, identify sources of misalignment
   - Estimate financial risk associated to misalignment (e.g. climate VaR)
   - Inform portfolio's risk management strategy (solvability, rating)

Interested in? Here is what we are up to

- **New research projects**:
  - EU FET Innovation Launchpad **CLIMEX** - Climate Exposure Tool for Financial Risk Analysis (with Univ. of Zurich, Paris School of Economics)
  - Austrian Climate Research Program’s **GREENFIN** - Scaling up green finance to achieve the climate and energy targets in Austria (with IIASA, UNIBO, EIB)
  - Axis-ERANET **BIOCLIMAPATHS** - Assessing climate-led socioecological impacts and opportunities for resilience pathways in the EU bioeconomy (with PIK, IIASA)
  - EC H2020 **CASCADES -** Cascading climate risks: Towards adaptive and resilient European societies

- **Talks:**
  - **Snowmass (CO) Energy modelling forum 2019**
  - **EAEPE conference**, “climate financial risks and opportunities”, Warsaw (PO), Sept. 2019
  - **CREDIT conference**, Univ. Ca’ Foscari Venice, Sept. 2019

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