Climate scenarios, transition risk and climate stress-tests for financial institutions

Prof. Stefano Battiston, Ca' Foscari Univ. of Venice, Univ. of Zurich

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Outline

1. Climate investment gap and transition risk in IPCC AR6
2. Climate economics scenarios
3. From scenarios to financial valuation: climate stress tests
4. The (missing) endogeneity of climate scenarios

Climate risk: a stream of works (selected)

Climate stress-test

Transition risk

- Climate stress-test of the financial system, Battiston ea. 2017 Nat Clim Ch.
- Connecting IAM with financial risk measures (VaR)
- Classification of economic activities CPRS)
- Application to Mexican financial system including banks and funds, Roncoroni ea. 2021 J. Fin. Stab.

Physical risk

- Asset-level climate physical risk assessment and cascading financial losses, Bressan ea. 2022 ssrn 4062275

Scenarios

- Scenarios and impact of climate transition risk on **risk measures**, Battiston & Monasterolo 2020 SSRN 3743647
- **Endogeneity** of climate scenarios *Battiston ea. 2021 Science*

Policy applications:

- *Banque de France Financial Stability Report*
- *EIOPA Financial Stability Report 2020*
- *National Bank of Austria, Financial Stability Report 2020*
- *NGFS Case Studies of Environmental Risk Analysis Methodologies*

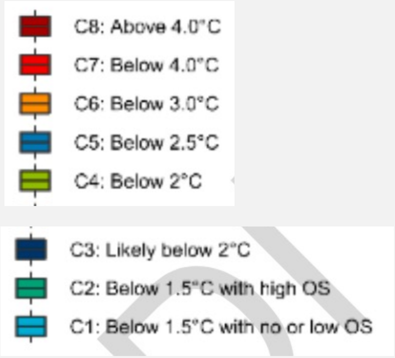
Climate investment gap

Mitigation implies a transformation across sectors

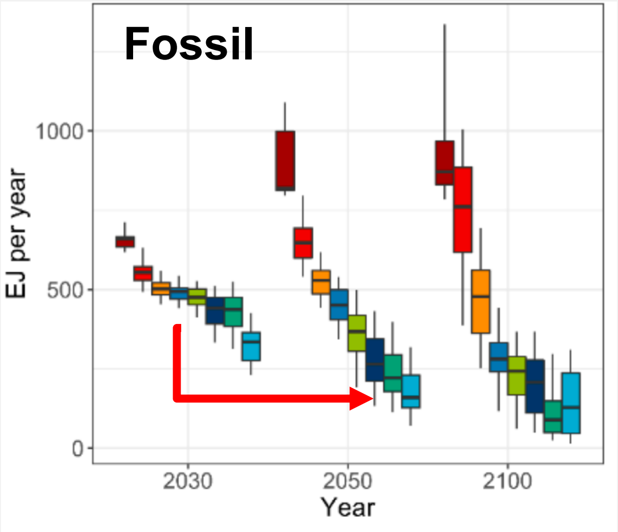
Decarbonization implies large changes across sectors: primary energy, electricity, transport, buildings and agriculture.

IPCC AR6 WGIII Ch.3 provides estimates to compare scenarios: Current policies scenarios vs transition scenarios.

Legend: categories of scenarios

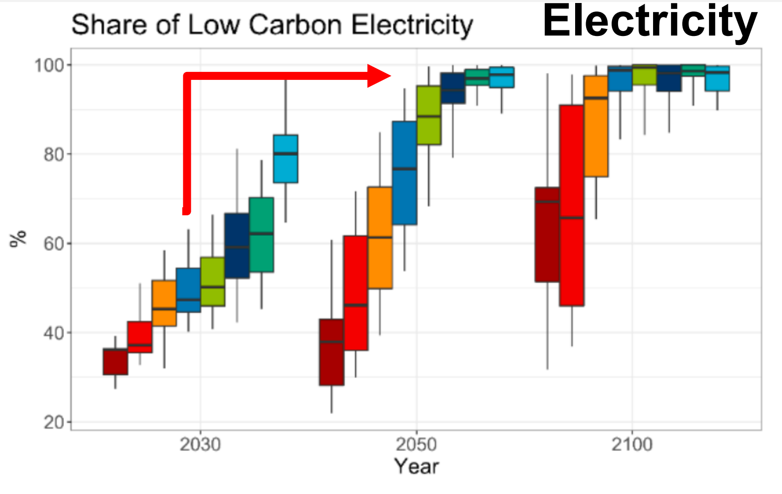


Fossil: example C5 → C1 implies decrease in output by ~ 60% by 2050



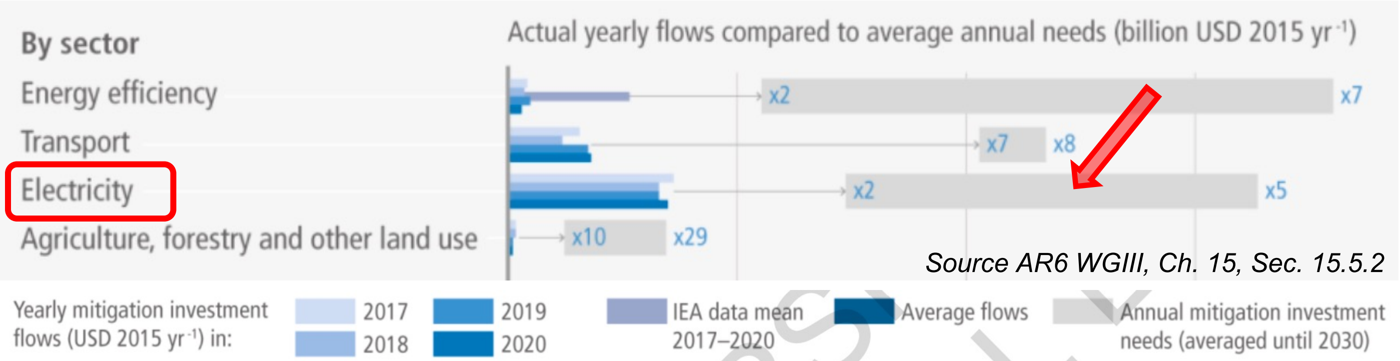
Source: IPCC AR6 WGIII Ch.3 Sec.3.

Electricity: growth + change in composition. Example C5 → C1 implies change in % low-carbon electricity ~30% → 95%.



Source: IPCC AR6 WGIII Ch.3 Sec.3.

Investment gaps despite available capital

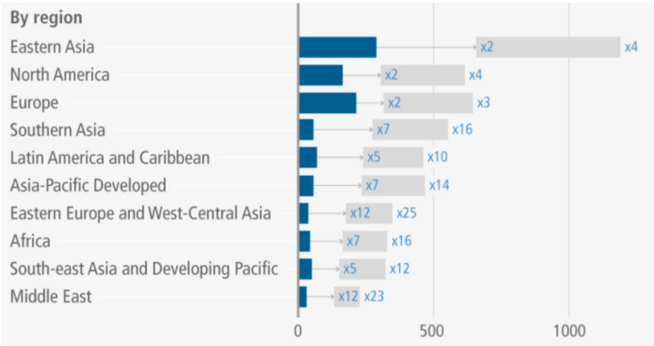


Source AR6 WGIII, Ch. 15, Sec. 15.5.2

Example: annual average total investments in global fuel supply and power sector:

- In 2019: ~ 1.6 t USD/y (IEA 2020)
- In 2030: ~ 1.91 t USD/y under Sustainable Development Scenario

(*) See Ch 15. for details on estimation. Current flows based on reports by CPI, IEA. Estimates of needs based on review of range of IAM model results.



Source AR6 WGIII, Ch. 15, Sec. 15.5.2

Investment needs exceed current flows by 3-6 times overall(*). See e.g. electricity:

variations across sectors and regions.

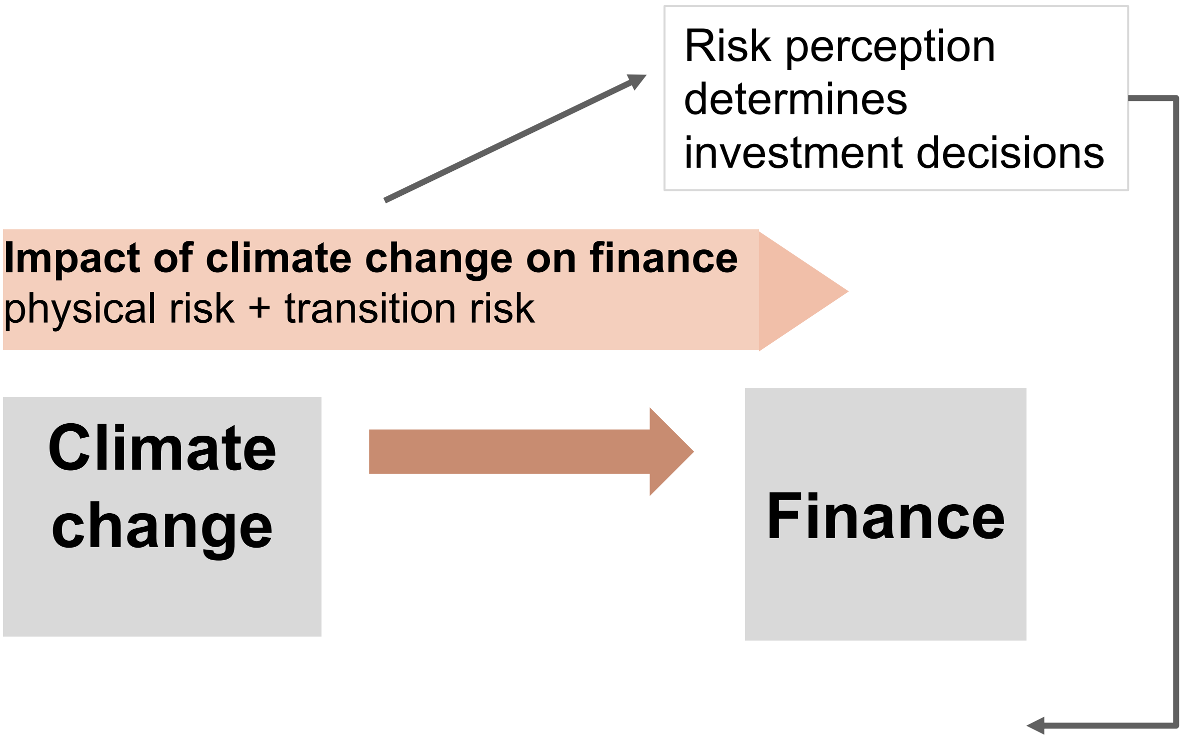
Mostly capital reallocation rather than new investments: global available capital sufficient to reduce/close gap.

