Climate change and the financial system

Dr. Irene Monasterolo, PhD

Institute for Ecological Economics,
Vienna University of Economics and Business (WU)
Boston University's Global Development Policy,
International Institute for Applied Systems Analysis

Topics overview

WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

1. **Climate change and the low-carbon transition**
2. **Climate-related financial risks**
3. **Risk transmission channels** to the economy and finance
4. **Climate risk disclosure**
5. **Climate risk assessment:** climate stress test

Objectives: what you will learn

- Students will acquire notions and tools to understand and critically elaborate on:
  - What are the climate change scenarios, how they are obtained and implications for use in climate economics and finance
  - Why climate risks differ from traditional risks analysed in finance
  - Main climate policies (fiscal, monetary, macroprudential) and why they differ in terms of implementation
  - Metrics and methods for disclosure and risk assessment

Central banks and financial supervisors started to worry about the climate

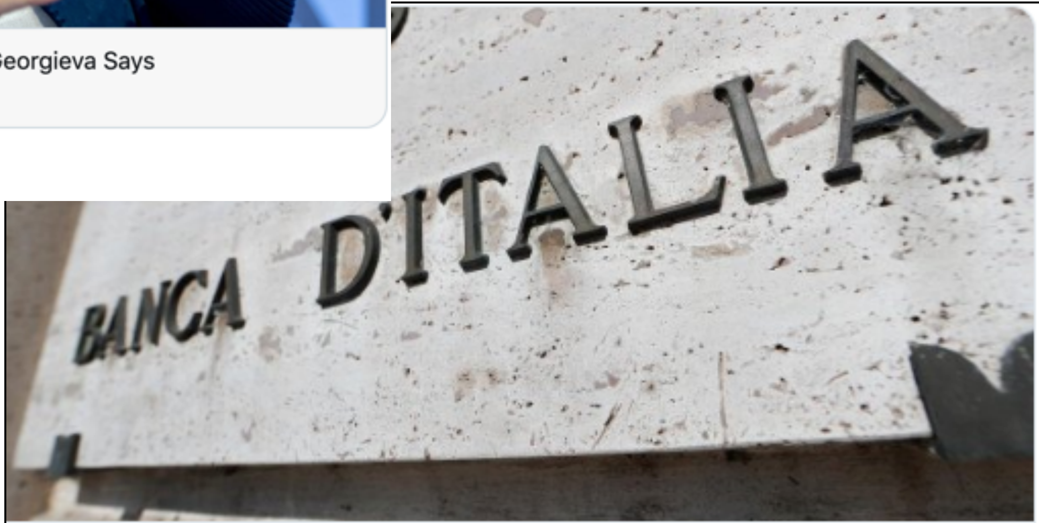
WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

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

IMF Will Include Climate in Country Analysis, Georgieva Says
bloomberg.com

11:58 AM · Oct 17, 2019 · Twitter Web App



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

Climate change and the financial system

WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

- Financial supervisors' concern of climate risks for financial stability (Carney 2015, ECB 2019, ESRB 2020):
  - **physical** risk: hazards affect firms' performance and asset value based on **location and exposure**
  - **transition** risk: climate policy, regulatory change affect firms' performance and asset value based on **energy tech.** (fossil/renew)
- Financial supervisors fear a **disorderly transition** (NGFS 2019):
  - Late/sudden introduction of climate policies whose impacts cannot be fully anticipated by investors
- Several central banks and financial regulators joined the Network for Greening the Financial System (NGFS):
  - Guidelines on **climate stress test** scenarios (NGFS 2020)
  - In action: climate stress tests (Dutch Central Bank 2019, Banque de France 2020, ECB 2021).

Should central banks and financial regulators worry?

Their concerns are grounded in research results:

- Battiston ea (2017)'s **Climate stress test**: investors highly exposed to *Climate Policy Relevant Sectors (CPRS)*, i.e. activities that can face losses and become stranded in a disorderly transition:
    - 43-45% of equity holdings' portfolios of pension funds and investment funds exposed to disorderly transition;
    - **Losses amplified by interconnectedness in financial networks** creating conditions for systemic risk
    - USA: 2/3 banks' syndicated loans exposed to transition risk (via fossil and uti firms in particular), indirect exposures: 16.16%
- *Climate risks and financial stability* research at the core of Special Issue on *Journal of Financial Stability* (Battiston ea 2021)

Take home messages

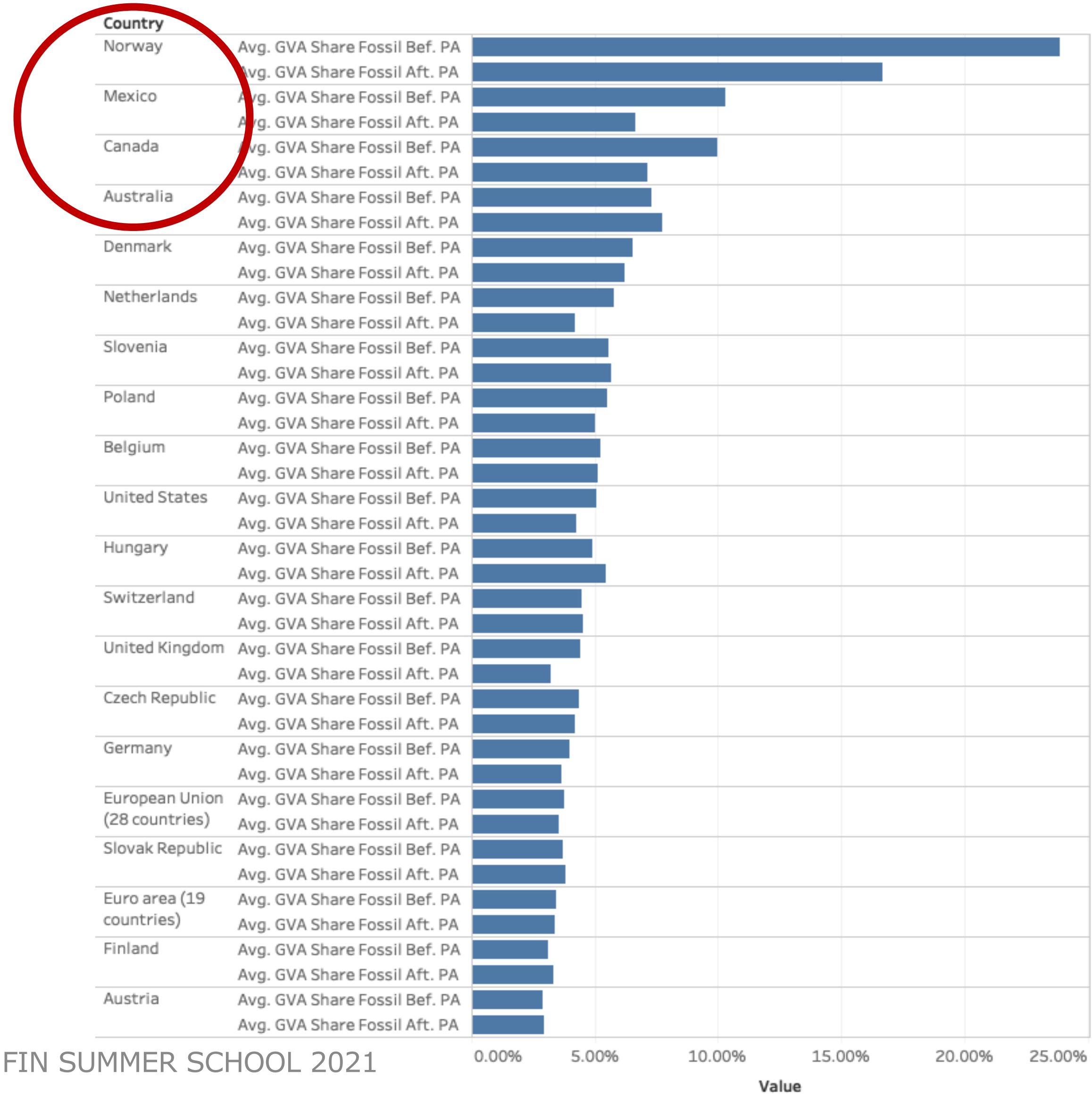
WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

- **Assessing the relation between climate change and the financial system:**

1. **Climate financial risk disclosure:**
   - assess investors' **exposure** to climate relevant activities (beyond emissions: energy tech) through standardized, granular classification of eco activities-> EU Taxonomy + "dirty" taxonomy (e.g. Climate Policy Relevant Sectors (CPRS))

2. **Climate financial risk assessment**:
   - **Climate scenarios:** consider the role of finance and its complexity because it can alter orderly/disorderly trajectories (Battiston ea 2021)
   - **Climate stress test**: consider network effects because financial actors' interconnectedness can amplify risks (eg second, thrid rounds)

Are we on a track?
Share of fossil fuels on Gross Value Added



Average share of fossil fuels on GVA by country, OECD data.

Climate objectives and scenarios

Limiting the impact of climate change to 2degC: the Paris Agreement

WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

- At COP 21 in Paris, on 12 December 2015, Parties to the UNFCCC reached a **landmark agreement to combat climate change** and to accelerate and intensify the actions and investments needed for a sustainable low carbon future.

- The Paris Agreement brings all nations into a common cause to undertake efforts to **mitigate climate change and adapt** to its effects

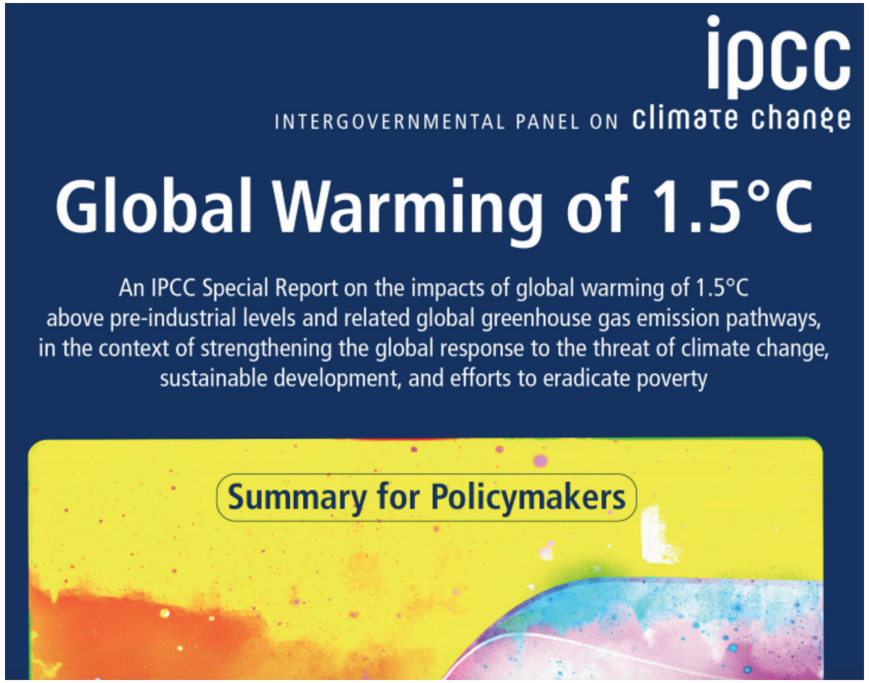
- **Max global temperature increase to 2ºC above pre-industrial levels (desirable 1.5ºC)**

- **Achieving this goal requires decarbonizing our production and consumption** system by 2050 – i.e., **cut anthropogenic CO2 emissions**

https://unfccc.int/process-and-meetings/the-paris-agreement/what-is-the-paris-agreement

The climate science report

- **Intergovernmental Panel on Climate Change (IPCC)** founded in 1988, is a UN body in charge of assessing (mostly) peer-reviewed research on climate and impacts, every 7years
- **It review climate mitigation scenarios** (not predictions!) of emissions concentration evolution based on assumptions (population, GDP growth, technological change, etc)
- Climate mitigation scenarios are developed by Integrated Assessment Models (IAMs)
- **IPCC 2018**: world is on a track for 3ºC of warming by 2100.
- Limiting warming to **1.5 °C will require drastic action by 2050**: curb emissions by at least 49% of 2017 levels by 2030, carbon neutrality by 2050



http://www.ipcc.ch/report/sr15/

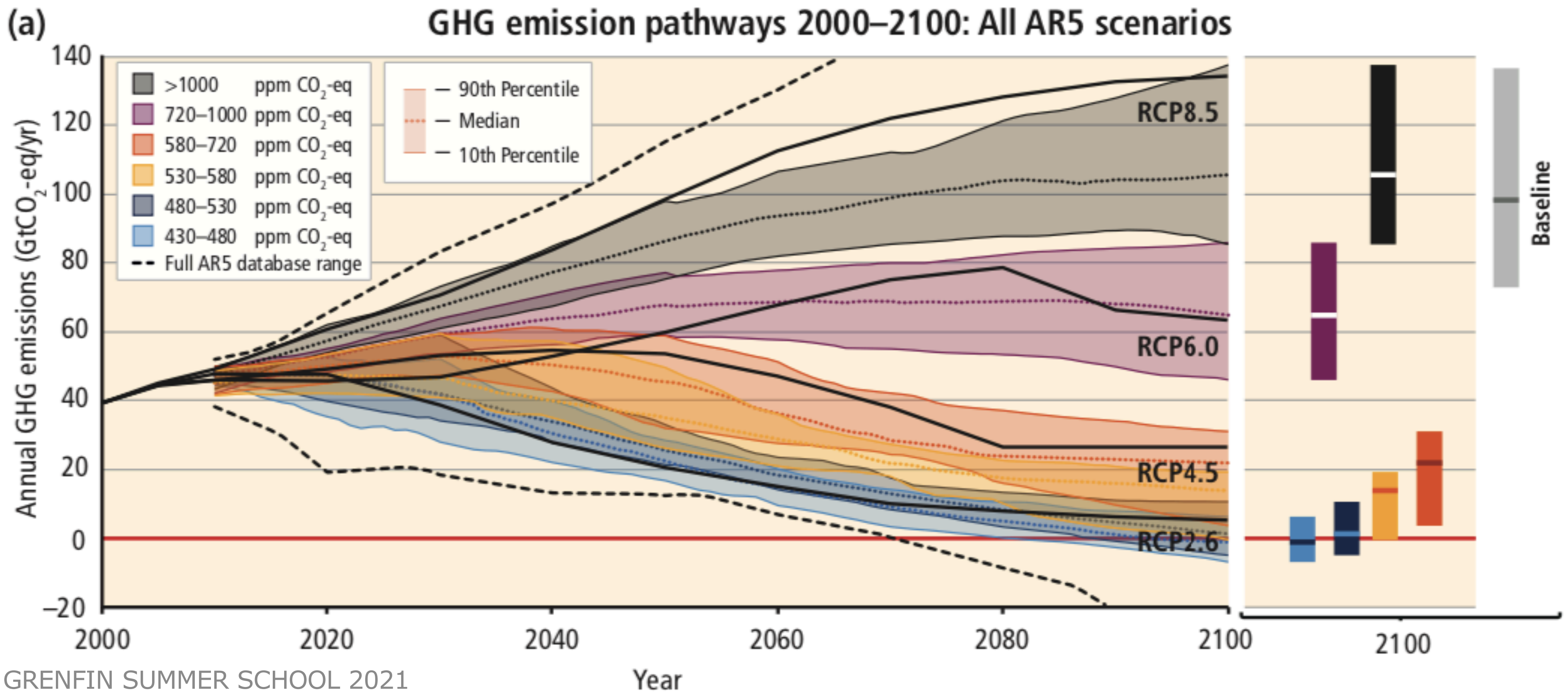
Representative Concentration Pathways (RCPs)

- **Representative Concentration Pathways** (RCPs) used to make **projections** based population size, economic activity, lifestyle, energy use, land use patterns, technology and climate policy.
- Four 21st century pathways of GHG emissions and atmospheric concentrations, air pollutant emissions and land use:
  - Stringent mitigation scenario (RCP2.6),
  - two intermediate scenarios (RCP4.5 and RCP6.0)
  - Scenario with very high GHG emissions (RCP8.5).
  - Baseline scenarios (without additional efforts to constrain emissions) lead to pathways ranging between RCP6.0 and RCP8.5

- RCP2.6 is representative of a scenario that aims to keep global warming *likely* below 2°C above pre-industrial temperatures. The RCPs are consistent with the wide range of scenarios in the literature as assessed by WGIII
- https://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_SPM.pdf

RCPs associated to emissions concentration

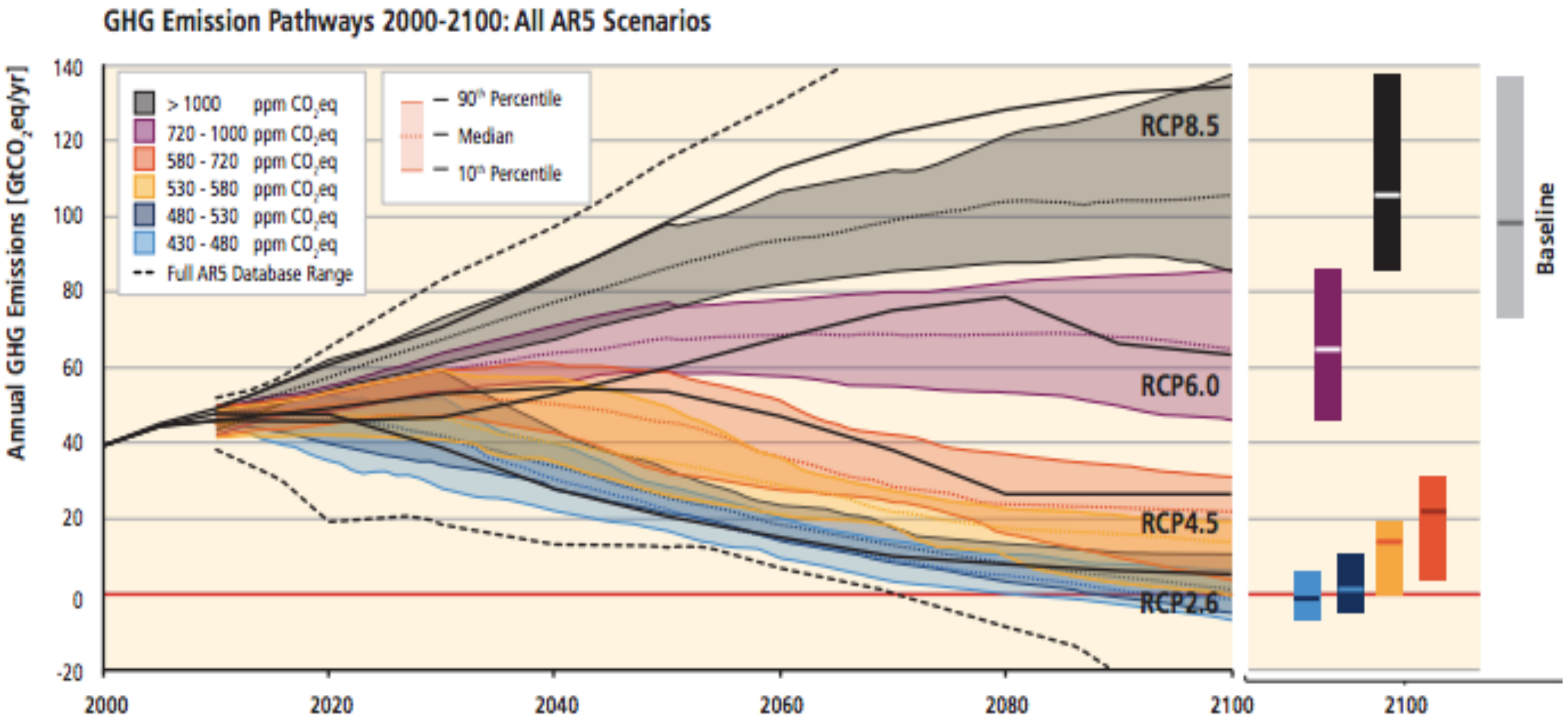
- CO2-equivalent concentrations in 2100 of about 450 ppm or lower are *likely* to maintain warming below 2C over the 21st century relative to pre-industrial levels. This implies 40 to 70% global anthropogenic GHG emissions reductions by 2050 compared to 2010, and emissions levels near zero or below in 2100.



And to temperature increase and climate change

WU WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

- 450 ppm-aligned scenarios are characterized by lower global GHG emissions in 2050 than in 2010 (40% to 70% lower globally) and negative emissions by 2100



Across RCPs, global mean temperature is projected to rise by 0.3 to 4.8 °C by 2100

	2046–2065	2081–2100
Scenario	Mean and *likely* range	Mean and *likely* range
RCP2.6	1.0 (0.4 to 1.6)	1.0 (0.3 to 1.7)
RCP4.5	1.4 (0.9 to 2.0)	1.8 (1.1 to 2.6)
RCP6.0	1.3 (0.8 to 1.8)	2.2 (1.4 to 3.1)
RCP8.5	2.0 (1.4 to 2.6)	3.7 (2.6 to 4.8)

Source: IPCC (2014) WGIII

What are climate mitigation scenarios?

WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

- **Climate mitigation scenarios are not predictions**. They describe what the economy and land use might look like in the next decades.
- Climate mitigation scenarios are paths forward to achieve mitigation goals in time, constrained by:
  - **laws of physics** (e.g., cumulative CO2 emissions, i.e. terms of carbon budget until 2100 leading to global warming levels with associated probabilities)
  - **technological constraints** (e.g. technological efficiency, limits to speed of technology deployment) and finite nature of the planet.
- **Process-based, large-scale Integrated Assessment Models (IAM):** used to develop long-term scenarios of emissions and socio-economic variables assessed by IPCC (*Mc Collum ea. 2018 Nat. Ener.*).

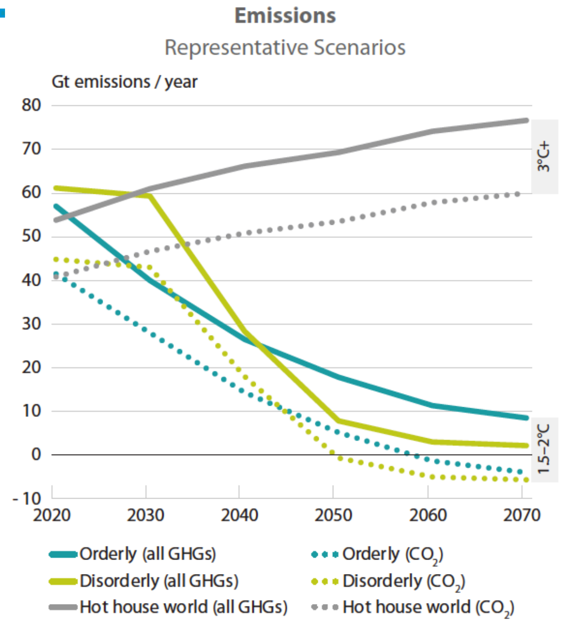
Use of climate mitigation scenarios for climate financial risk assessment

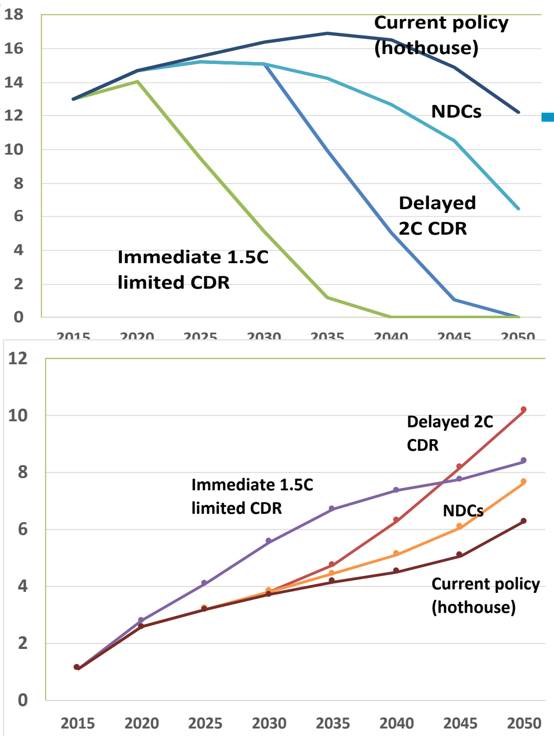
WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

- First scientific approach to show how to use IAM scenarios to assess climate-related financial risk: (Battiston ea. 2017 Nat. Clim. Ch.)
  - **translate IAM** trajectories into **financial shocks** on securities
  - **climate-stress test** of the financial system and individual institutions
  - introduces **Climate Policy Relevant Sectors**, i.e. categories of transition risk based on NACE4 codes of economic activities (used by several policy reports EIOPA 2018, 2019, ECB 2019, 2020, EBA 2020, ESMA 2020).

Expectations: shocks on sectors' output (IAM)

Climate scenarios

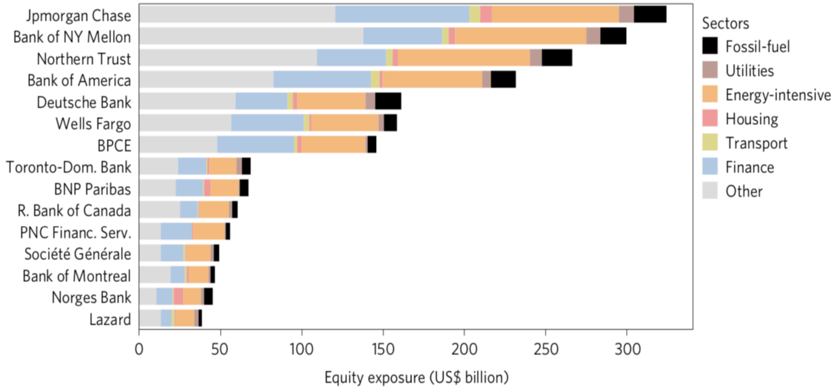




Electricity Coal (top) vs Wind (bottom) across NGFS scenarios, China, 2020-2050

WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

Climate risk exposures



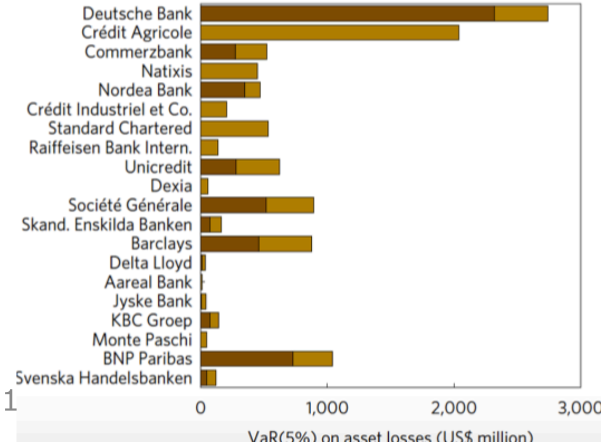
Battiston ea (2017)

Climate adjusted asset *valuation*

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**

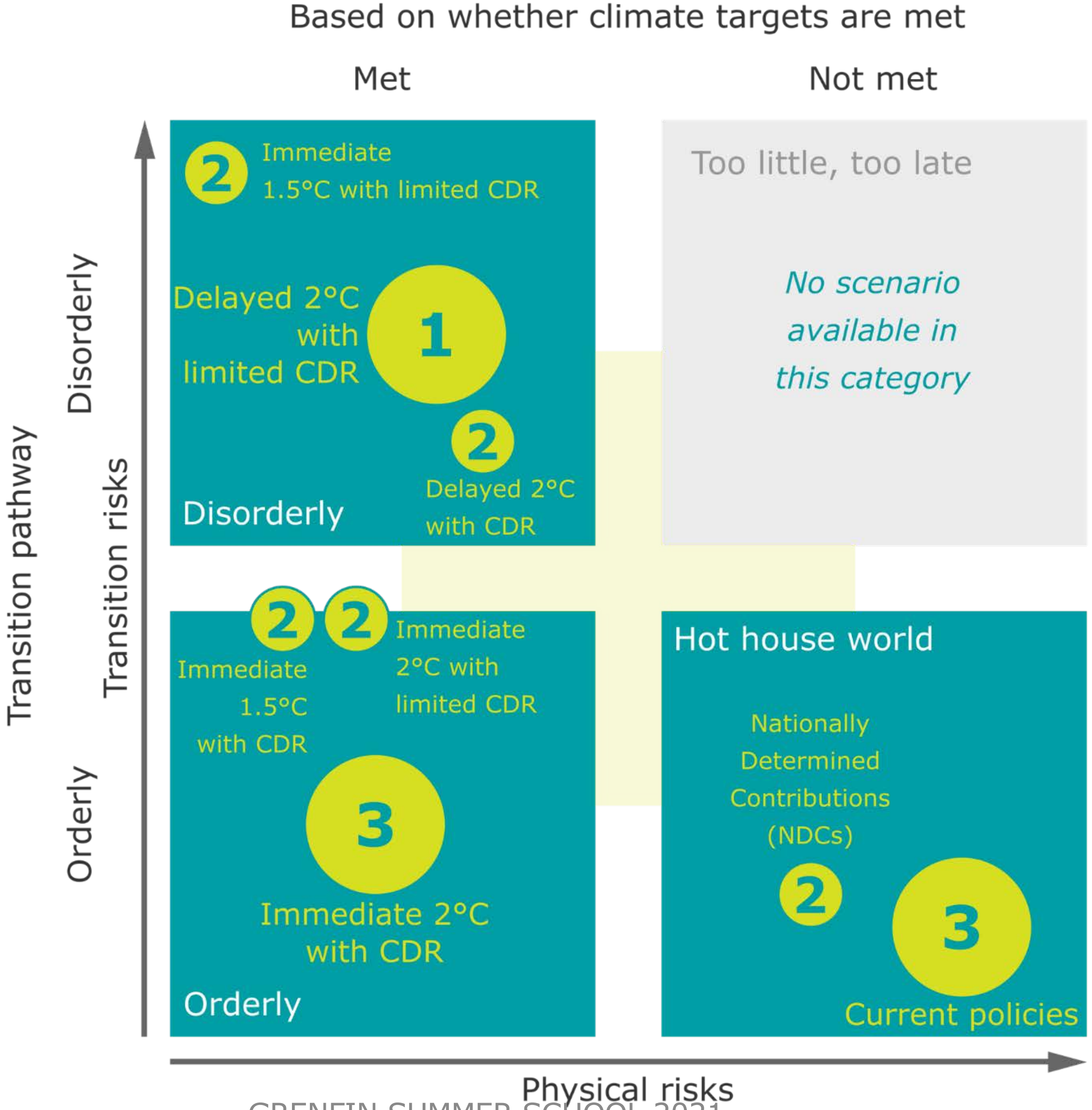
Battiston and Monasterolo (2020)

Climate stress test



Battiston ea (2017)

Network for Greening the Financial System's scenarios

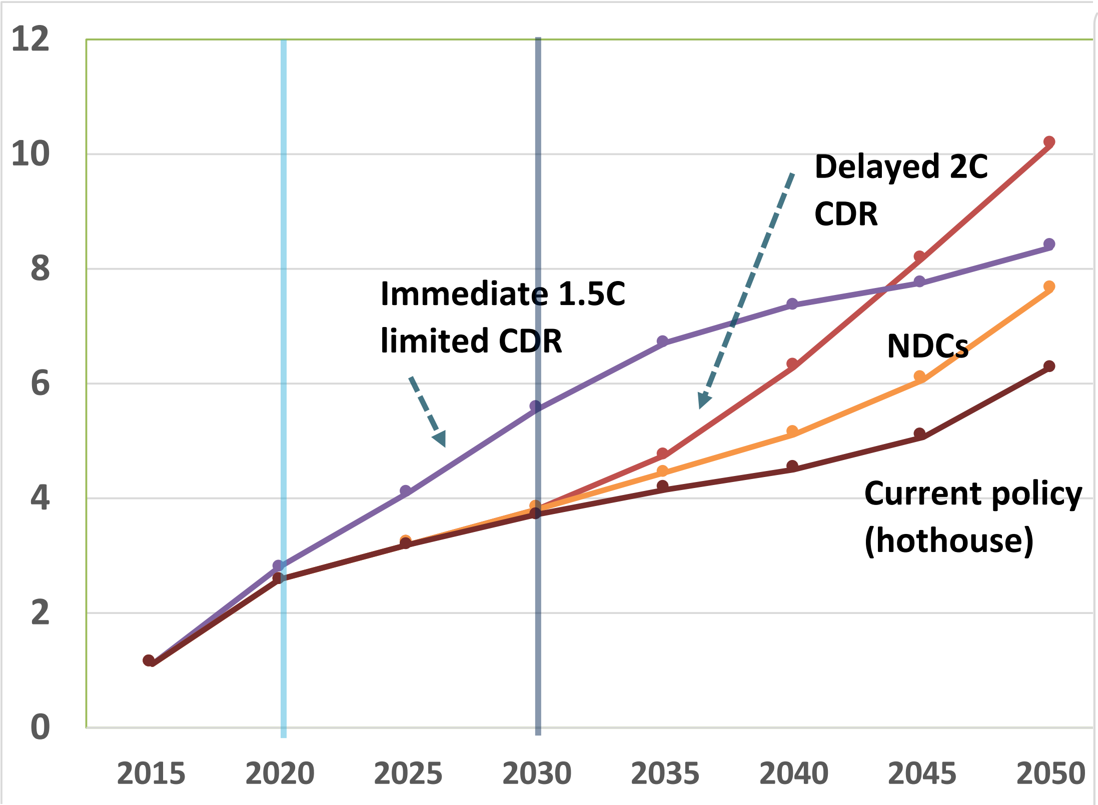


- Set of archetypical IAM scenarios assessed by the IPCC *(2013; 2018, 2022):* distinct features of the transition
  - timing of carbon price (2020, 2030)
  - temperature target (1.5C, 2C)
  - extent of reliance on Carbon Dioxide Removal (CDR)
- NGFS has followed these dimensions to identify 4 high-level scenarios