So what are the barriers, then?

To understand barriers we have to look at the relation btw climate and finance

Climate and finance: risks and impacts

Direction from climate to finance: risk



Source: author's illustration based on AR6 WGIII Ch.15

Climate-financial risk

Physical risk:

- **Direct:** increased frequency/magnitude of climate-related hazards and chronic impacts → losses on physical assets and human lives
- **Indirect**: reduced food and water security → increased risk of conflicts → decreased value of land and businesses in affected areas

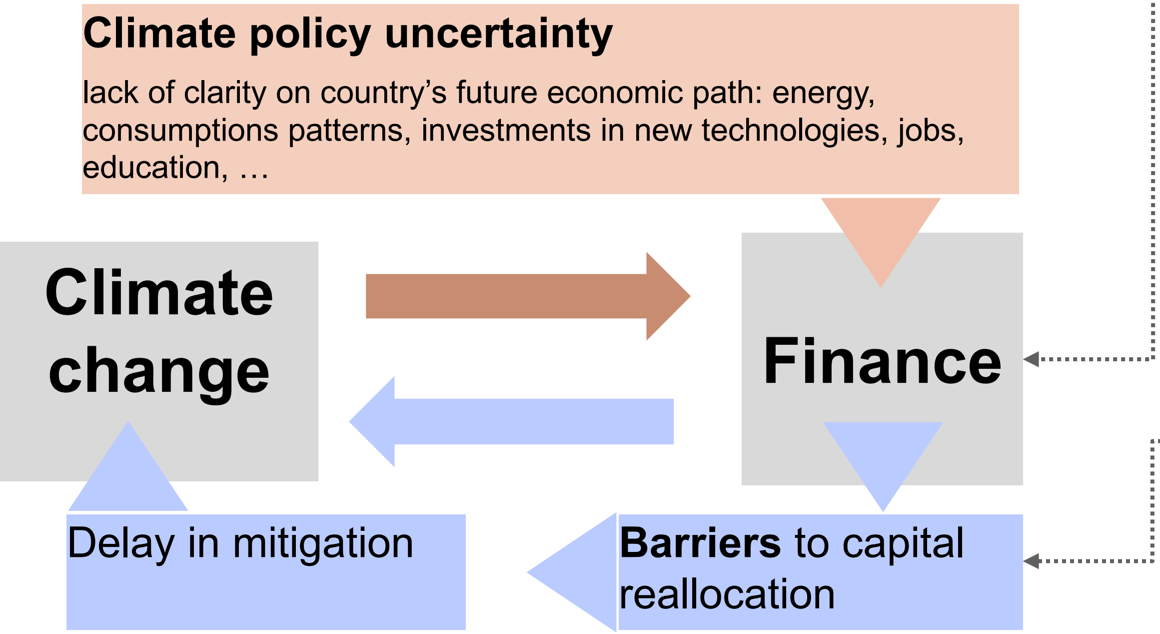
Transition risk:

- **Orderly** transition is ideal scenario.
- **Disorderly** transition: complexity of policy process implies possibility of late and sudden transition with unanticipated effects on prices and financial stability.
- The purpose of assessing transition risk is to avoid its materiality.

Source: AR6 WGIII Ch.15

Climate and finance: risks and impacts

Direction from finance to finance: impact



Source: author's illustration based on AR6 WGIII Ch.15

Impact of financial investments

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

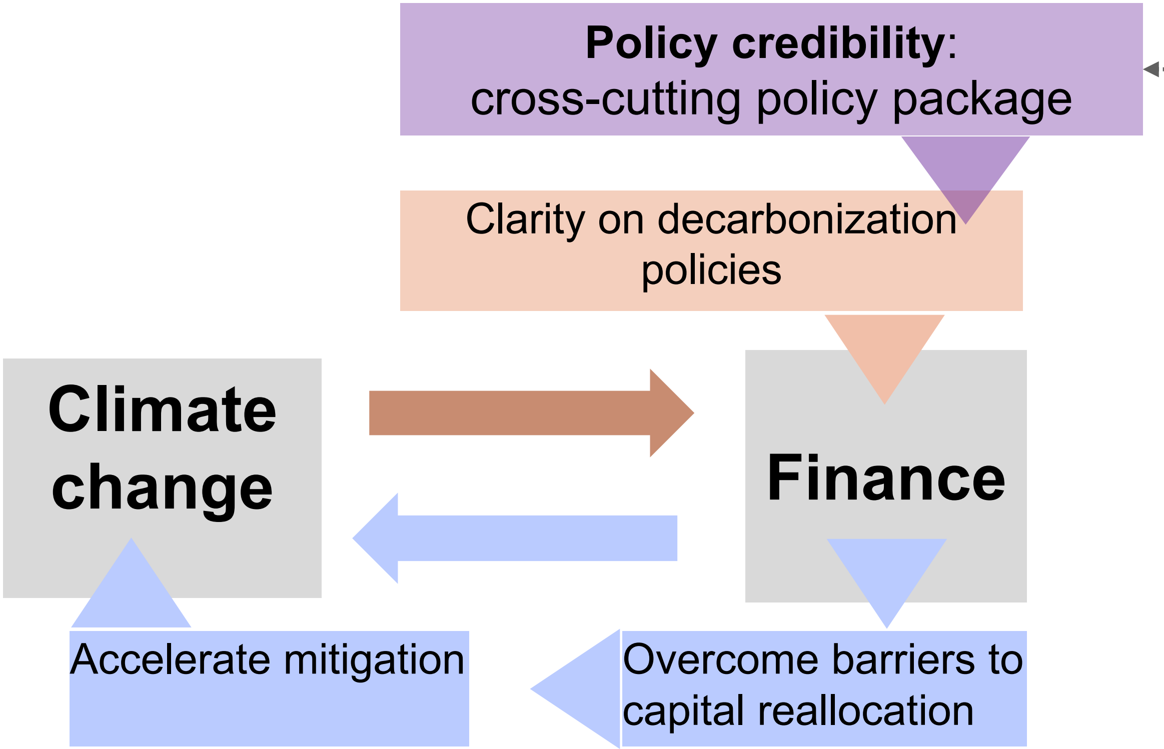
Barriers to mitigation

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

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

Source: AR6 WGIII Ch.15

Policy credibility



Source: author's illustration based on AR6 WGIII Ch.15

Endogeneity and role of governments

Endogeneity of climate scenarios implies key role of clear policy signalling (Battiston ea. 2022 Science):

- reduce uncertainty on future scenarios and
- create incentives to reallocate capital towards climate-aligned investments for decision makers in public and private financial institutions and households

Policy options: Cross-cutting policy packages are best-suited. Options include:

- **National** level: economic (fiscal, industrial, welfare policies): e.g. fossil/ren subsidies, R&D, jobs, education
- **International** level: Market creation and de-risking mechanisms via multilateral/national climate funds and development banks;

Political feasibility of the transition requires instruments with attention to economic, social, gender equity.

Source: AR6 WGIII Ch.15

Climate mitigation scenarios.

Climate transition risk

Transition risk: *risk associated to changes in the values of assets which cannot be fully anticipated or hedged by market players, as a result of a late-and-sudden alignment to climate targets (e.g. 2 degrees C).*

Multiple causes/dimensions for limited ability to anticipate:

1. uncertainty in policy process leading to the introduction of a climate policy
2. social dynamics of market players that try to guess if/when the majority will switch to low-carbon investment strategy before they do it themselves
3. technological innovations causing unexpected changes the cost technologies (e.g. solar PV)
4. social dynamics triggered by climate-related events to demand policy intervention

Remark. *Standard assumption is that market players are good at anticipating price changes and that policy makers would not introduce climate policies that entail economic losses.*

- *However, events of recents years show that market players may collectively make wrong predictions on policy outcome and that policies that entail new risks are sometimes adopted, even unexpectedly so (e.g. US elections, Brexit, COVID-19).*

What are climate mitigation scenarios?

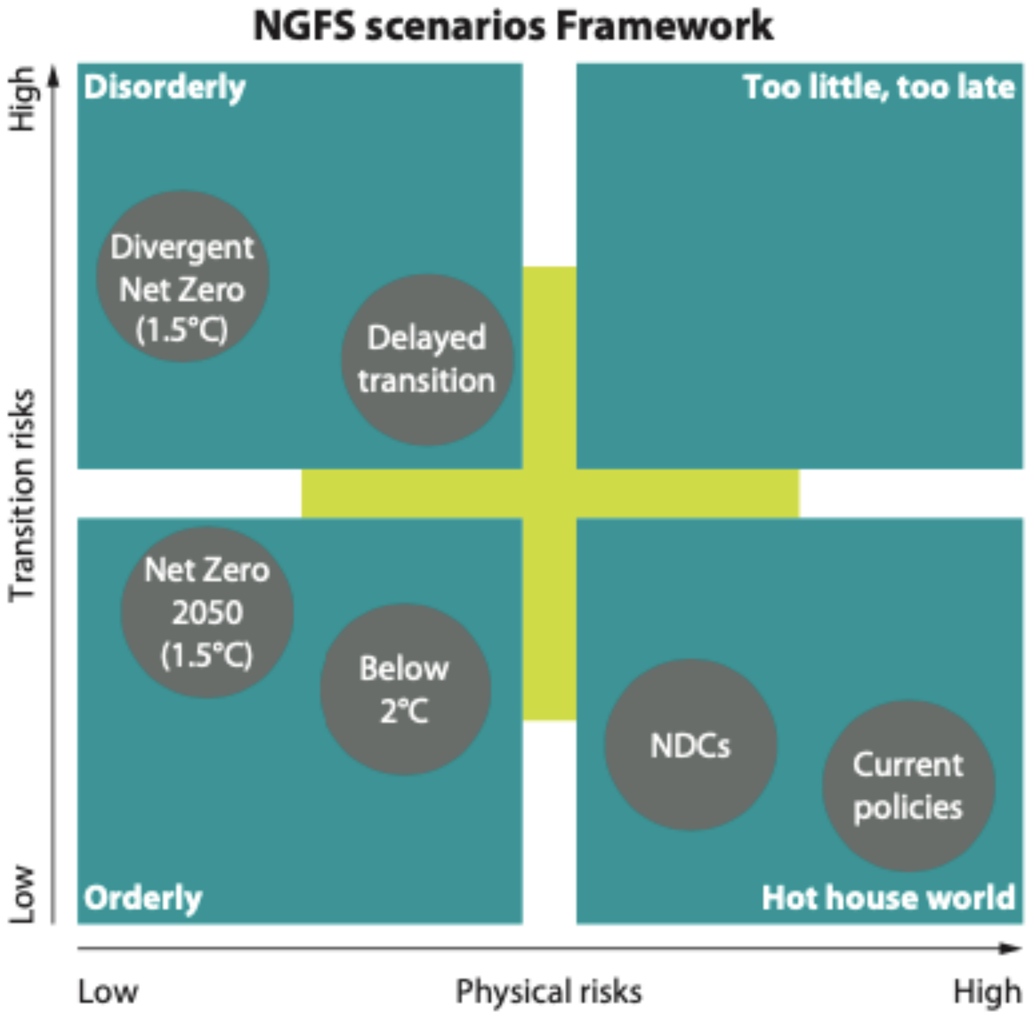
Climate mitigation scenarios are not predictions. They describe what the economy and land use might look like in the next decades.

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)
- by 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.*).

What are climate mitigation scenarios?



Source: NGFS 2021

IAM scenarios assessed by the IPCC *(2013; 2018, 2022)* have some distinct features of the transition

- timing of carbon price (2020, 2030)
- temperature target (1.5C, 2C)
- extent of reliance on Carbon Dioxide Removal (CDR)

Based on IPCC scenarios, NGFS has identify 4 high-level scenarios:

- Disorderly; Orderly; Hot-house world; Too-little, too late
- Within each high-level scenario: one or more specific scenarios are provided, each generated with one or several models

NGFS climate mitigation scenarios

Orderly

Net Zero 2050 limits global warming to 1.5°C through stringent climate policies and innovation, reaching global net zero CO_2 emissions around 2050. Some jurisdictions such as the US, EU and Japan reach net zero for all GHGs.

Below 2°C gradually increases the stringency of climate policies, giving a 67% chance of limiting global warming to below 2°C.

Disorderly

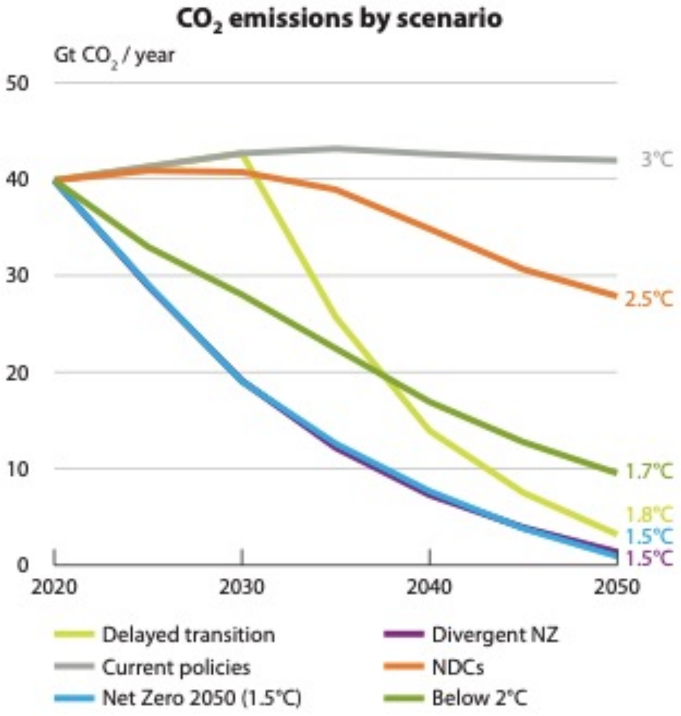
Divergent Net Zero reaches net zero around 2050 but with higher costs due to divergent policies introduced across sectors leading to a quicker phase out of oil use.

Delayed transition assumes annual emissions do not decrease until 2030. Strong policies are needed to limit warming to below 2°C. CO_2 removal is limited.

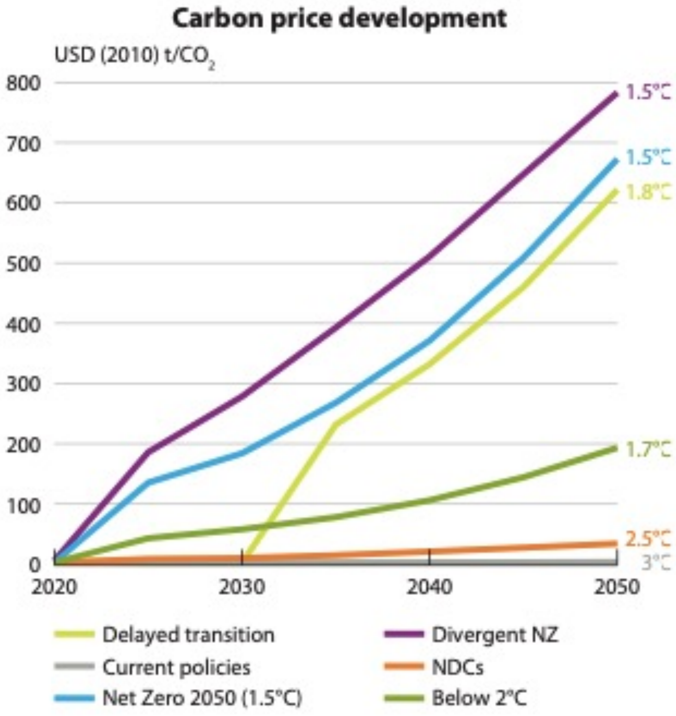
Hot house world

Nationally Determined Contributions (NDCs) includes all pledged policies even if not yet implemented.

Current Policies assumes that only currently implemented policies are preserved, leading to high physical risks.



Source: IIASA NGFS Climate Scenarios Database, REMIND model. End of century warming outcomes shown.



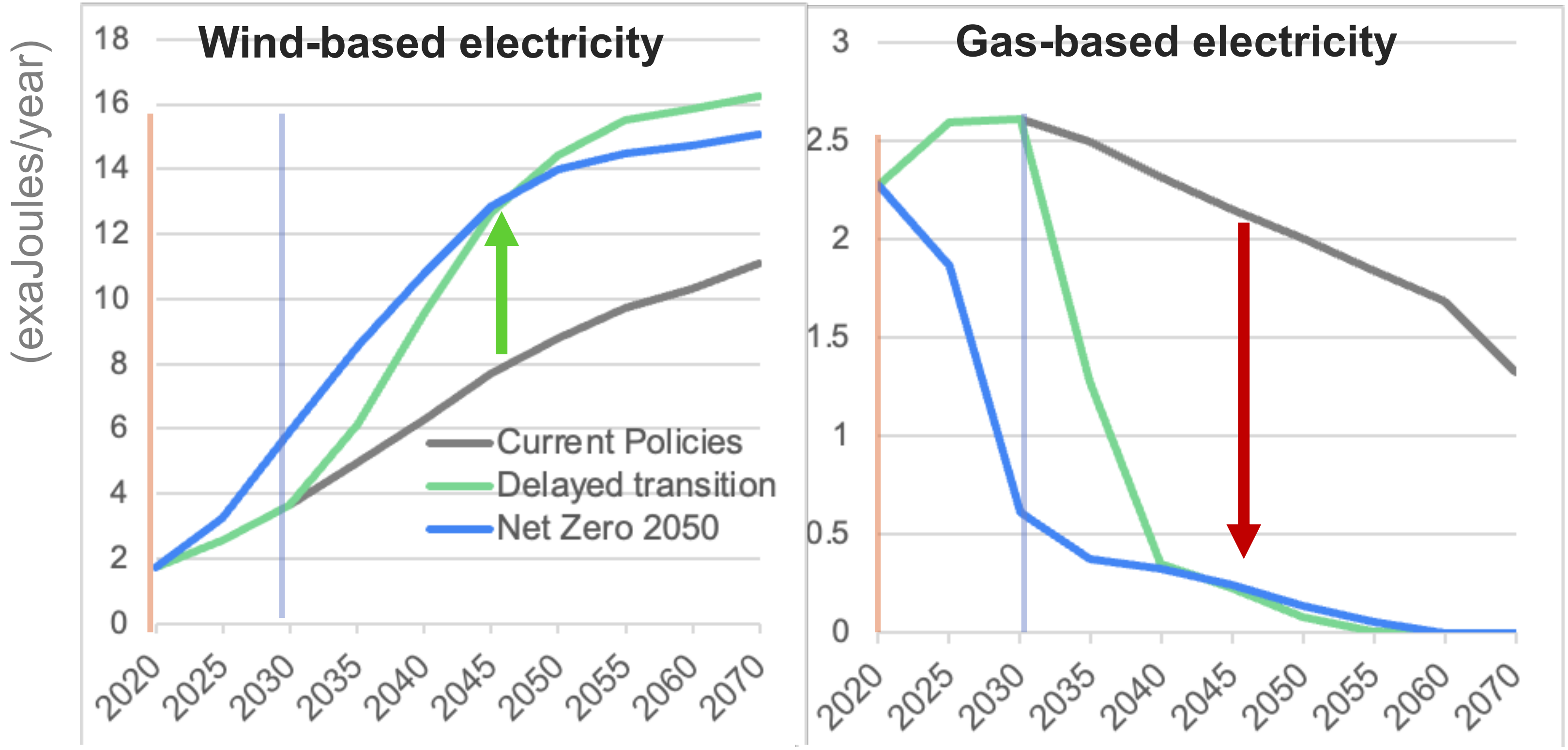
Source: IIASA NGFS Climate Scenarios Database, REMIND model. Carbon prices are weighted global averages. End of century warming outcomes shown.