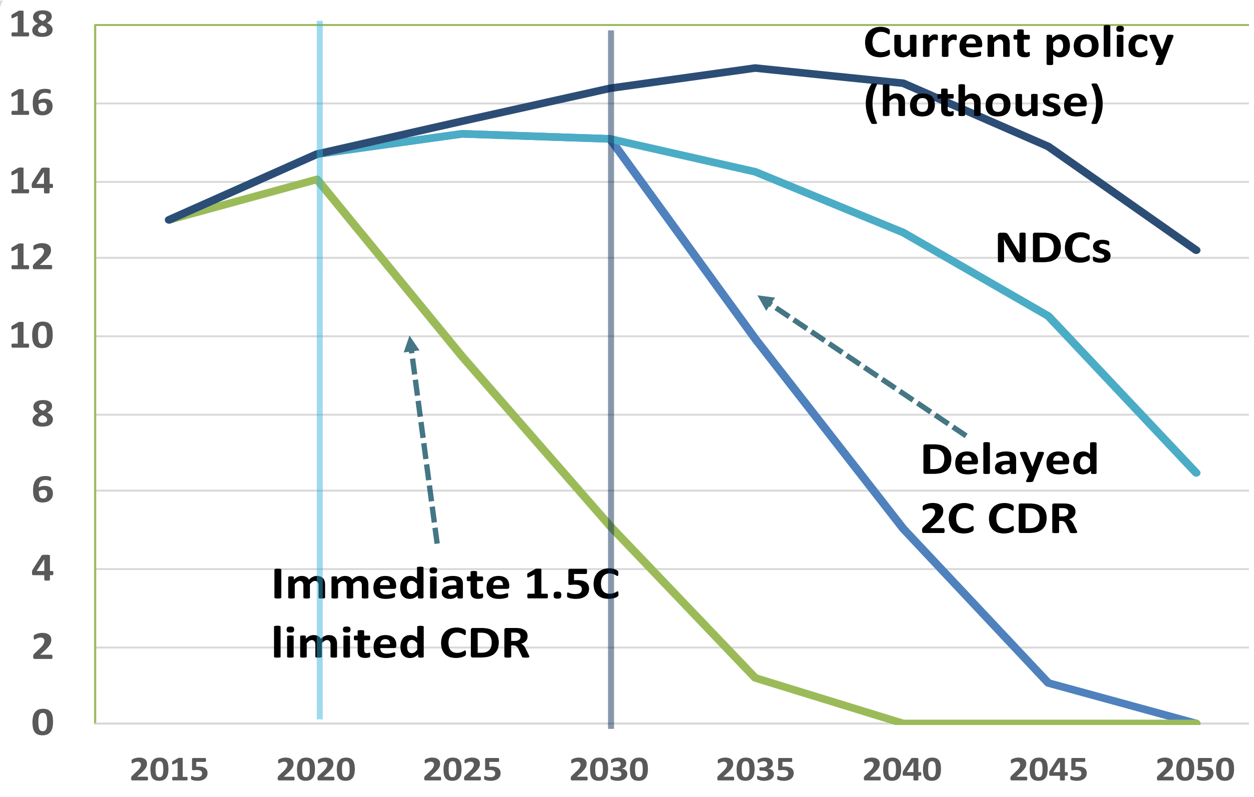
Source: NGFS 2020

NGFS mitigation scenarios
Example

Output Electricity across NGFS scenarios (disorderly transition). Region: China, 2020-2050. Model: REMIND-Mag-Pie.



Wind-based electricity output (ExaJoules/year)



Coal-based electricity output (ExaJoules/year)

Climate-related financial risks

Climate as a new type of risk for financial actors

WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

- **Deep uncertainty:** climate forecasts and its impact contain irreducible uncertainties e.g. presence of tail events (Weitzman 2009) and tipping points (Solomon et al. 2009) that may trigger domino effects (Lenton et al. 2019)
- **Non-linearity:** distribution of extreme climate-related events (heat/cold waves) is highly non-linear (Ackerman 2017) and makes historical data poor proxy of future events
- **Forward-looking** nature of risk: climate impacts are expected in mid to long term while time horizon of finance is shorter (months for investors, 3y for central banks)
- **Endogeneity:** successful transition depends on governments and firms' investment decisions (policy, investments). But both decisions depend on perception of climate risk → occurrence of climate risk scenarios (above 2C) to realize depends on risk perception of decision makers.

Monasterolo (2020). Climate change and the financial system, *Annual Rev. Res. Econ*

Climate change and financial stability: where does risk come from?

- **2 channels** of climate risk transmission to finance (Carney 2015):
  - **Physical**: impact of extreme weather events on eco. activities:
    - Insurance, banks: losses on value of financial contracts owned and traded
    - Government: lower GDP growth ->lower fiscal revenues -> impact on eco. competitiveness, budget balance, creditworthiness
  - **Transition**: policy, tech., regulatory shocks:
    - Losses on carbon-intensive assets -> investors' portfolios -> cascading effect on their investors in the financial network
- 2 channels are connected (yet treated separately), leading to **stranded assets**
- **NGSF (2019): climate transition risk to happen sooner and be more financially relevant than physical risk**

Monasterolo (2020). Climate change and the financial system, *Annual Rev. Res. Econ*

Climate physical risks for financial institutions

- Climate change **physical risk** refers to risk of damages to physical assets, natural capital and/or human lives resulting into output losses, as a result of climate induced weather events.
- Based on the available scientific information, in the current Greenhouse Gases (GHG) emission trajectory: severe socio-economic consequences are likely to occur (IPCC reports), resulting in particular from:
  - sea level rise
  - increased frequency of extreme weather events such as:
    - drought, floods and heatwaves.

Consequences of physical risks for financial institutions

Adverse consequences of physical risk include:

- the destruction of immobilized productive capital, with negative implications on firms' performance and values of securities and loans
- drops in productivity, employment and Gross Domestic Product (GDP) and sovereign credit risk
  - also via loss of arable land productivity
    - with implications on food commodities' production and prices, famine and social unrest; relocation of millions of people living in areas exposed to climate physical risks, even within developed countries.
- drops in properties' values, with implications for banks and insurance companies.

Physical risk versus transition risk

- **Physical risks:** impacts of climate change on physical assets are interconnected:
  - Effect of droughts and high-intensity rainfalls reinforce each other via soil drying and soil erosion
  - Commonly said that that in the EU and UK we do not need to worry about physical risk in the short term. Not entirely true.

- **Transition risks:** unanticipated changes in asset values resulting from not aligning smoothly to a 2 degree trajectory. We tend to think:
  - market players are good at anticipating price changes and is unlikely that policy makers would agree to pass climate policies that could entail risks.
  - However, the events of the last 3 years show that market players may collectively make wrong predictions and policies that entail new risks are sometimes adopted, and unexpectedly so.

Examples of materiality of climate risk

WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

THE WALL STREET JOURNAL.

Subscribe | Sign In

English Edition ▾ | October 23, 2019 | Print Edition | Video

ome World U.S. Politics Economy Business Tech Markets Opinion Life & Arts Real Estate WSJ. Magazine

BUSINESS

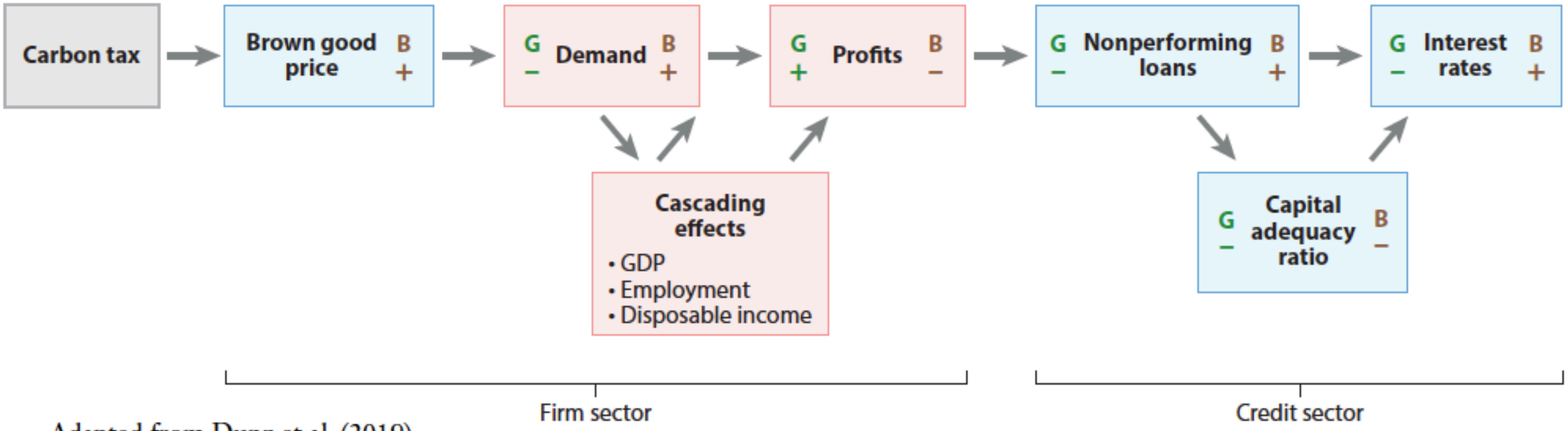
PG&E: The First Climate-Change Bankruptcy, Probably Not the Last

The fast fall of PG&E after California's wildfires is a jolt for companies considering the uncertain risks of a warming planet

By Russell Gold

Jan. 18, 2019 9:00 am ET

Climate transition risk transmission: unanticipated carbon tax

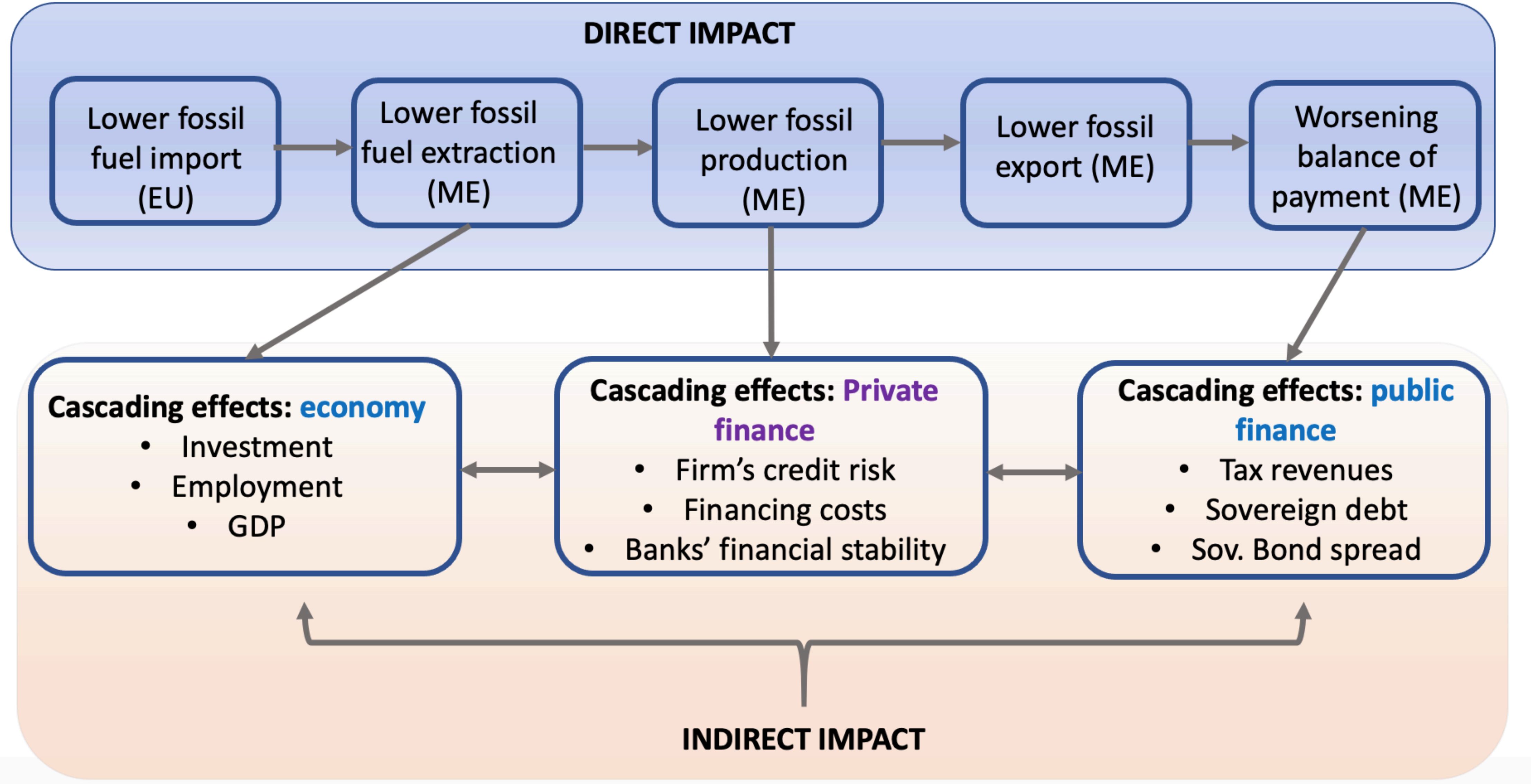


Adapted from Dunz et al. (2019)

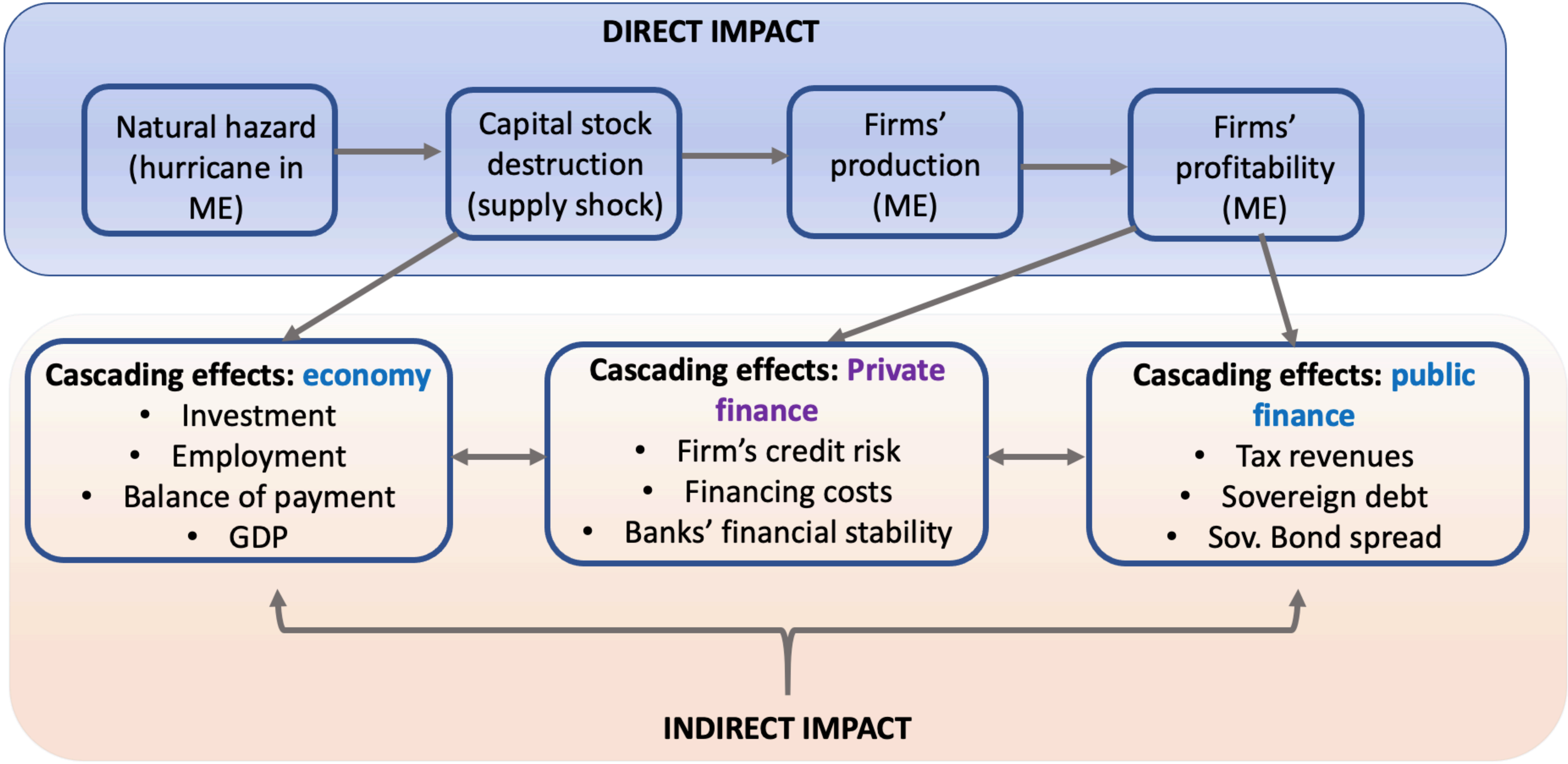
- Carbon tax (CT) can be transferred to households via mark-up pricing, affecting demand
- CT may induce a relative price effect in favor of green capital goods, lowering their demand
- Both channels contribute to decreasing the profitability of brown firms, lowering their ability to service loans
- NPL risk can be transferred to the bank, revising capital ratio and worsening lending conditions