Source: NGFS 2021

NGFS mitigation scenarios - Example

Example: output of electricity of gas vs wind across 3 NGFS scenarios:

- CurrPolicies, Delayed Transition, NetZero2050
- for the region EU, 2020-2070, under model “REMIND-Mag-Pie”.
- going from CurrPolicies to mitigation scenario: a consistent increase / decrease of output



Changes in **investors’ expectations over future production trajectories** can translate in differences in future credit risk, depending on the technological profile of the firm

Source:
NGFS scenario data.
Authors’ own elaboration

Financial risk: climate transition risk analysis

Concept: translate IPCC climate mitigation scenarios into:

- adjustment in valuation of financial contracts at counterparty level (Battiston et al. 2017)

What is transition risk?

- Risk resulting from financial actors' expectations: adjustment from baseline to transition scenario.

Use: approach widely used by supervisors (e.g. ECB, BoE) and practitioners (e.g. top consulting firms)

Reference: NGFS scenarios (2020; 2021), based on IPCC

Quantitative assessment of transition risk losses
Scenario analysis - Climate stress-test

Climate financial risk analysis and stress-testing

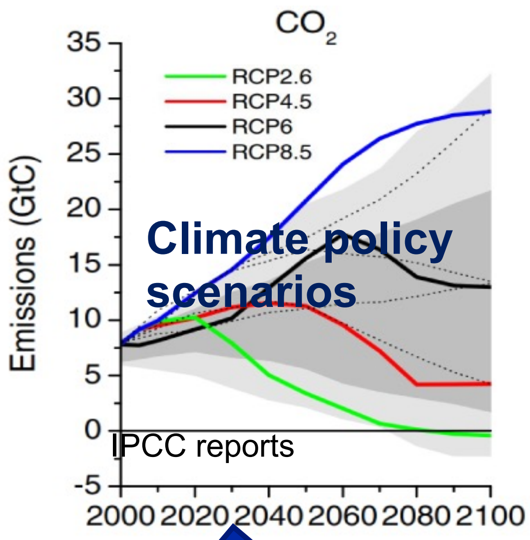
Counterparty level technological profile

1. Analyse counterparty i's revenues share by **technology** across CPRS granular (e.g. coal vs wind based electr., ICE vs EV automotive)
2. Estimate current **market share** in each technology
3. Estimate i's future production trajectory in a given scenario X, based on **NGFS sector-level trajectory** and on I's market shares
   – NOTE: i's technology share endogenous!
4. Estimate i's future cashflows along the time trajectory, in each NGFS scenario

Counterparty level financial valuation

1. Compute financial instrument valuation under baseline scenario B
   - Equity: standard valuation based on future discounted profits trajectory
   - Bonds and loans: future compound profits trajectory combined with a structural model of default
2. Calibration: possibly using counterparties PD, LGD provided by banks
3. Assume adjustment in investors' expectations about realization of transition scenario P.
4. Recompute financial valuation under scenario P to give valuation adjustment BP

Framework for Climate stress-testing

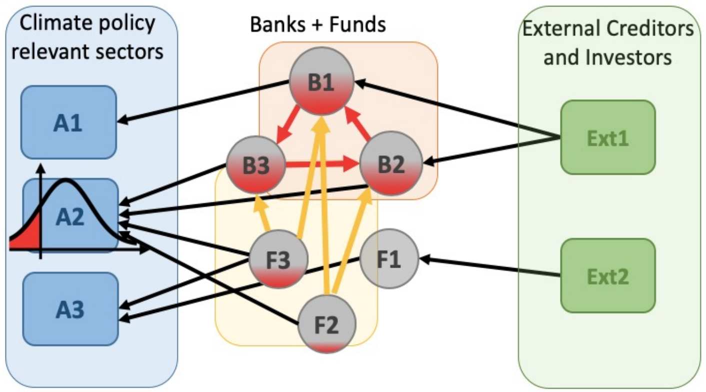


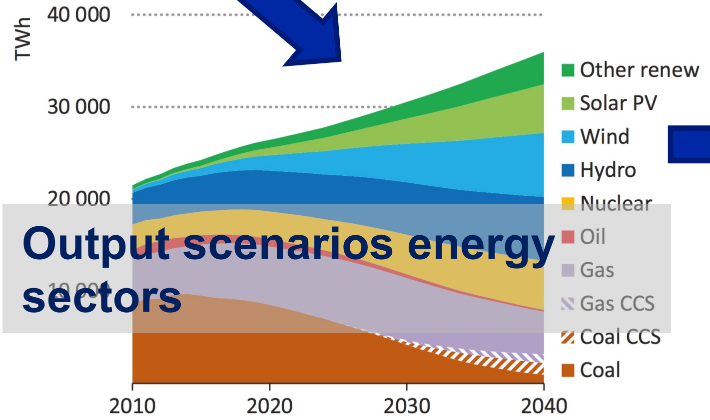
Climate policy scenarios

Disorderly transition: late-sudden alignment to climate targets

→ GVA shocks on revenue streams of securities issuers/borrowers

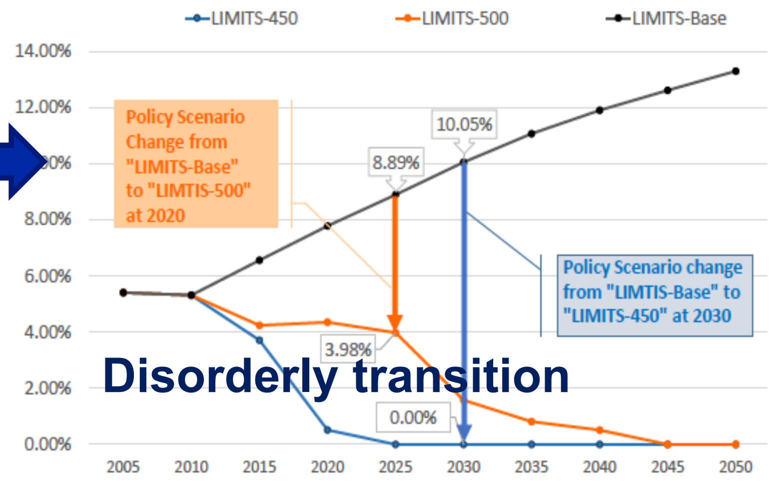
→ valuation adjustment of issuers' default prob., bond spread, credit risk (CVA)



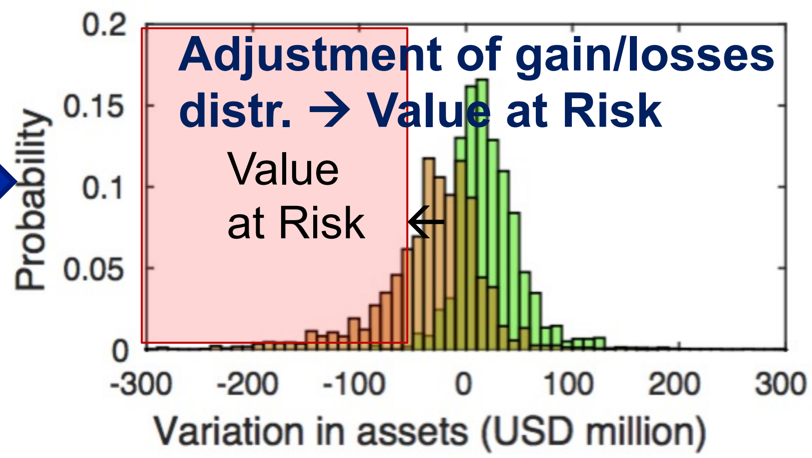


Output scenarios energy sectors

[source: LIMITS Kriegler ea. 2013]