Spillover transition risk: Direct/indirect impacts of EU carbon tax on Messico

WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS



Climate physical risk transmission: natural disasters



Who will bear the risk?
Climate-financial risk disclosure

Disclosure

- G20 FSB Task Force Climate-Related Financial Disclosure (TCFD): 4 recommendations on climate-related financial disclosures for financial investors:

Source: TCFD 2017 Final report, https://bit.ly/2TGfihl

Challenges to implementation: classification needed

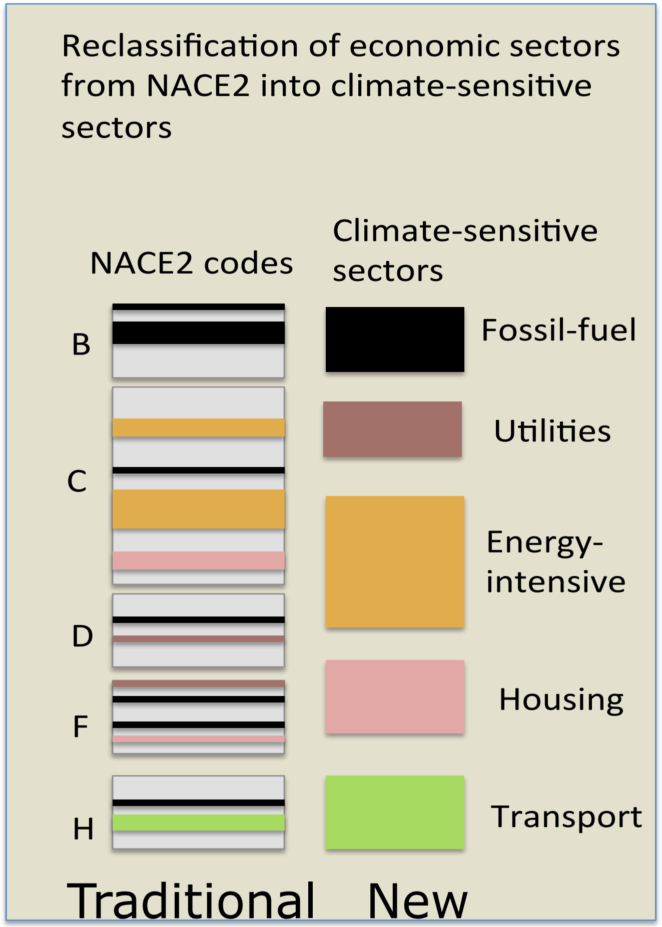
- Exposure to transition risk: i) **energy technology mix** of business lines (not in ISIC); ii) **policy** sensitivity, iii) (mis)alignment with **EU Taxonomy**
- Most analyses use **emissions or ESG** (backward looking) but neglect climate relevant dimensions: energy tech profile of business lines and CAPEX (forward looking)
- **Climate Policy Relevant Sectors (CPRS, Battiston ea 2017):** financial risk from activities' climate relevance (NACE 4-digit), identified by:
  1. direct and indirect contribution to **GHG emissions (Scope 1,2,3)**
  2. **relevance for climate policy** implementation (i.e. costs sensitivity to climate policy change, e.g. the EU carbon leakage directive 2003/87/EC)
  3. role in the energy value chain: **energy tech mix of business lines**

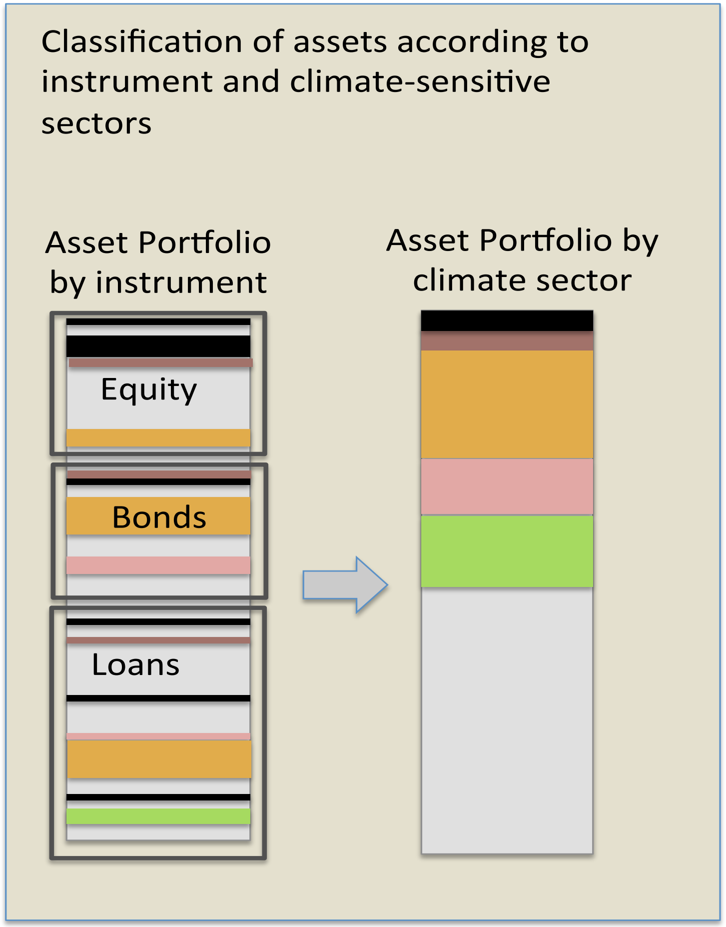
- Full classification: https://www.finexus.uzh.ch/en/projects/CPRS.html

CPRS examples

CPRS Level 1	Category of economic activities	Role in GHG emissions value chain	Specific policy processes	Nature of transition risk in relation to business model	NACE 4 digits Main groups of codes (selected, see full table)
Fossil fuel	Carry out / support production / delivery of primary energy based on fossil fuel.	Mostly indirect CO2 emissions	Oil politics, taxes/subsidies	No fuel substitutability	B-Mining and quarrying: coal, oil and gas; C-Manufacturing: coal, oil and gas; D-Electricity and gas (e.g. 35.21); G-Wholesale: fuel sales (e.g. 47.30); H-Transportation: pipelines (e.g. 49.50).
Utility electricity	Carry out or support production of secondary energy.	Mostly direct CO2 emissions (fuel mix).	Electricity authorities (e.g. feed-in tariffs)	Medium fuel substitutability (e.g. wind farms).	D-Electricity production, transmission and distribution (e.g. 35.11, 35.12, 35.13)
Energy intensive	Manufacturing activities with intensive use of energy according to EU classification Carbon Leakage	Mostly direct CO2 emissions (fuel mix).	No specific policy processes as a group.	Low substitutability (e.g. steel or rockets)	See Carbon Leakage list. B-Mining and quarrying (e.g. 07.10, 07.29, 08.91 etc.); C-Manufacturing (about 200+ sectors, e.g. 11.01, 13.10, 15.11 etc.). NOTE: Nace codes falling in other CPRS are not included.
Transport	Provision of or support to transport services (e.g. vehicles manufacturing, roads and railways)	Mostly direct CO2 emissions (fuel mix).	Transport authorities and policies.	Low substitutability (e.g. motor vehicles fleet)	C-Manufacturing: motor vehicles, ships and trains (e.g. 29.10, 29.20, 30.11, 30.20 etc.); F-construction: roadways and railways (e.g. 42.11, 42.12); G-Wholesale: vehicles (e.g. 45.32); H-Transportation: land, air, and sea transport (49.10, 49.20, 49.41, 50.10, 51.10, etc.)
Buildings	Provision of or support to buildings services (e.g. residential and commercial)	Mostly direct CO2 emissions (fuel mix).	Housing policies.	Low substitutability (e.g. heating/cooking)	F-Construction: residential and commercial building (e.g. 41.10, 41.20, 43.22, 43.91 etc.); I-Accommodation (e.g. 55.10, 55.20); L-Real-estate (e.g. 68.10,68.20, 68.30); M-Professional: architectureal activities (e.g. 71.11)
Agriculture	Provision of and support of agriculture and forestry	Direct CO2 emissions from fossil fuel; other direct GHG emissions. Negative emissions (afforestation).	Agricultural policies.	Low Substitutability (as for transport). But emission reductions via low carbon farming.	A - Agriculture forestry and fishery (from 01.10 to 02.40)

Reclassification from NACE Rev. 2 into CPRS



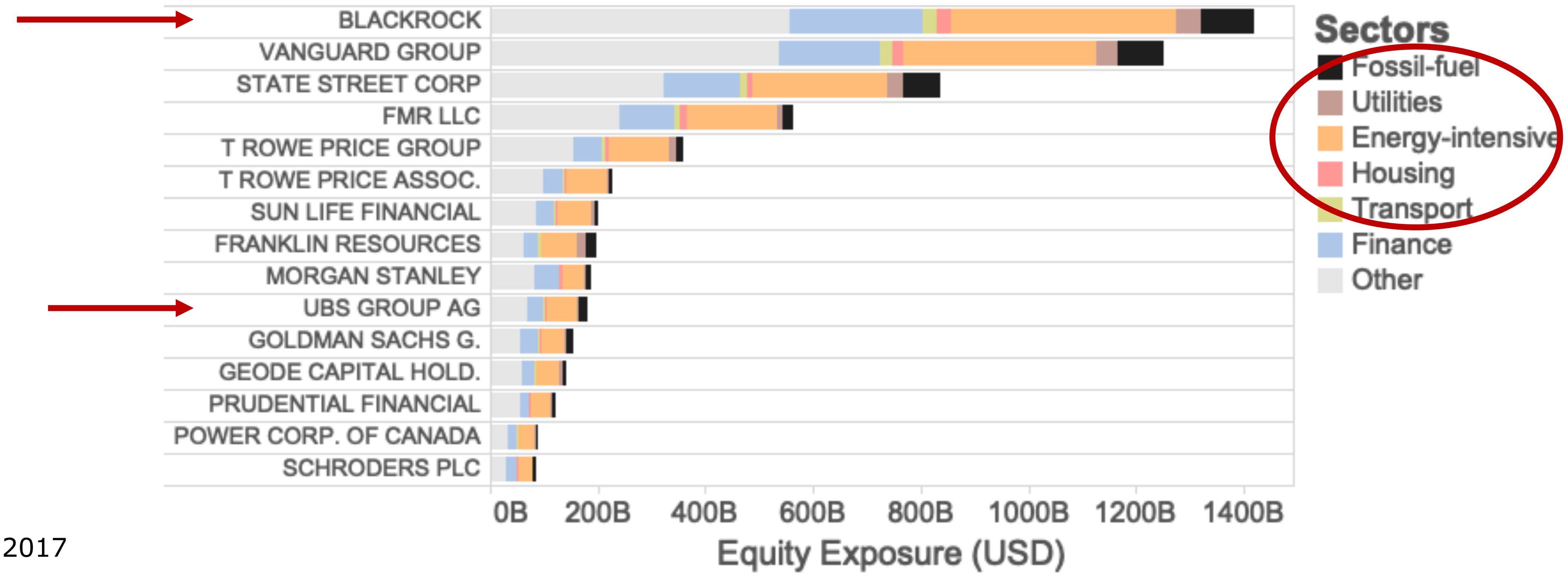


Battiston, S., Mandel, Antoine, Monasterolo, I., Schuetze, F., Visentin, G.: A Climate stress-test of the EU financial system, Nature Climate Change, 7, 283–288 (2017)

Investors are highly exposed to CPRS

WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

- CPRS represent important value of investment funds’ equity holdings of investment funds’ portfolios



Source: Battiston ea. 2017

Example: CPRS exposure of syndicated loans' portfolios of US banks

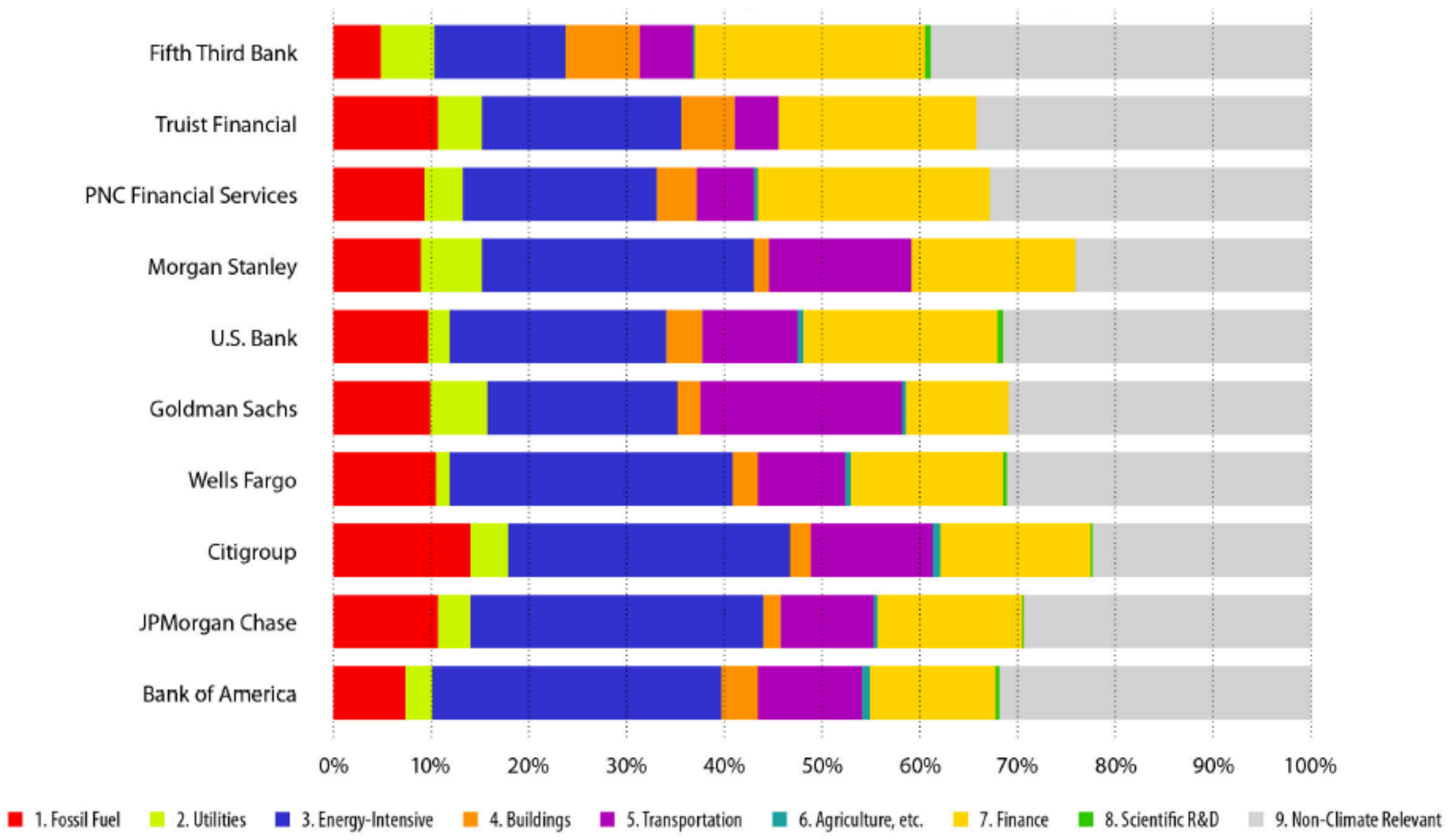
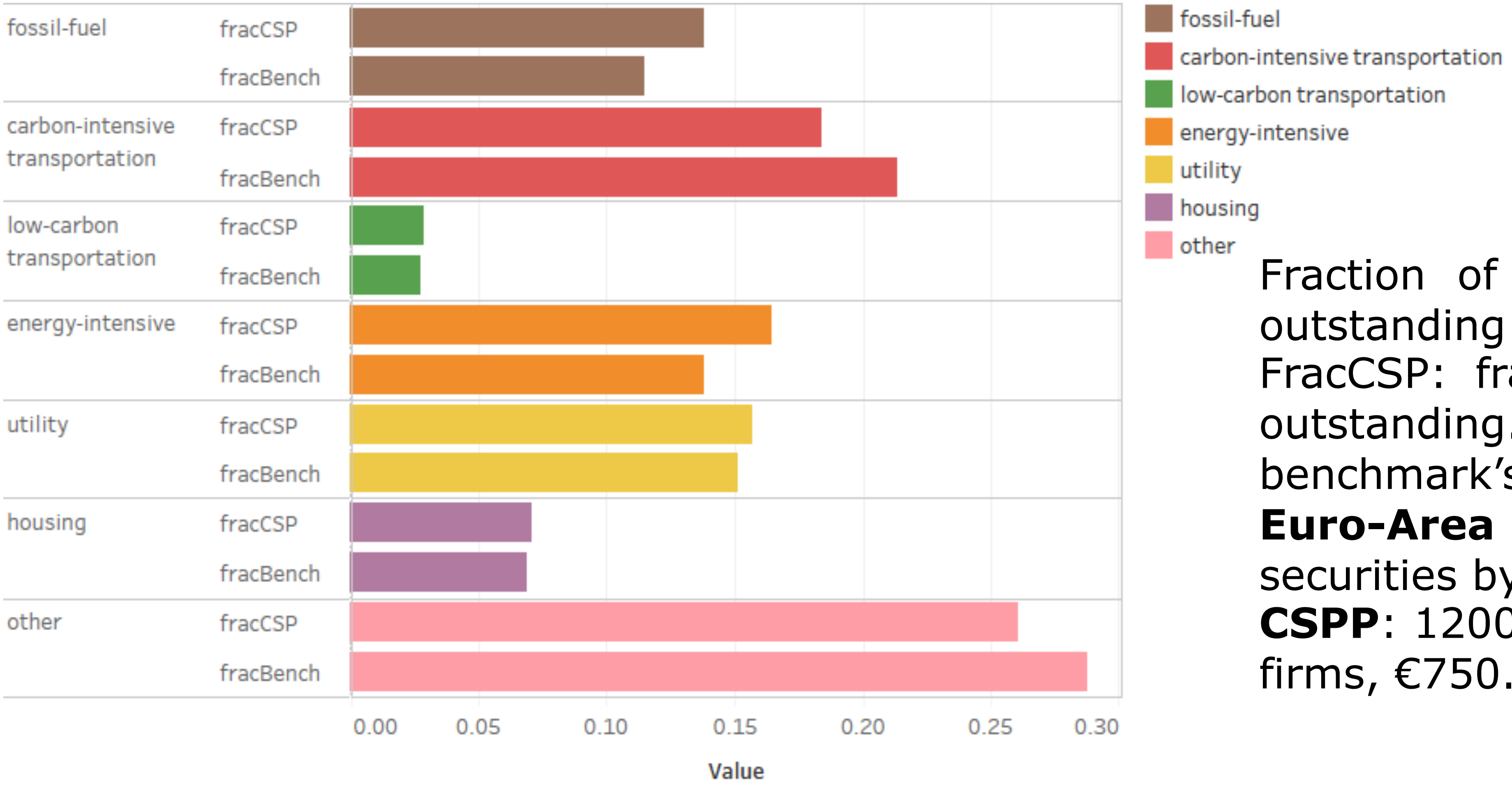


Fig. Percentage composition of portfolio of syndicated loans of major U.S. banks by climate-policy-relevant sector. Source: CERES 2020

ECB's quantitative easing exposure to CPRS



Fraction of bonds on total amount outstanding (e.g. 0.2 equals 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?* https://www.finexus.uzh.ch/en/news/cspp_sustainable_finance.html

CPRS applied by several central banks and financial regulators

- *JRC study of EU Taxonomy financial impact (Alessi ea 2019)*
- ***ECB Financial Stability Review*** *2019, 2020*
- ***EIOPA's Financial Stability Review*** *2019*
- ***EBA Risk assessment*** *of the EU banking system, Dec. 2020*
- ***ESMA*** Draft advice to European Commission under Article 8 of the Taxonomy Regulation (2020)
- ***National Bank of Austria**, Financial Stability Report 2020*

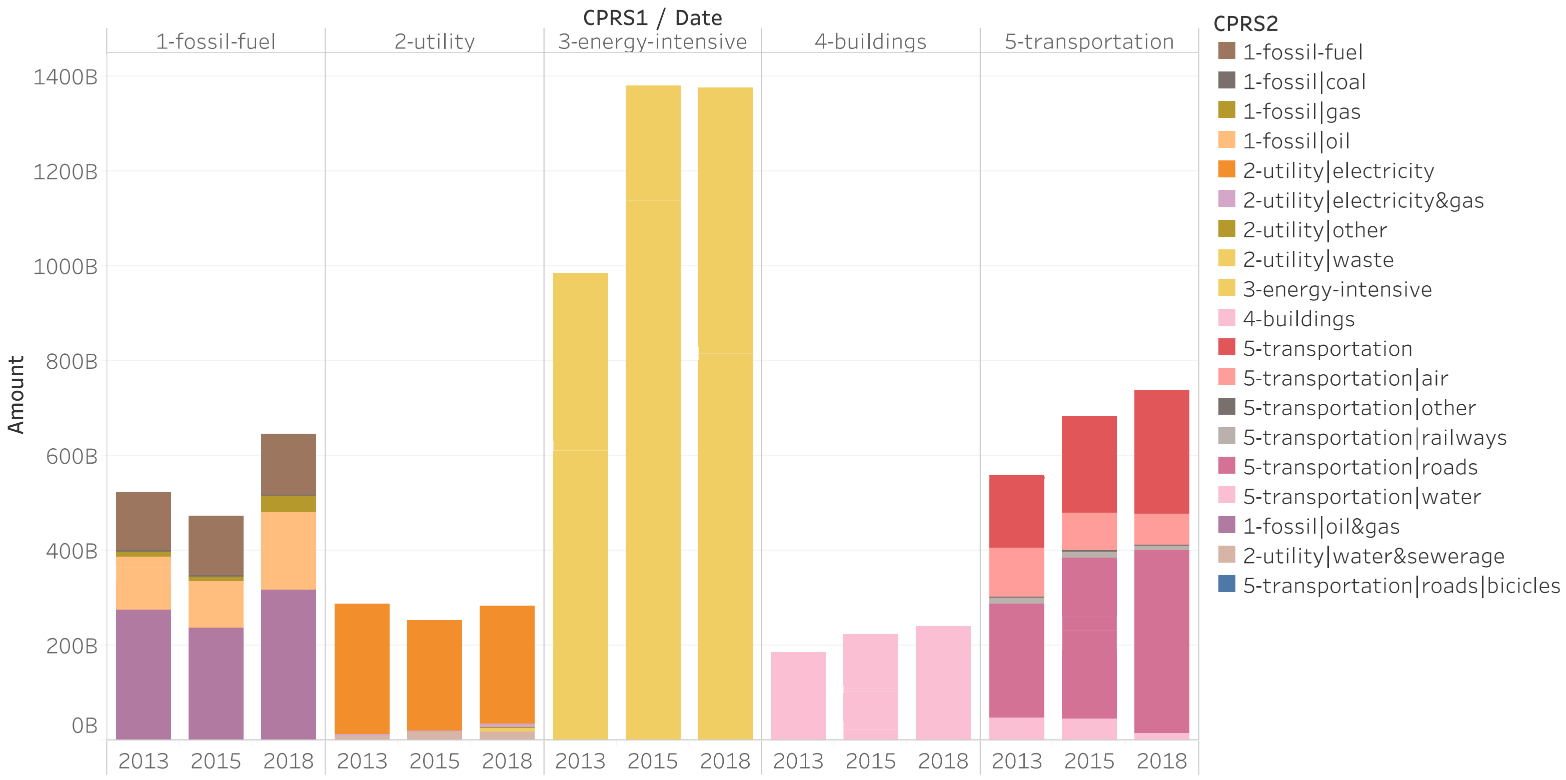


Fig. 2Breakdown by CPRS Main and CPRS 2 for the equity of EU resident issuers in 2018 in billion (B) EUR. Source: Alessi et al. (2019).

Exposures can lead to carbon stranded assets

WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

The term ***stranded assets*** refers to assets the value of which could decrease (i.e. be “stranded”) as a result of either:

- the introduction of climate policies or regulations that discourage the utilization of the fossil fuel in the context of climate change mitigation. If the introduction of such policies is uncertain and investors cannot anticipate them -> disorderly transition
- more frequent/extreme natura hazards (floods, hurricanes, etc) that destroy firms’ capital stock affecting productivity and value of the activities

When it comes to a precise definition, there seem to be different uses of the term in the grey literature (e.g. Leaton et al. 2012):

- oil and gas reserves and infrastructures for drilling
- the latter + financial assets of the firms that own the rights to use those reserves
- the latter + plus other activities related to fossil industry

Conditions for stranded assets to realize

- **2 structural conditions for asset stranding** in economy and finance:
  - Diverting capital assets away from carbon-intensive industries must be *costly or impossible in the short term*,
  - Investors may not price policy/technology shocks in their decisions by divesting (investing in) from contracts issued by high-carbon (low-carbon) firms
- **Economy**: fossil companies hit by an unanticipated drop in demand for their products->their economic performance shrinks-> cascading losses in business value chain->write-offs (Rozenberg et all. 2014)
- **Finance**: economic losses negatively affect financial returns of fossil capital stocks-> drop in market valuation and value of financial contracts -> cascading losses on portfolios of investors that are exposed to these financial contracts.

Rozenberg, J., Vogt-Schilb, A. and Hallegatte, S., 2014. *Transition to clean capital, irreversible investment and stranded assets*. The World Bank.

Limits with the definition of carbon stranded assets

WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

- No standardized definition of carbon stranded assets
- No classification of sectors at risk (no detailed list of NACE codes)
- only negative connotation (shadows green opportunities-> low market signaling/high moral hazard)
- *Thus it is difficult to compare estimates of stranded assets across models, countries or investors.*
- To overcome this limitation, we developed the Climate Policy Relevant Sectors (CPRS, Battiston et al. 2017) are identified based on general criteria, cover activities affected both in terms of risk and opportunities, it is based on a publicly available list of NACE codes.

Monasterolo (2020). Embedding Finance in the Macroeconomics of Climate Change: Research Challenges and Opportunities Ahead *CESIFO Forum 04/20*

How material is the risk of stranded asset?

- Depends from the type of transition to low-carbon economy:
  - **Orderly:** introduction of credible and stable policies->investors *can* anticipate the policy and price it (e.g. increase (decrease) exposure to sustainable (unsustainable) assets-> smooth price adjustment and market signaling
  - **Disorderly:** delayed policy introduction (late and sudden wrt targets, eg EU2030)->investors *do not* fully anticipate the policy impact on the economy and finance-> no portfolio alignment to sustainability
  - **Carbon stranded assets can realize** and lead to asset price volatility if large asset classes and systemic investors involved (Monasterolo et al. 2017)
    - Policies to mitigate it: carbon tax reinvestment for reconversion of some carbon intensive firms; bail out of fossil firms?
    - In reality, most fossil firms are buying renewable plants and buy insurance to hedge against risk (Exxon)

Do we have the right data?

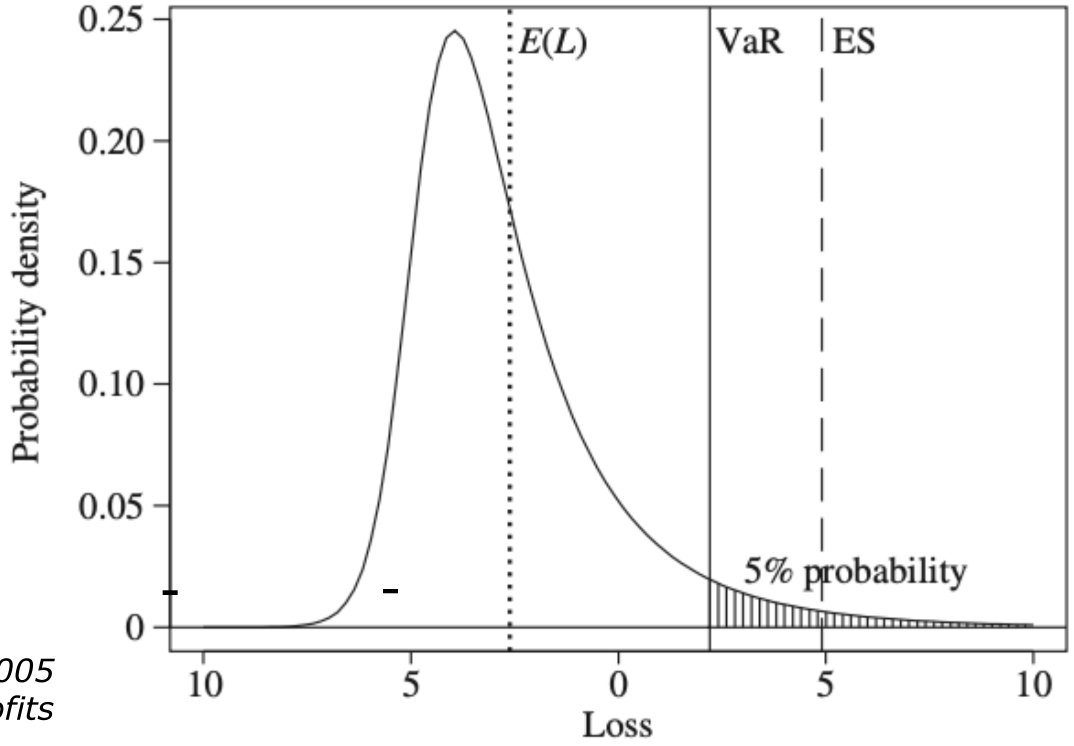
- Currently available data are sufficient to carry out a rough estimate of climate risk of financial institutions. **However, knowledge gaps:**
- **Non financial information:**
  - Firm revenues from energy technology (fossil/renewable) across business lines
  - Science-based classification of stranded assets to complement EU taxonomy
- **Financial information**:
  - Data on holdings classified by their climate risk (physical, transition) and counterparty
- **Are we looking at the right variables?**
  - Transition risk: see above
  - **Physical risk**: beyond emissions and geo-referenced location of activities, **downscaled (local) assessment of disasters' losses by sector needed.**

How much risk?
Climate-financial risk assessment

Financial risk

- Notion of risk in Basel III. Basel Committee on Banking Supervision. Revised standards for minimum capital requirements https://www.bis.org/bcbs/publ/d352.pdf (Jan 2016, include:
  - A shift from **Value-at-Risk (VaR)** to an **Expected Shortfall (ES)** measure of risk under stress. Use of ES will help to ensure a more prudent capture of "tail risk" and capital adequacy during periods of significant financial market stress.

- Value-at-risk at confidence level c (e.g. 0.95 = 95%) is the 1-c (e.g. 5%) percentile of the Profits and Losses distribution of the portfolio
- Expected shortfall at q% level is the expected return on the portfolio in the worst q% of the cases (hence also called ''conditional value at risk'' because conditioned to returns lower than worst q%)



Source: Mc Neils et al. 2005
NOTE: negative values of loss L represent profits

From climate valuation adjustment to climate stress test

WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

- In 2017, **Climate Stress-test** embedded for the first time IAMs' forward-looking climate scenarios in a stress test of individual portfolios and the financial system:

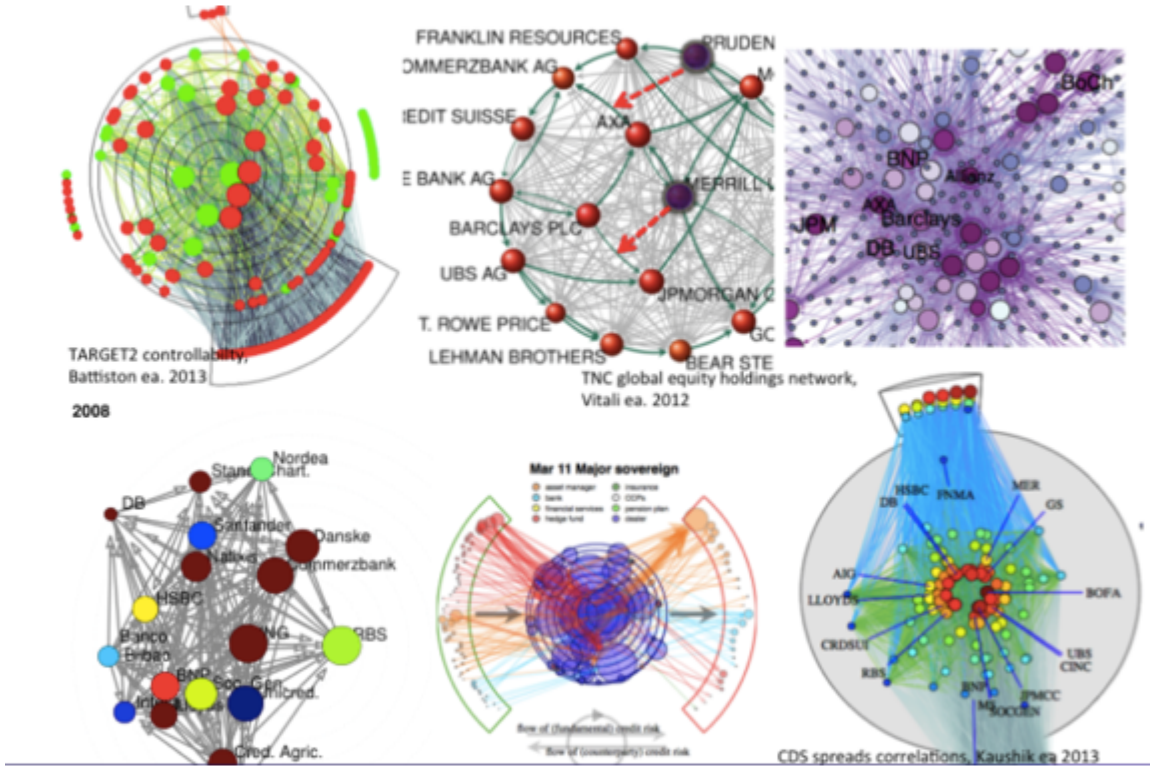
    1. Shocks are obtained from differences in sectors' output between IAMs' trajectories (*BAU* and *P*) by energy technology, region, time, or within trajectories
    2. **Asset price and risk adjustment** of individual financial contracts/securities: scenario-adjusted Probability of Default (PD)
    3. **Climate financial risk analytics** for investors' portfolios, i.e. the Climate Value at Risk, Expected Shortfall, Climate Spread (for bonds), conditional to the scenarios.
    4. **Assessment of the largest losses** for individual portfolios, considering risk amplification driven by financial interconnectedness (2nd, 3rd round, etc) and implications on systemic financial risks.