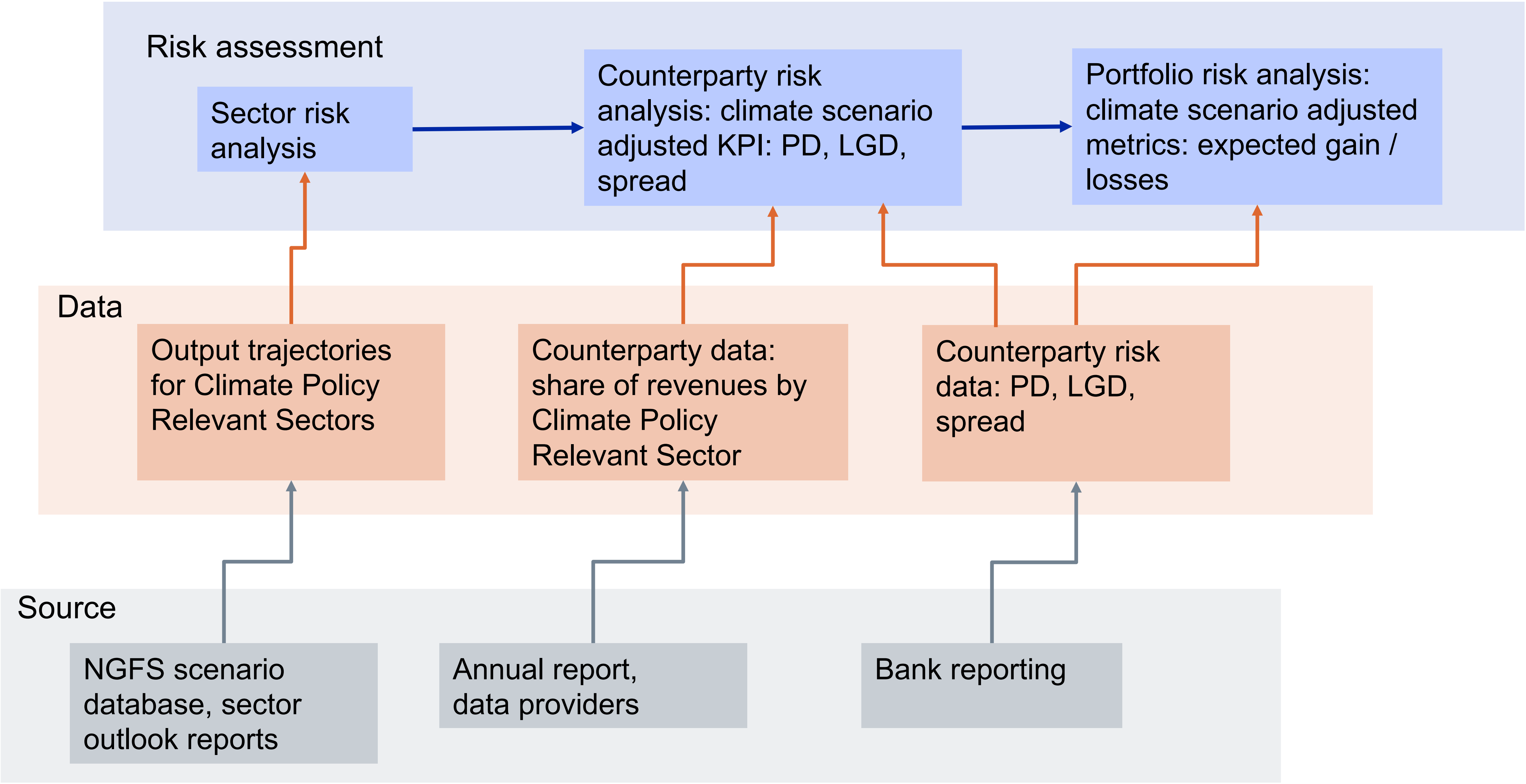


Disorderly transition



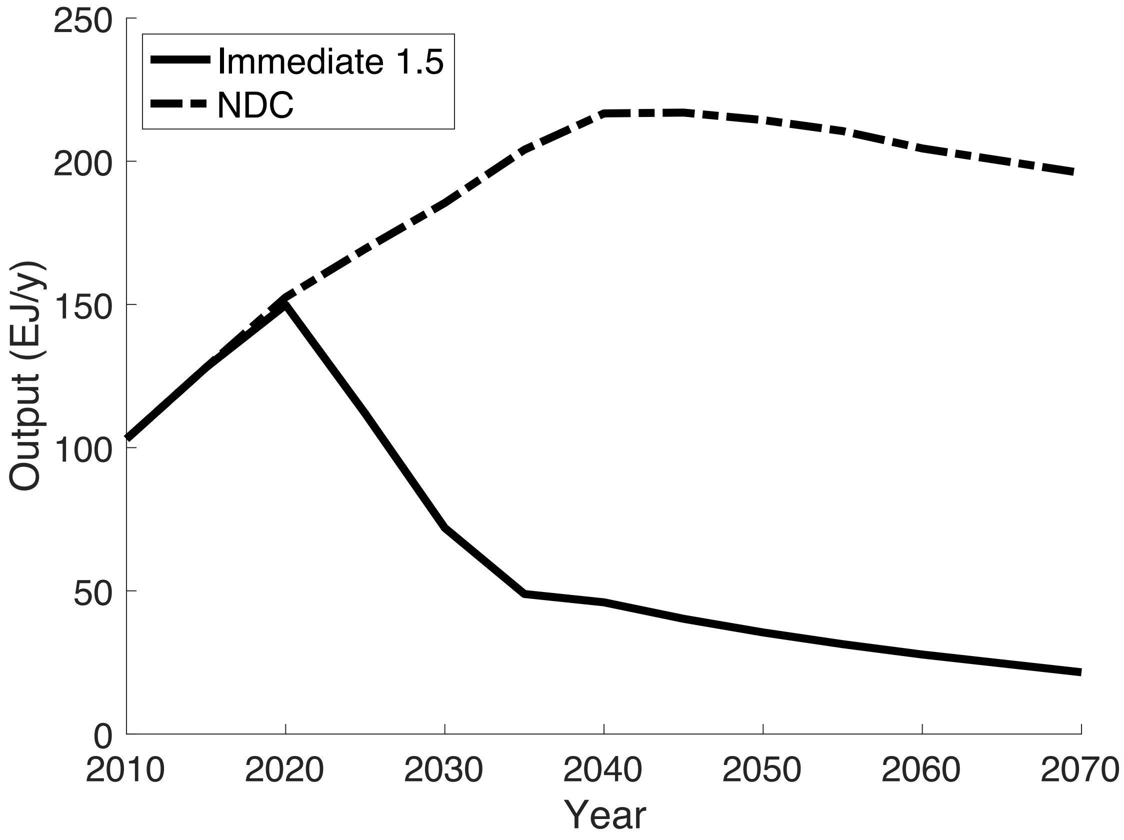
Adjustment of gain/losses distr. → Value at Risk

Climate financial risk analysis and stress-testing



Transition risk: financial valuation procedure - example

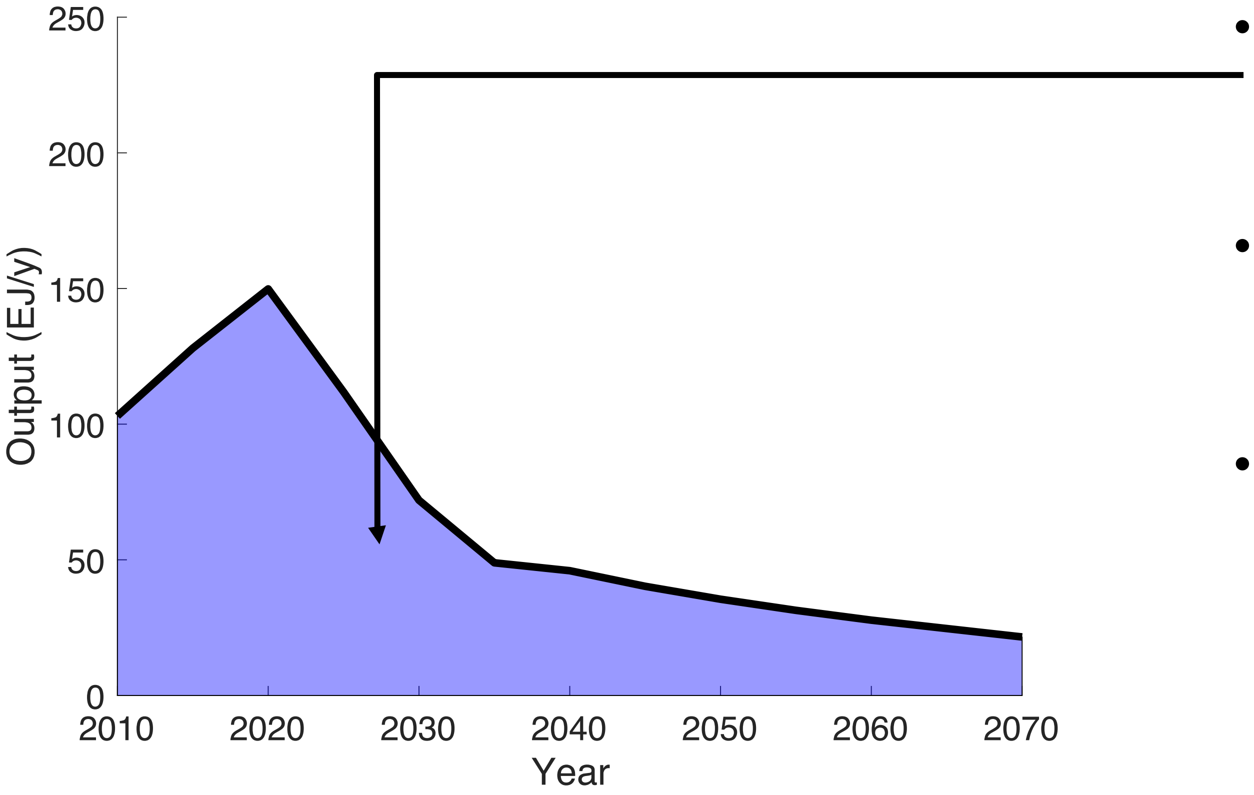
Trajectories at sector level Sector: fossil|gas. Model: REMIND-Magpie



- Comparison of examples of sector-level output trajectories (2010 – 2070):
  - B = Nationally Determined Contribution (NDC, baseline)
  - P= Immediate 1.5C with limited CDR (disorderly).
- For each trajectory, we carry out valuation today of financial instrument issued by a firm in the fossil|gas sector.

Transition risk: financial valuation procedure - example

Trajectories at sector level Sector: fossil|gas. Model: REMIND-Magpie

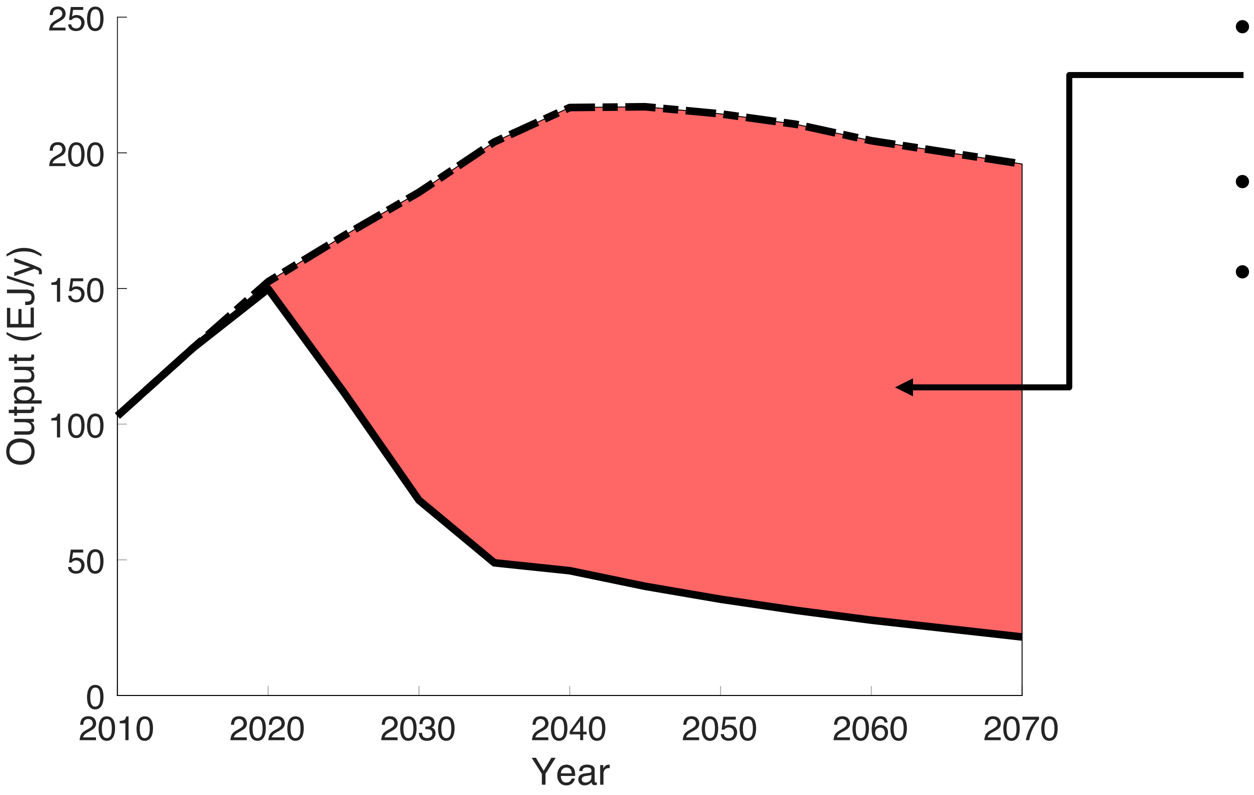


- Blue area represents cumulative output of companies active in the fossil|gas sector in scenario **P**.
- Valuation of financial instrument equity computed from discounted sum of dividends.
- Assumption: dividends depend on output (via profits) in scenario B.

$$V_{P,j}^{\text{equity}} = \sum_{t=t_0}^{t_{\max}^{\text{equity}}} \frac{\text{div}_j(\Omega_{P,j,t}(O_{P,j,t}))}{(1+r)^{t-t_0}}$$

Transition risk: financial valuation procedure - example

Trajectories at sector level Sector: fossil|gas. Model: REMIND -Magpie



- The red area corresponds to the loss in output between the scenarios **B** and **P**.
- We then compute relative shock.
- It represents the change in valuation of the security **today**, after a change of agents' expectations on future scenario of output

$$\Omega_{B,P}^{\text{equity}} = \frac{V_P^{\text{equity}} - V_B^{\text{equity}}}{V_B^{\text{equity}}}$$

Transition risk: financial valuation procedure - example

A simple relation holds between the relative shock on equity and the relative shock on expected discounted output under two assumptions:

- dividends are proportional to profits with αj as proportionality factor, i.e.
- profits are proportional to output with βj as proportionality factor, i.e.

$$div_j(\Omega_{P,j,t}) = \alpha_j \cdot \Omega_{P,j,t}, \qquad \Omega_{P,j,t}(O) = \beta_j \cdot O_{P,j,t}.$$

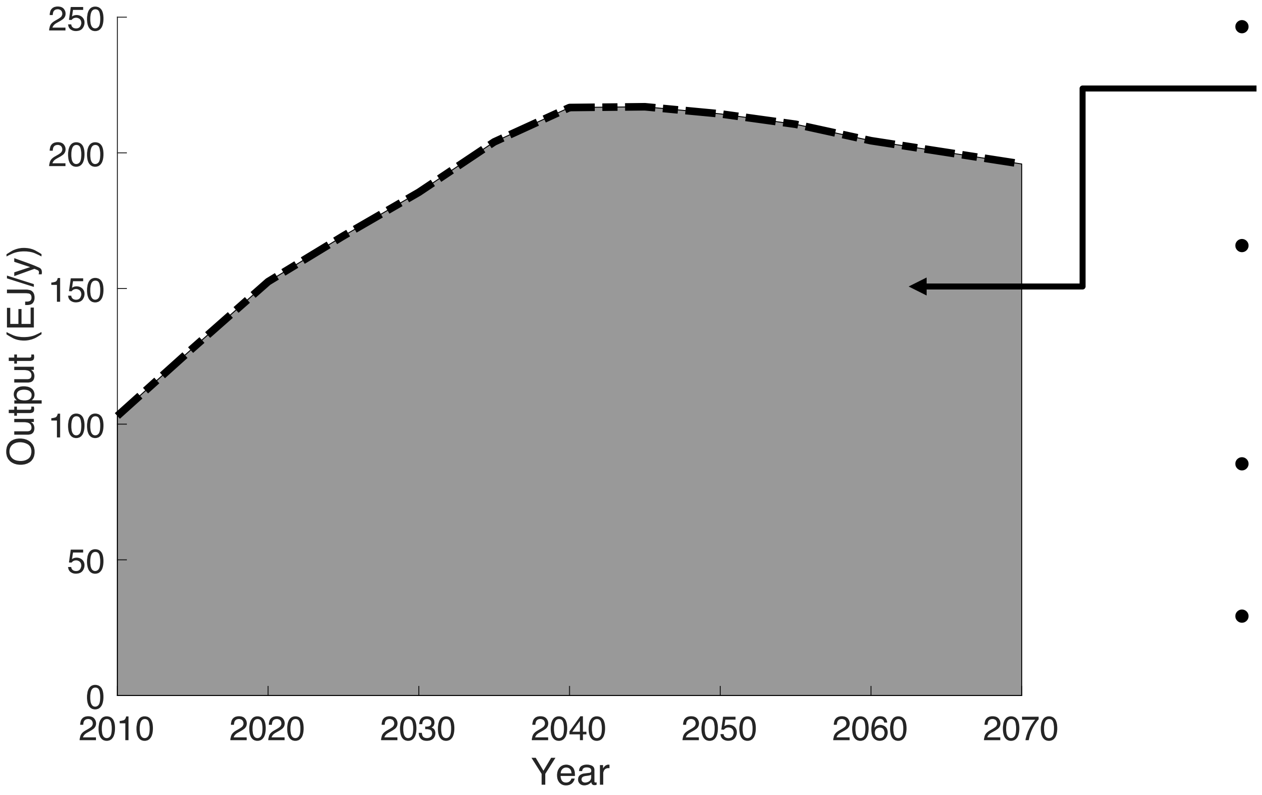
$$U_{P,j}^{\text{equity}} = \frac{\sum_{t=t_0}^{t_{\max}^{\text{equity}}} \frac{\text{div}_j(\Omega_{P,j,t}(O_{P,j,t})) - \text{div}_j(\Omega_{B,j,t}(O_{B,j,t}))}{(1+r)^{t-t_0}}}{\sum_{t=t_0}^{t_{\max}^{\text{equity}}} \frac{\text{div}_j(\Omega_{B,j,t}(O_{B,j,t}))}{(1+r)^{t-t_0}}} =$$

$$= \frac{\sum_{t=t_0}^{t_{\max}^{\text{equity}}} \frac{\alpha_j \beta_j O_{P,j,t} - \alpha_j \beta_j O_{B,j,t}}{(1+r)^{t-t_0}}}{\sum_{t=t_0}^{t_{\max}^{\text{equity}}} \frac{\alpha_j \beta_j O_{B,j,t}}{(1+r)^{t-t_0}}} =$$

$$= \frac{\sum_{t=t_0}^{t_{\max}^{\text{equity}}} \frac{O_{P,j,t} - O_{B,j,t}}{(1+r)^{t-t_0}}}{\sum_{t=t_0}^{t_{\max}^{\text{equity}}} \frac{O_{B,j,t}}{(1+r)^{t-t_0}}}.$$

Transition risk: financial valuation procedure - example

Trajectories at sector level Sector: fossil|gas. Model: REMIND-Magpie



- Grey area represents cumulative output of companies active in the fossil|gas sector in scenario **B**.
- Valuation of financial instrument equity computed from discounted sum of dividends.
- Assumption: dividends depend on output O (via profits Omega) in scenario B.
- r discount factor

$$V_{B,j}^{\text{equity}} = \sum_{t=t_0}^{t_{\max}^{\text{equity}}} \frac{\text{div}_j(\Omega_{B,j,t}(O_{B,j,t}))}{(1+r)^{t-t_0}}$$

Climate credit risk model: corporate bonds

Source: Battiston, S., Monasterolo, I. (2020). On the dependence of investor's probability of default on climate transition scenarios. Available at SSRN (abstract_id=3743647), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3743647

Transition risk: financial valuation procedure – bond and loans

- For bonds and loans: similar intuition but more complex model
- **Probability of default (PD)** and **Loss Given Default (LGD)** depend on:
  - projected compounded profits from valuation time until maturity, conditional to scenarios
- More details available soon in:
  - report of climate transition risk analysis recently conducted with an NGFS member
  - model documentation and sensitivity analysis (Battiston et al. 2021b)

From climate scenarios to financial valuation adjustment

Definitions

- **Climate policy scenarios** $\{B, P_1, ..., P_n\}$:
  - GHG emission reduction targets (e.g. P = 2 degrees C; B (Baseline) = Current Policies)
- **Climate economic scenarios** $\{..., Y_{C,S,P,M,...}\}$:
  - output trajectories for each sector S, under each scenario P, for a given country C, estimated with given climate economic model M (e.g. NGFS scenario database)
- **Expectation adjustments** $\{BP_1, ..., BP_l, ..., BP_n\}$:
  - changes in markets' expectations over future trajectories $B \to P$)
- **Financial valuation adjustment** $\{..., \frac{V(Y_{j,P,M})-V(Y_{j,B,M})}{V(Y_{j,B,M})}, ...\}$:
  - changes in forward-looking financial valuation V of asset related to firm j (e.g. bond) resulting from changes in markets' expectations
  - $Y_{j,B,M}$ output of firm j depends on its technology mix, transition exposure (CPRS) and business geography (multinational corporations)