Battiston et al. (2017). A Climate stress-test of the EU financial system. Nature Climate Change, 7, 283–288.

Why do we need Financial Network Models?

WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

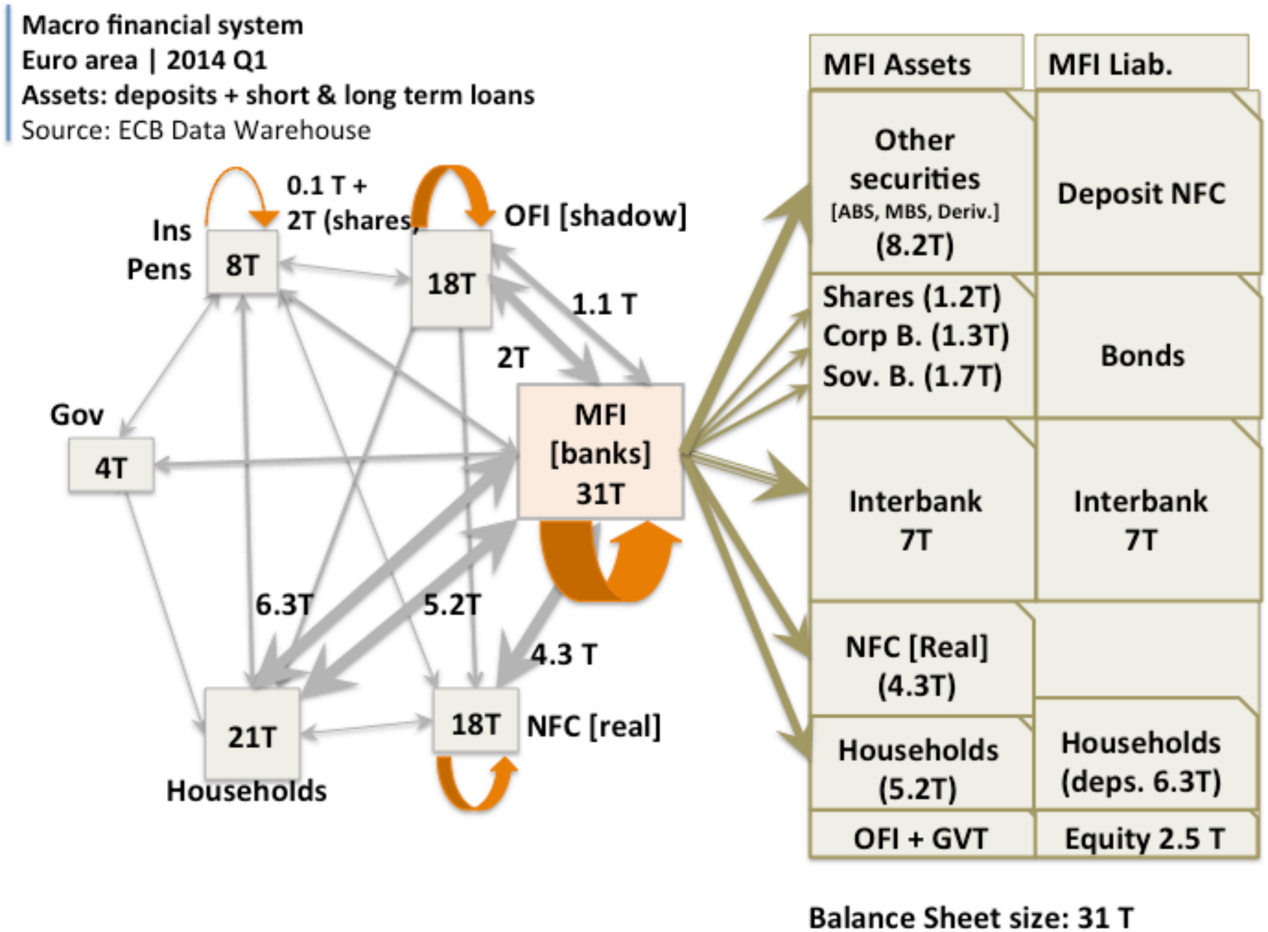
- Because important unintended effects and **externalities** can only be captured by network approach
- Financial networks allow to assess **risk propagation** through chains of financial contracts, analysing:
  - **Exposure** to risk
  - **Impact** of on social and climate objectives
  - **Transfer** of income/wealth -> cascading effects



Battiston ea (2016). The price of complexity, *PNAS*

Indirect exposures matter

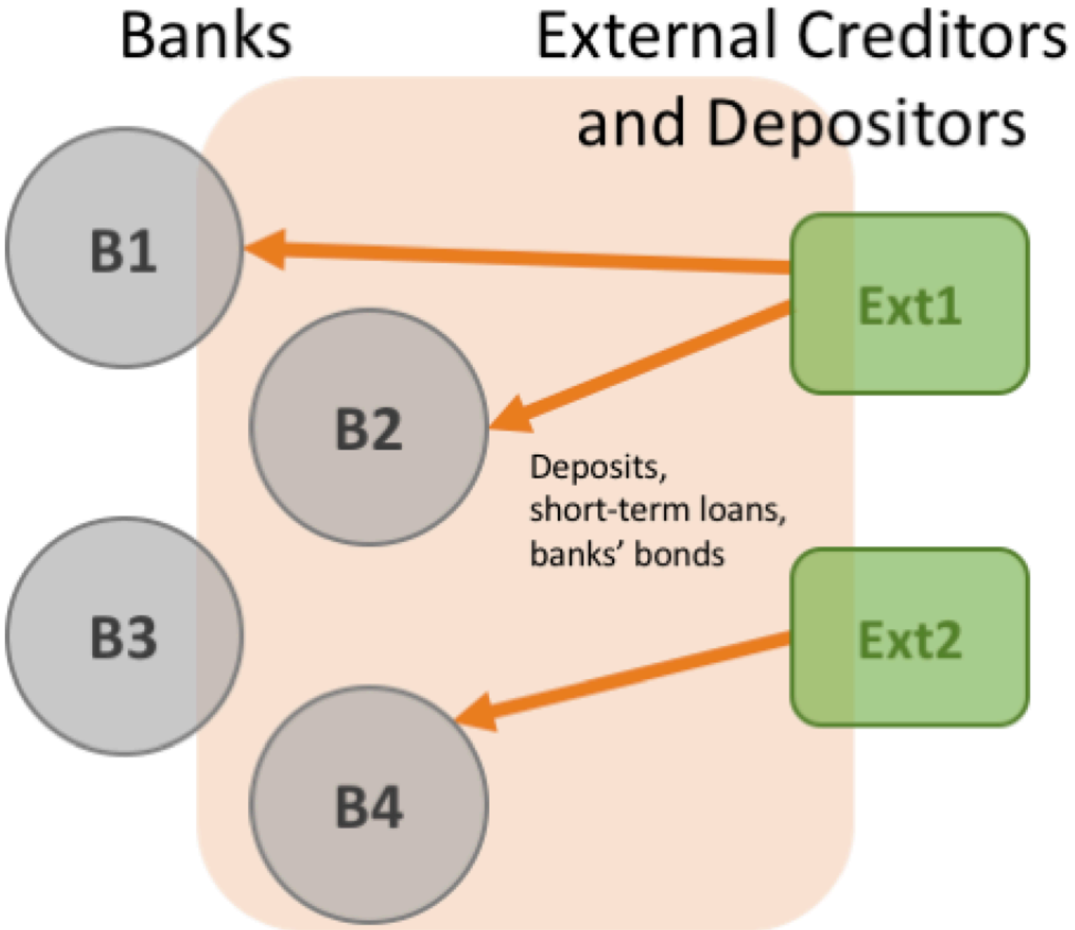
- Large portion of total assets held by financial institutions **are issued by other financial institutions** (40% for banks in Euro Area)
- 25% of total market capitalization is invested in equity issued by companies in the financial sectors
- 40% of the bond market is represented by outstanding obligations issued by financial institutions
- Thus, systemic risk can materialize through second-round effects



Battiston ea (2016). The price of complexity, *PNAS*

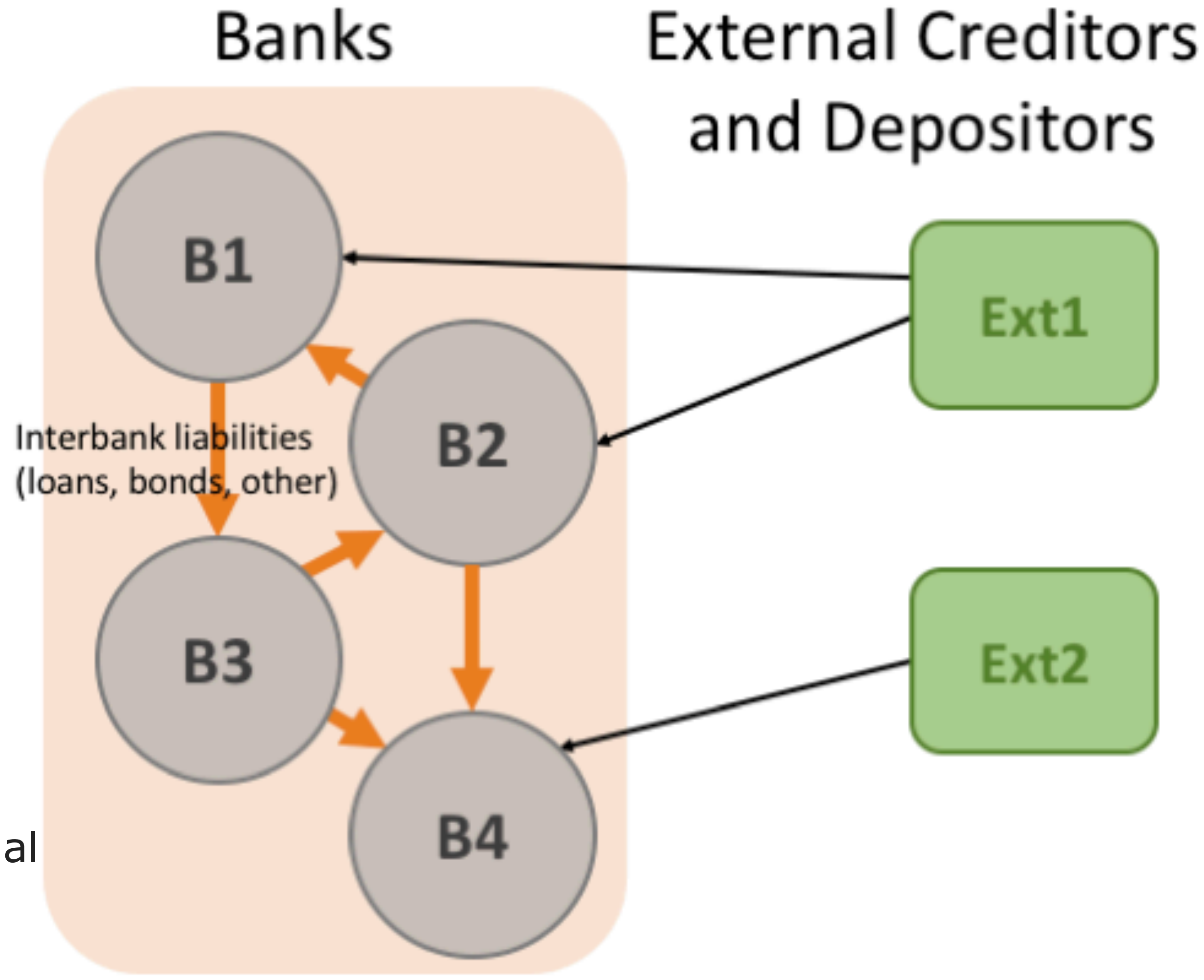
Illustration of climate distress propagation

WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS



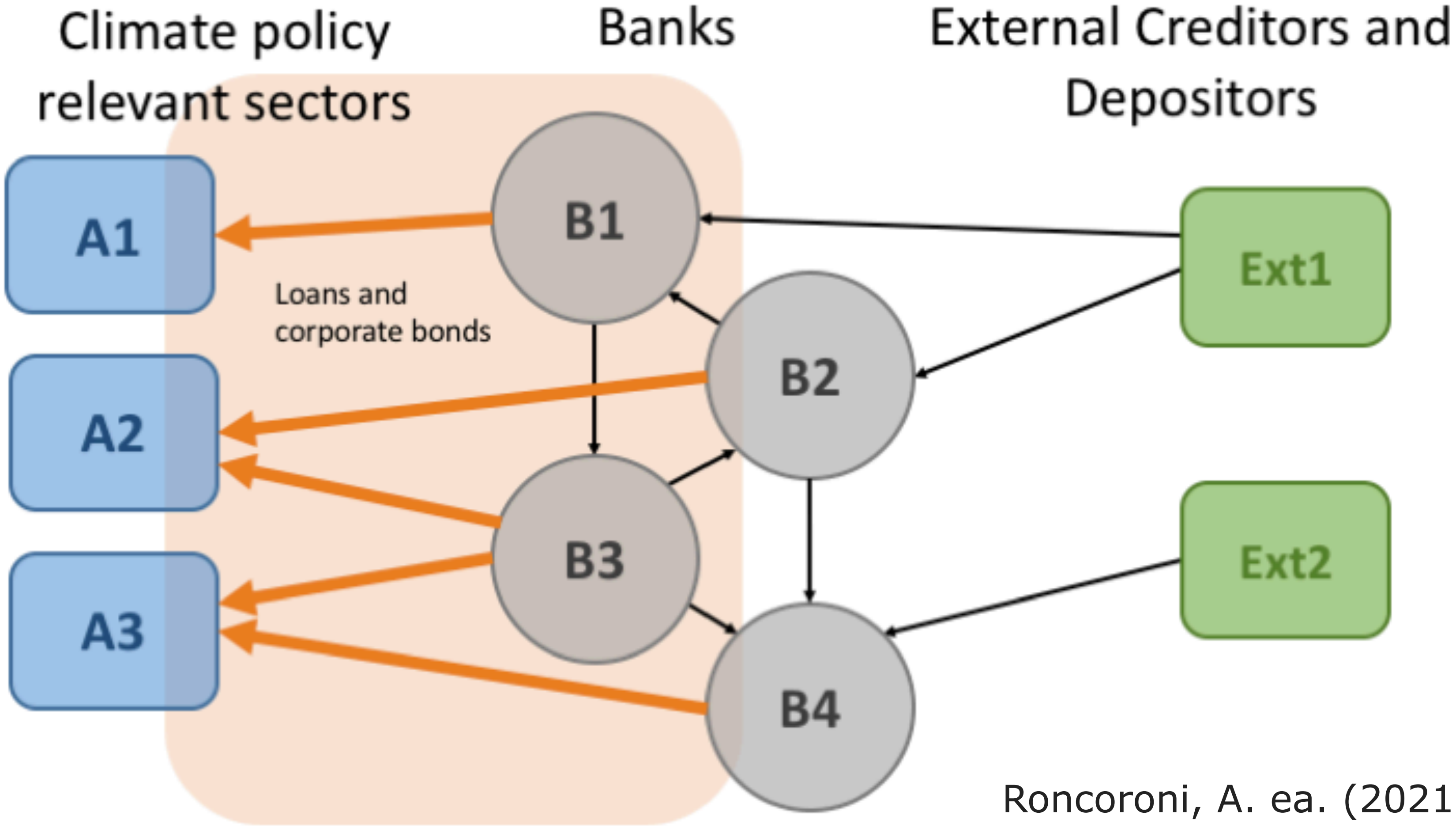
Roncoroni, A. ea. (2021). Climate risk and financial stability in the network of banks and investment funds. *Journal of Financial Stability*, *54*, 100870.