Sources: Battiston, S., & Monasterolo, I. (2020). On the dependence of investor's probability of default on climate transition scenarios. Available at SSRN 3743647. *Battiston, Mandel, Monasterolo 2019, CLIMAFIN Handbook: Pricing climate financial risk Part 1* https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3476586

Adjustment of firm's revenues across business lines

- Consider two time steps $t = 0$, $t = T$
- Decompose revenue adjustment $u_j(BP)$ of firm j's across sectors:

$$u_j(BP) = \frac{\text{rev}_j(P) - \text{rev}_j(B)}{\text{rev}_j(B)} = \sum_S (u_{j,S}(BP)\ w_{j,S}(B)), \quad \text{with:}$$

  - $u_{j,S} = \frac{\text{rev}_{j,S}(P) - \text{rev}_{j,S}(B)}{\text{rev}_{j,S}(B)}$ relative shock on j's revenues from sector S;
  - $w_{j,S} = \frac{\text{rev}_{j,S}(B)}{\text{rev}_j(B)}$ share of j's revenues from S, under scenario B
- Focus on selected Climate Policy Relevant Sectors: Primary Energy Fossil (**PrFos**), Electricity Fossil/Renewable (**ElFos/ElRen**):

$$u_j(BP) = u_{j,\text{PrFos}}(BP)\ w_{j,\text{PrFos}}(B) + u_{j,\text{ElFos}}(BP)\ w_{j,\text{ElFos}}(B) + u_{j,\text{ElRen}}(BP)\ w_{j,\text{ElRen}}(B).$$

- Assumption: adjustment $u_j(BP)$ in revenues leads to adjustment $\xi_j(BP)$ on j's asset at T depends via elasticity χ_j^0:

$$\xi_j(BP) = \chi_j^0\ u_j(BP)$$

Sources: Battiston, S., & Monasterolo, I. (2020). On the dependence of investor's probability of default on climate transition scenarios. Available at SSRN 3743647. *Battiston, Mandel, Monasterolo 2019, CLIMAFIN Handbook: Pricing climate financial risk Part 1* https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3476586

Impact of expectation adjustments on firm's revenues

Remarks

- Firm j considered as a portfolio of (low/high carbon) activities.
- In transition scenarios: losses for high-carbon activities (stranded assets), gains for low-carbon activities.
- Assumption: adjustment of j's revenues from sector S, $u_{j,S}(BP)$, is approximated with relative change in aggregate output of sector S (e.g. ElFos) from scenario B to P, according to climate economic model M, in the scenario database (e.g. NGFS).
- Which transition scenarios eventually occurs remains uncertain because of **endogeneity**: it depends on investors' expectations (climate sentiments, Dunz et al., 2021) and credibility of governments' policies (Battiston et al. 2021).

Sources: Battiston, S., & Monasterolo, I. (2020). On the dependence of investor's probability of default on climate transition scenarios. Available at SSRN 3743647. *Battiston, Mandel, Monasterolo 2019, CLIMAFIN Handbook: Pricing climate financial risk Part 1* https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3476586

Corporate default: a simple structural model

Shocks and default condition

- Consider two time steps: issue time $t_0 = 0$, maturity $t = T$
- Firm j's balance sheet: asset $A_j(t_0 = 0)$, $A_j(T)$; liability $L_j(T)$.
- Default condition:

$$A_j(T) = A_j(0)(1 + \eta_j) < L_j(T)$$

  - $\eta_j(T) \in \mathbb{R}$: **idiosyncratic shock** (e.g. on j productivity),
- Adjustment of expectations $\rightarrow$ adjustment in asset: $\xi_j(\mathrm{BP})$
- New default condition:

$$A_j(T) = A_j(0)(1 + \eta_j + \xi_j(BP)) < L_j(T)$$

$$\iff \eta_j < \theta_j(BP) = L_j(T)/A_j(0) - 1 - \xi_j(BP)$$

  - $\theta_j(BP)$: default threshold under adjustment of expectations BP
  - for high-carbon: negative $\xi_j(BP) \rightarrow \theta_j(BP) > \theta_j(B)$: PD is higher under BP than under B

Sources: Battiston, S., & Monasterolo, I. (2020). On the dependence of investor's probability of default on climate transition scenarios. Available at SSRN 3743647. *Battiston, Mandel, Monasterolo 2019, CLIMAFIN Handbook: Pricing climate financial risk Part 1* https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3476586

Issuer's default probability: proposition

Proposition. Default prob. adjustment $\Delta q_j(\mathrm{BP})$

- Assuming
  - idiosynchratic shocks are **independent** from $\xi_j(\mathrm{BP})$ shock
  - $\xi_j(\mathrm{BP})$ shock on asset proportional to shock on revenues via elasticity $\xi_j = \chi_j^0\, u_j(BP)$
- Then, the **adjustment** in default probability $\Delta q_j(BP)$
  - increases with shock magnitude $|u_j(BP)|$ if $u_j^{\mathrm{BP}} < 0$, and decreases viceversa
  - Under approximation of small shock, $\Delta q_j(BP)$ can be linearized to be proportional to shock on CPRS revenues:

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

Sources: Battiston, S., & Monasterolo, I. (2020). On the dependence of investor's probability of default on climate transition scenarios. Available at SSRN 3743647.
Battiston, Mandel, Monasterolo 2019, CLIMAFIN Handbook: Pricing climate financial risk Part 1
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3476586

Adjustment in investor's PD and Expected Shortfall

Propositions

We prove several propositions on how investor's ES and PD are adjusted conditional to a transition scenario (Appendix). In short:

- ES(BP) increases with adjustment on bond default probability q(BP)
- Adjustment of PD of a leveraged investor can be derived analytically (numerically) in absence (presence) of correlation among bonds
- Under some assumptions of homogeneity, ES and PD decrease with share of climate-aligned revenues (i.e. renewable energy activities)

Sources: Battiston, S., & Monasterolo, I. (2020). On the dependence of investor's probability of default on climate transition scenarios. Available at SSRN 3743647. *Battiston, Mandel, Monasterolo 2019, CLIMAFIN Handbook: Pricing climate financial risk Part 1* https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3476586

Sensitivity of loss distribution to disorderly transition scenarios

Consider a financial investor:

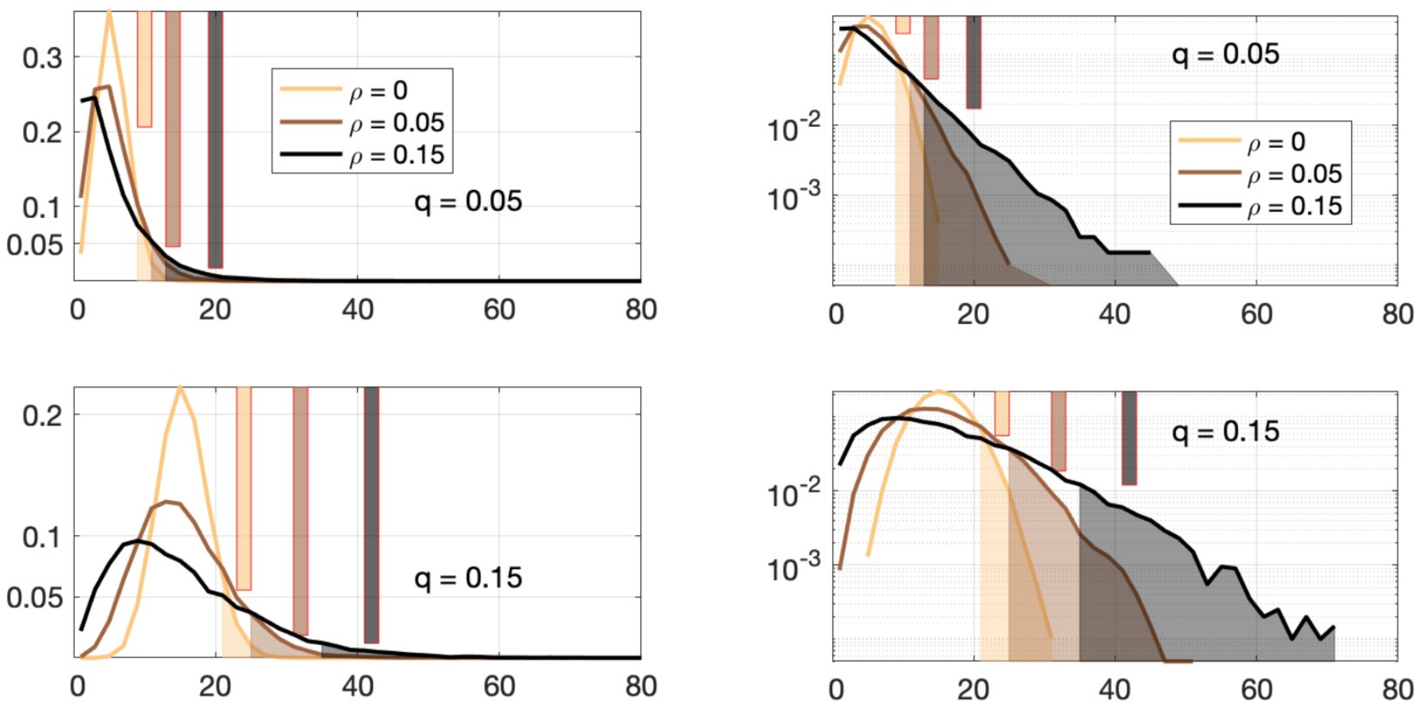
- with a portfolio of n corporate bonds financed with leverage (in figure: n=100, leverage = 20)
- with individual bond probability of default q and correlation ρ (varying as indicated in figure)

- Left: probability distribution of losses on the portfolio for varying q and ρ
- Right: idem but y-axis in log scale to zoom on the tail
  - Value-at-Risk: left edge of shaded area
  - Expected Shortfall: vertical bar

Effects observed:

- VaR and ES: shift to the right with increasing q and with increasing ρ
- more mass in the tail with increasing ρ

Source: Battiston & Monasterolo 2020
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3743647