Illustration of climate distress propagation



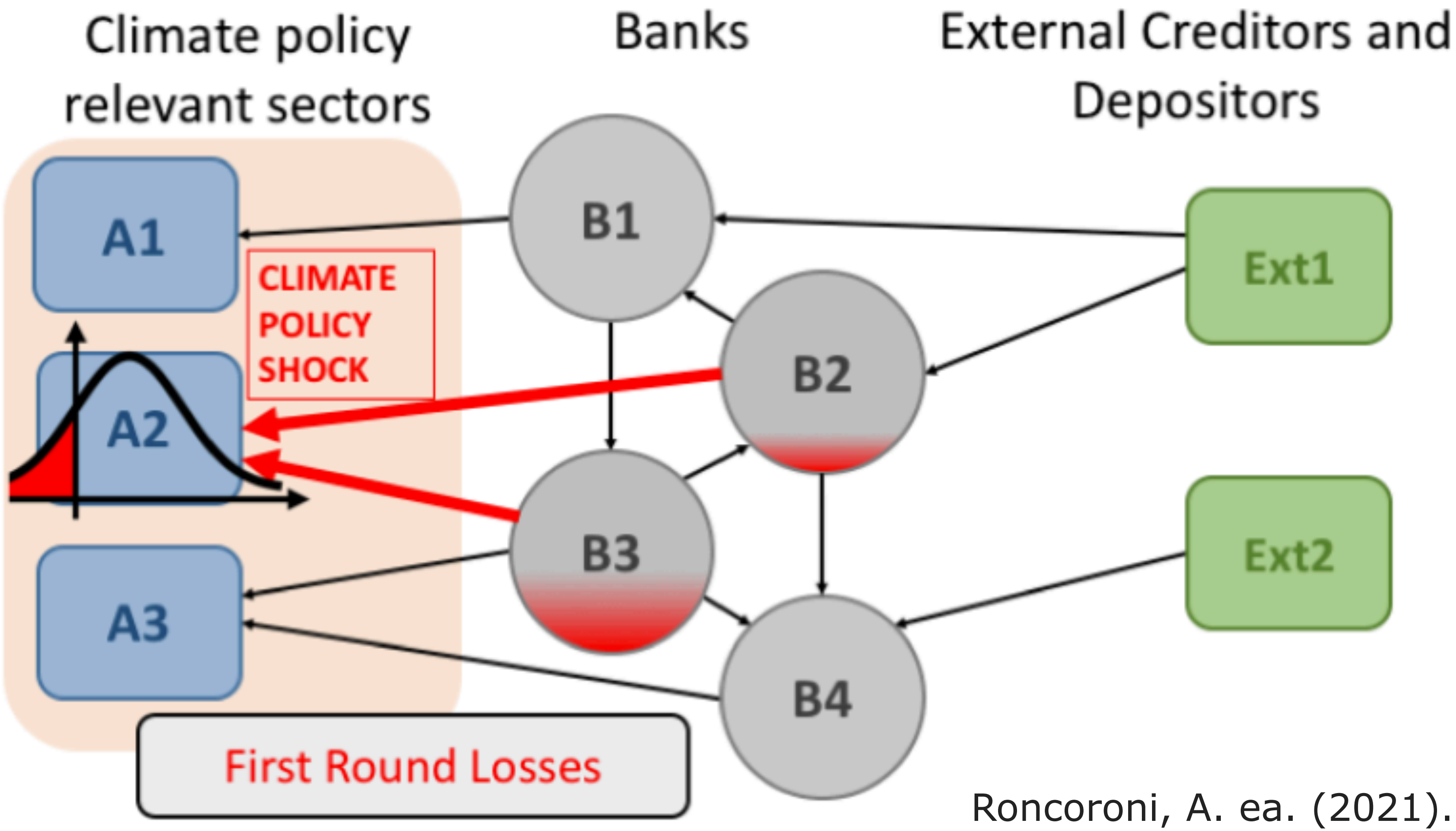
Roncoroni, A. ea. (2021). Climate risk and financial stability in the network of banks and investment funds. *Journal of Financial Stability*, *54*, 100870.

Illustration of climate distress propagation



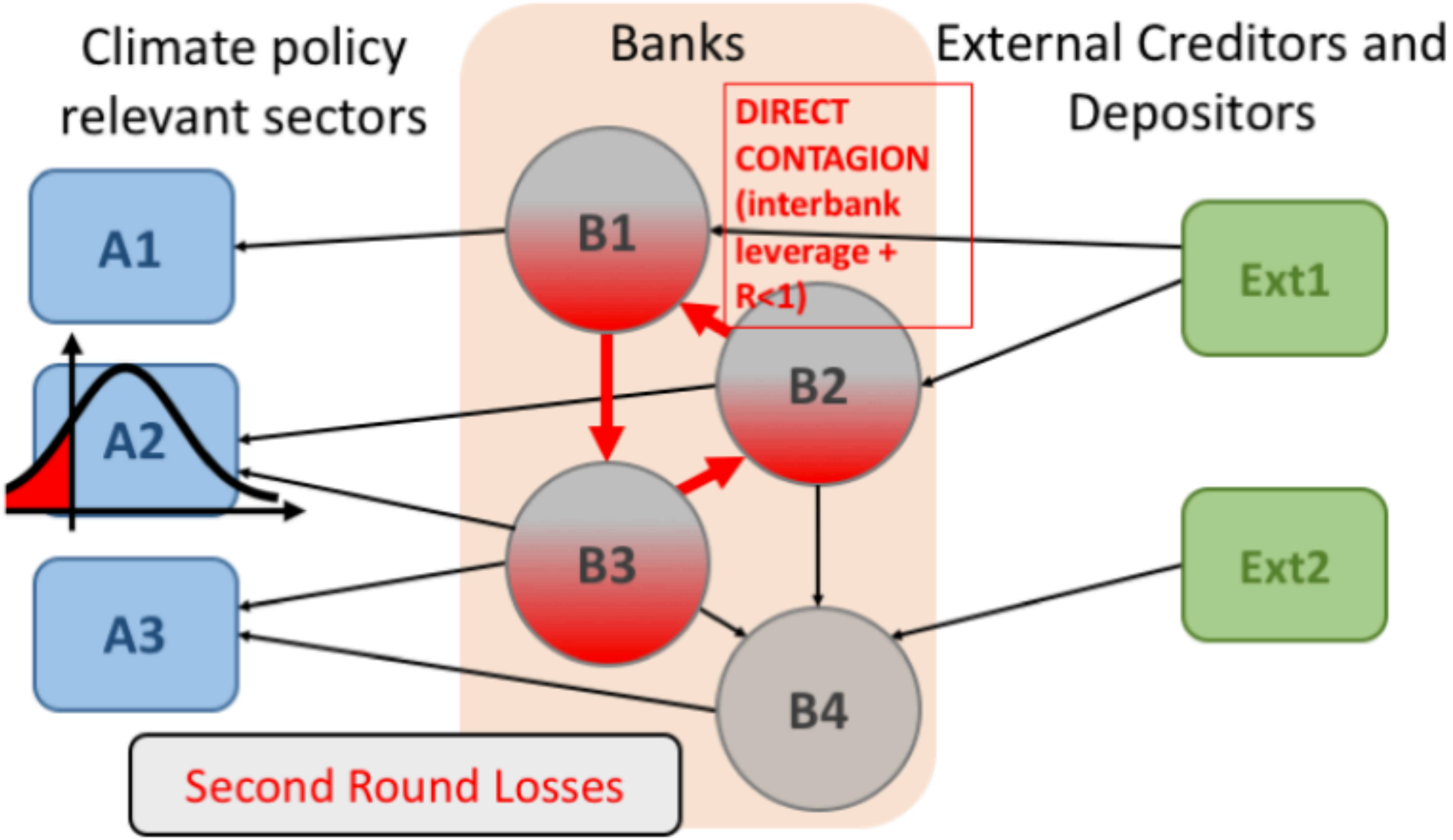
Roncoroni, A. ea. (2021). Climate risk and financial stability in the network of banks and investment funds. *Journal of Financial Stability*, *54*, 100870.

Illustration of climate distress propagation



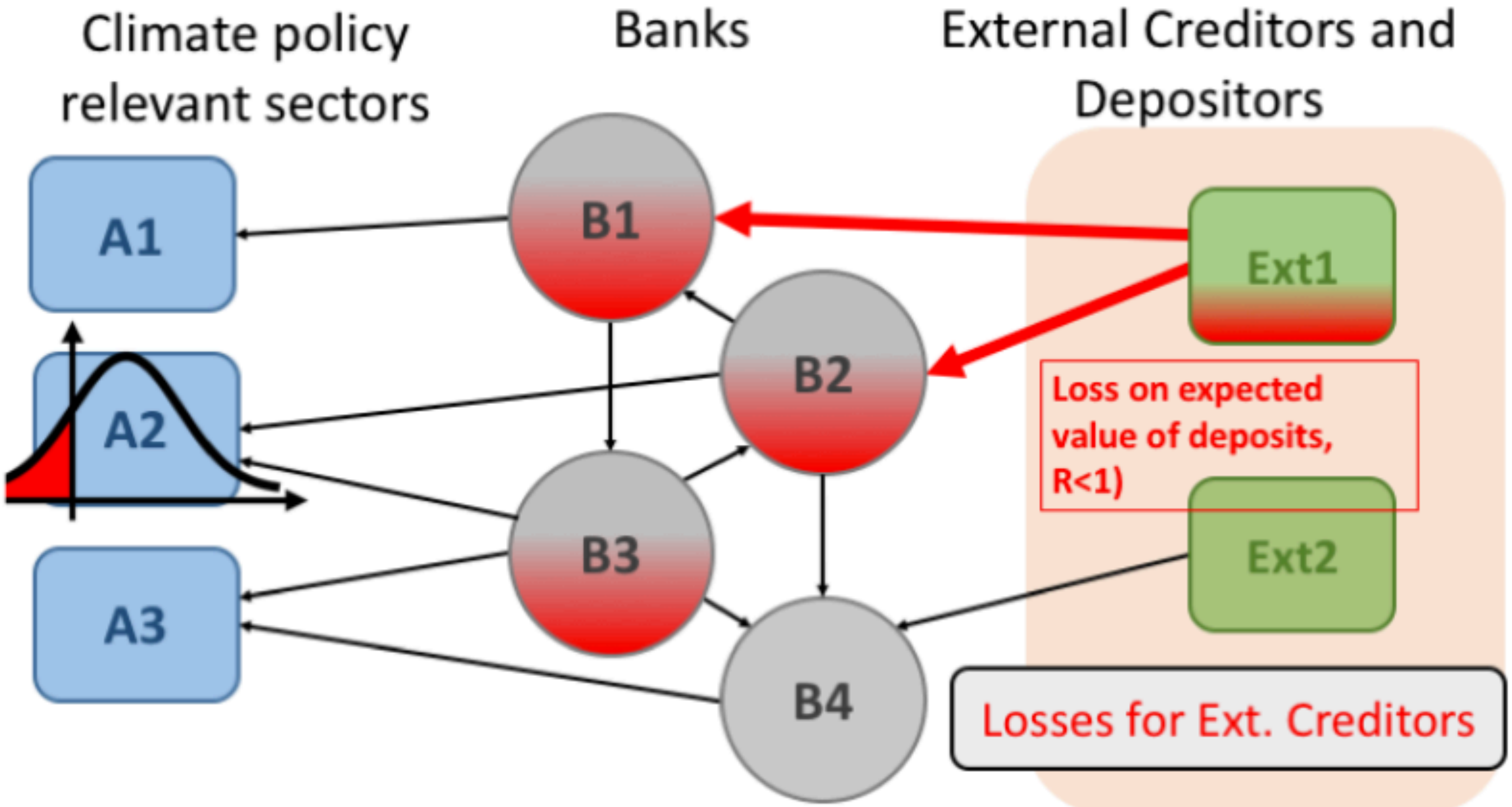
Roncoroni, A. ea. (2021). Climate risk and financial stability in the network of banks and investment funds. *Journal of Financial Stability*, *54*, 100870.

Illustration of climate distress propagation



Roncoroni, A. ea. (2021). Climate risk and financial stability in the network of banks and investment funds. *Journal of Financial Stability*, *54*, 100870.

Illustration of climate distress propagation



Roncoroni, A. ea. (2021). *Journal of Financial Stability*, *54*, 100870.

Climate stress test of the financial system

- **Large exposures and (high/low-carbon) investment strategy can drive systemic risk**

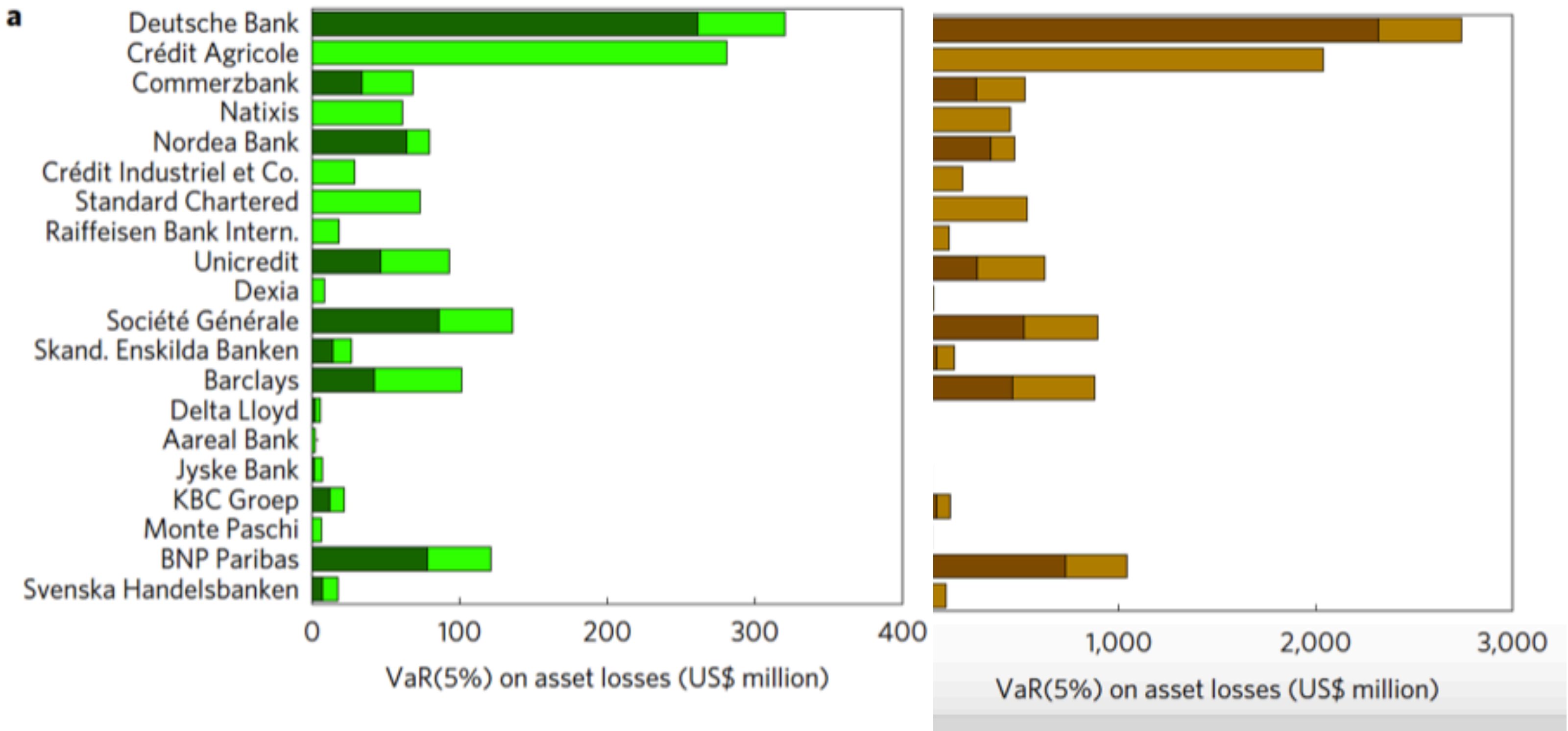


Fig. ***Value at Risk*** *(5% significance) on equity holdings of* ***20 most affected EU banks*** *under scenario of low/high carbon investment strategy. Dark/light colors: first/second round losses. Source: Battiston ea (2017)*

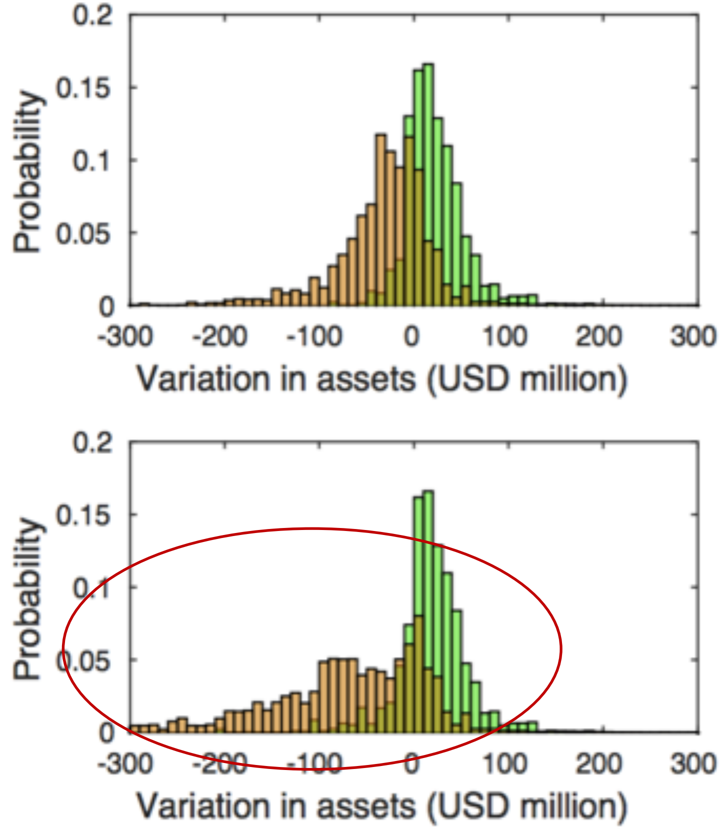


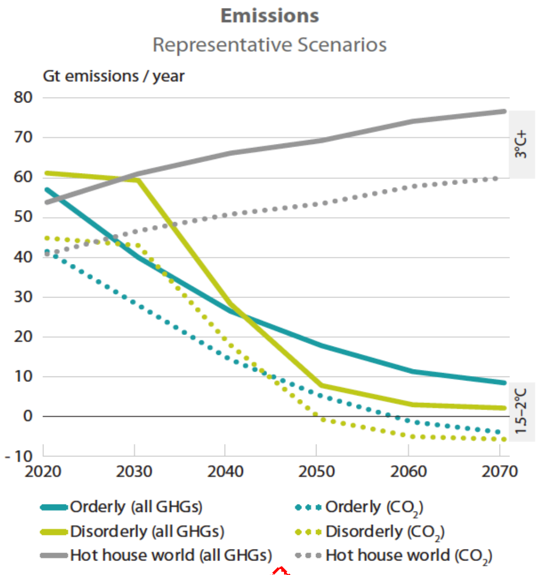
Fig.: 1st round (top). **2nd round** (bottom) polarizes distribution of losses.

Limits of mitigation scenarios

- **NGFS climate mitigation scenarios** are reference tool among investors to assess risk (NGFS 2019, 2020, 2021; UNEP 2020): provide financial system with relevant information to assess risk.
- **Scenarios can shift market expectations**. But scenario do not account for financial actors' looking at the scenarios and impacting on the scenarios:
- Macro-financial feedback loop is missing: **expectations ←→ scenarios**

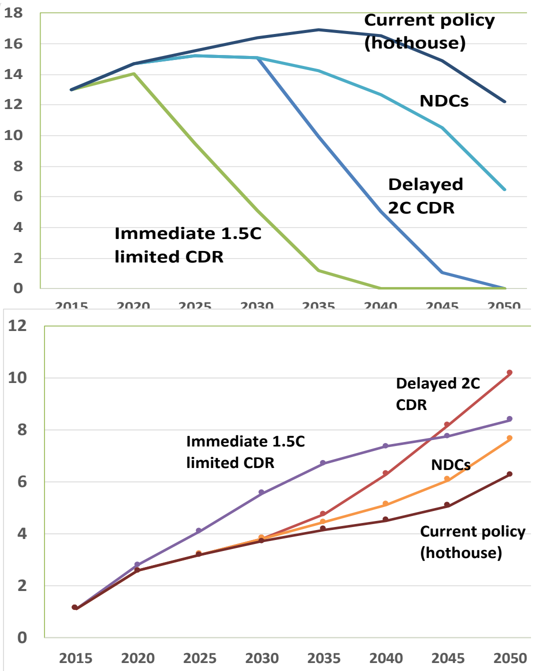
Macro-financial feedback loop is missing

Climate scenarios (NGFS)



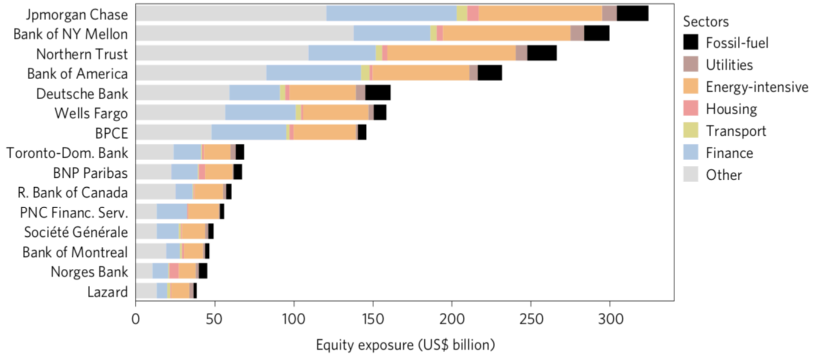
Missing!

Expectations: shocks on output



Electricity Coal (top) vs Wind (bottom) across NGFS scenarios, China, 2020-2050

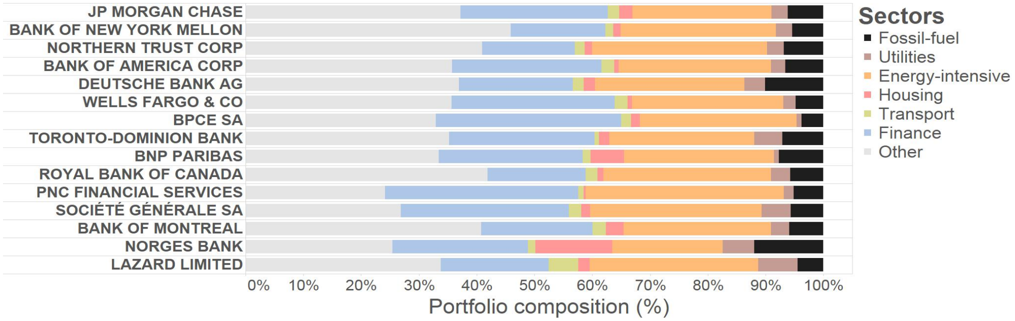
Climate risk exposures *(disclosure)*



Battiston ea (2017)

Climate adjusted asset *valuation*

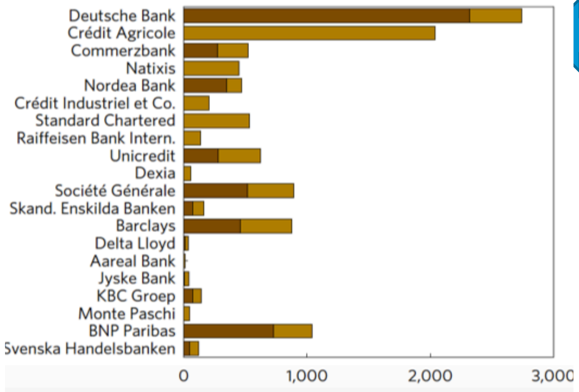
New investments and capital



Missing!

Battiston ea (2017)

Climate stress test



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

Battiston and Monasterolo (2020)

Why does this matter?

- Why does this matter? For financial instability: missing feedback loop expectations – scenarios can lead to underinvestments wrt to climate targets and disorderly transition (transition risk) or missing the transition (physical and/or transition risk)

Example: Consider a utility firm that seeks financing to shift its power plants from high to low-carbon technologies.

- If the bank perceives the strategy as **less risky** than status quo (high carbon), because climate policy (e.g. carbon price) is perceived as **credible**, it will charge a lower interest rate on the loan, thus facilitating the firm's technological conversion.
- If the bank perceives the strategy as **more risky** than status quo (high carbon), because climate policy is perceived as **non credible**, it will charge a higher interest rate on the loan, thus delaying the firm's technological conversion.

Battiston S. ea. (2021). Accounting for finance is key for climate mitigation pathways. *Science*, *372*(6545), 918-920.

Enabling or hampering?

Hampering role:

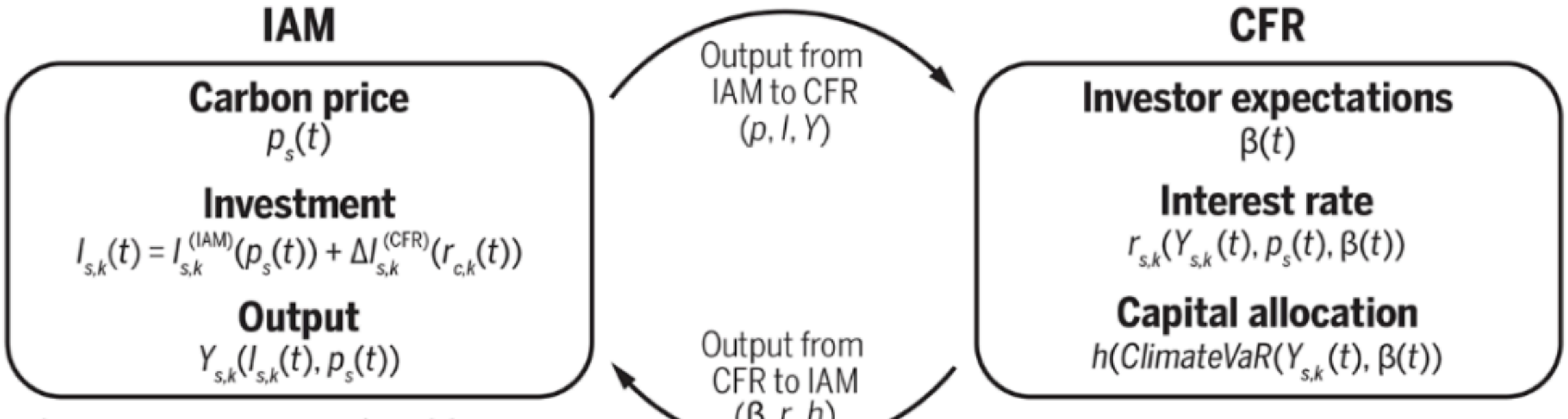
- If investors interpret NGFS orderly transition as scenario where:
  - high-carbon firms only slightly more risky than low-carbon (firms adjust tech mix and spread stranded assets over time)
- Limited reallocation of capital could be insufficient to fund investments assumed in scenario
- Transition more costly for society, because it can lead to abrupt reallocations of capital and price adjustments.

The enabling or hampering roles of the financial system can explain how the **orderly** and **disorderly** transition in NGFS scenarios emerge endogenously from the interplay of policy timing and investors' reactions.

Battiston S. ea. (2021). Accounting for finance is key for climate mitigation pathways. *Science*, *372*(6545), 918-920.

IAM-CFR framework

- We develop a new IAM-CFR framework to link Integrated Assessment Models (**IAM**) and Climate Financial Risk model (**CFR**) in a circular way, applicable to various IAMs and CFR.
- It captures interaction **expectations – scenarios** and generate new scenarios that can be more coherent with investment needs and can support financial stability objective.

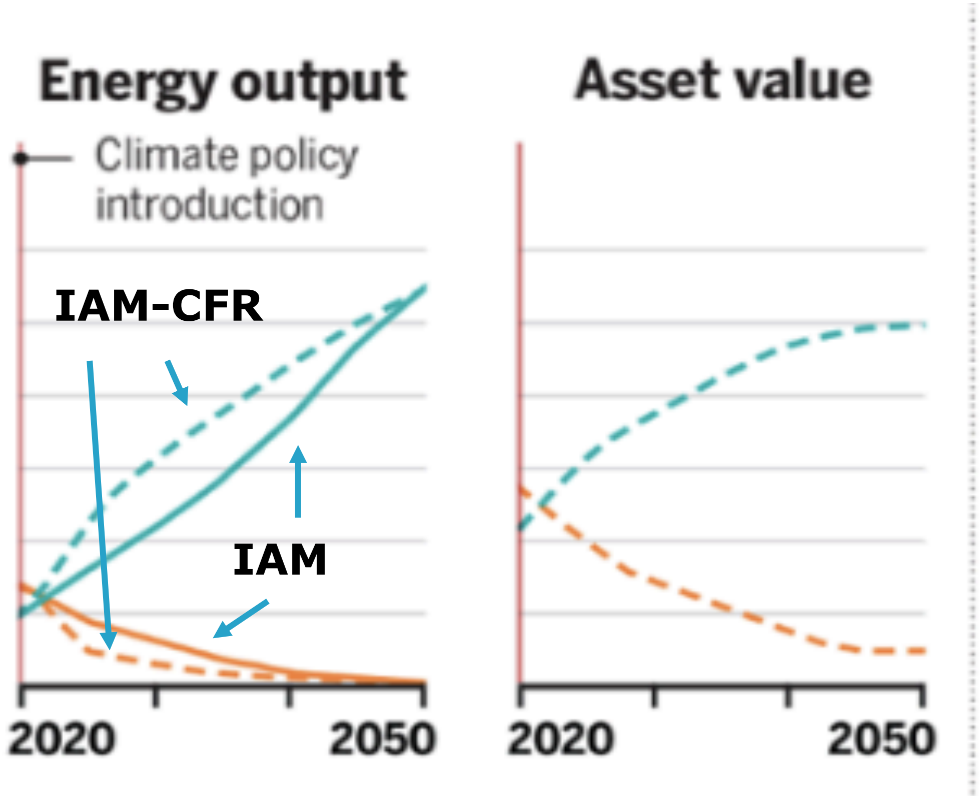


t, time; *c*, country; *s*, economic activity.

- Set of IAM climate mitigation scenarios →
- → CFR models financial risk of high/low-carbon firms along scenarios.
- → Interest rate fed back to the IAMs to compute new scenarios
- Repeat

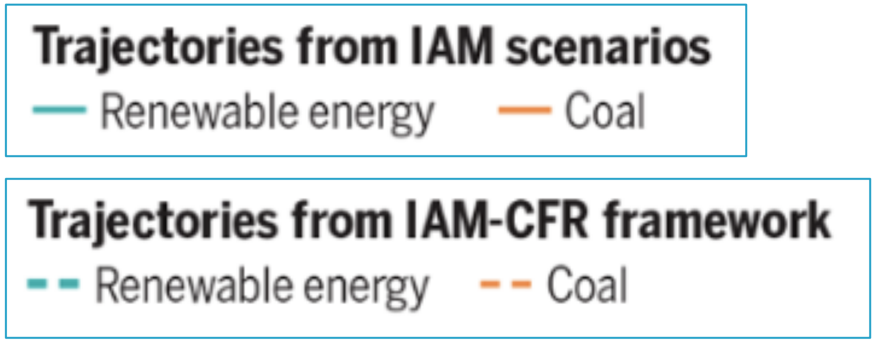
IAM-CFR framework

IAM-CFR allows to generate new trajectories that account for investors' expectations from the scenarios.



How to read the plot:

- Solid curves (same top and bottom): common stylized behavior of output across IAM
- Dashed curves: IAM-CFR trajectories for output and asset valuation



Source: Battiston ea. 2021 Science

Key messages for climate-related financial risk assessment

- **Investors' ability to withstand climate risks** depends on i) exposures, ii) climate scenarios, iii) financial risk characteristics
- **Lesson 1 - disclosure of exposures**:
  - Standardized, compulsory disclosure at fin./non fin. level
  - Science-based taxonomies (also for stranded assets, e.g. CPRS)
  - Consider forward-looking risk (beyond emissions)
- **Lesson 2 - risk assessment**:
  - Understand characteristics and limits of climate scenarios
  - Introduce finance and its expectations in climate scenarios
- **Lesson 3 - financial risk matters**:
  - Financial interconnectedness and network effects matters to avoid to underestimate risk.

References

Battiston S. ea. (2021). Accounting for finance is key for climate mitigation pathways. *Science*, *372*(6545), 918-920.

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.

Battiston, S., Caldarelli, G., May, R. M., Roukny, T., Stiglitz, J. E. (2016). The price of complexity in financial networks. *Proceedings of the National Academy of Sciences*, 113(36), 10031-10036.

Battiston, S., Puliga, M., Kaushik, R., Tasca, P., & Caldarelli, G. (2012). Debtrank: Too central to fail? financial networks, the fed and systemic risk. *Scientific reports*, 2(1), 1-6

Dunz, N., Naqvi, A., & Monasterolo, I. (2021). Climate sentiments, transition risk, and financial stability in a stock-flow consistent model. *Journal of Financial Stability*, *54*, 100872.

Monasterolo, I. (2020). Embedding Finance in the Macroeconomics of Climate Change: Research Challenges and Opportunities Ahead. In *CESifo Forum* (Vol. 21, No. 4)

Monasterolo, I. (2020). Climate change and the financial system. *Annual Review of Resource Economics*, *12*, 299-320.

Roncoroni, A. ea. (2021). Climate risk and financial stability in the network of banks and investment funds. *Journal of Financial Stability*, *54*, 100870.