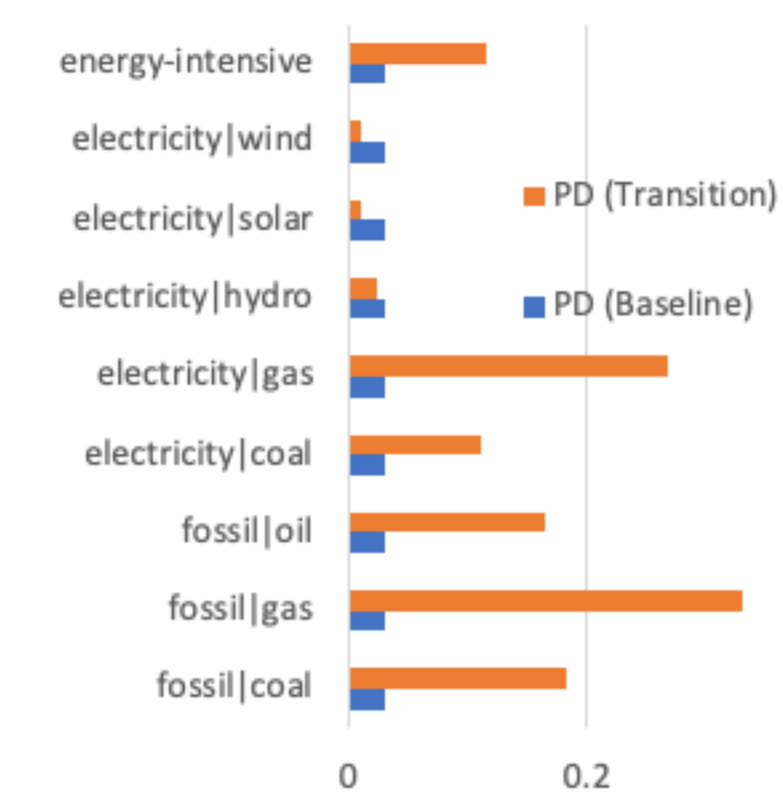


Example output:
shocks on bond valuation for selected sectors and parametrization

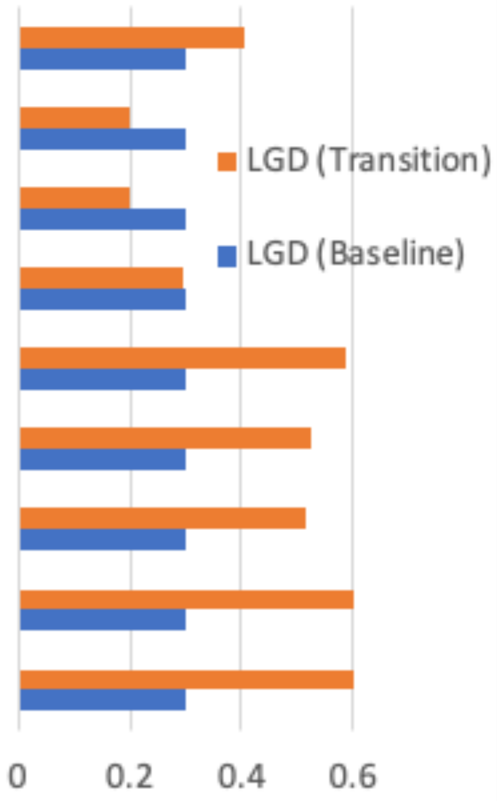
Formulas
- Bond valuation: k = (1 – PD) + (1 – LGD) PD
- Bond shock: (k(Baseline) – k (Transition)) / k(Baseline)

Results
- Bond shock varies across sectors and technology (and climate transition scenario

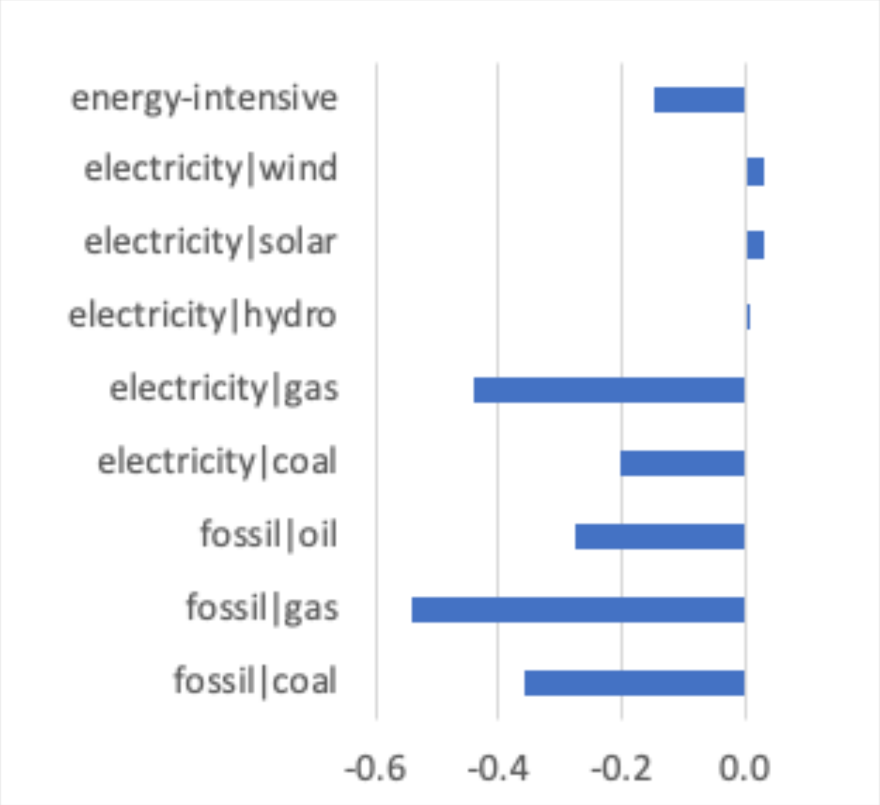
PD (Baseline vs Transition)



LGD (Baseline vs Transition)



Bond valuation shock



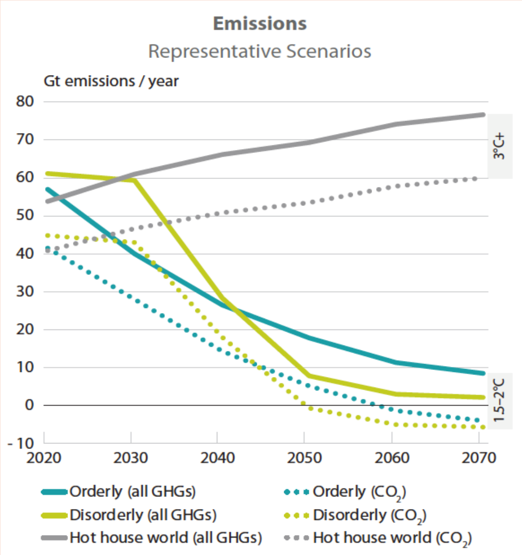
Endogeneity of transition scenarios

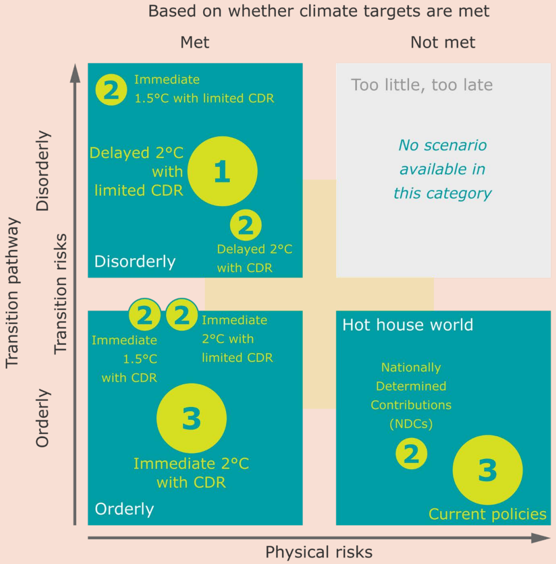
Endogeneity of risk and macro-financial feedback loop: take home message

- NGFS climate mitigation scenarios are already a **reference** tool for investors assess climate-related financial risk
- Scenarios can **shift markets' expectations**, but do **not account** for impact of financial actors' looking at the scenarios themselves.
- This missing feedback loop is key for financial stability and for climate targets, because it can lead to under-investing wrt to climate targets.
- Missing **endogeneity** matters for understanding the dynamics of the low-carbon transition: can make difference btw achieving or missing climate targets
- Opportunity: we introduce a framework to **model** interaction expectations-scenarios: it generates new transition scenarios that are more coherent with investment needs and climate targets (Battiston ea. 2021, Science)
- Key role for **policy credibility**, implications for **fiscal and financial policies**

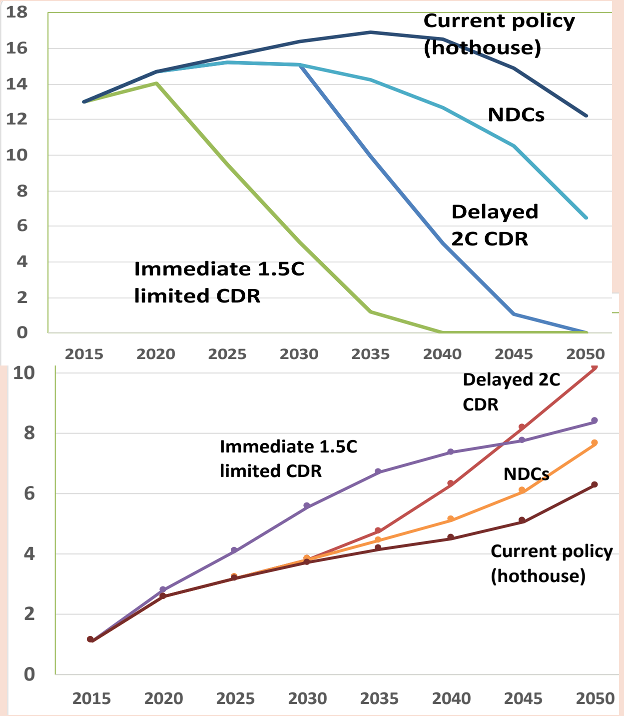
Macro-financial feedback loop is missing

Climate scenarios' (IPCC, NGFS)

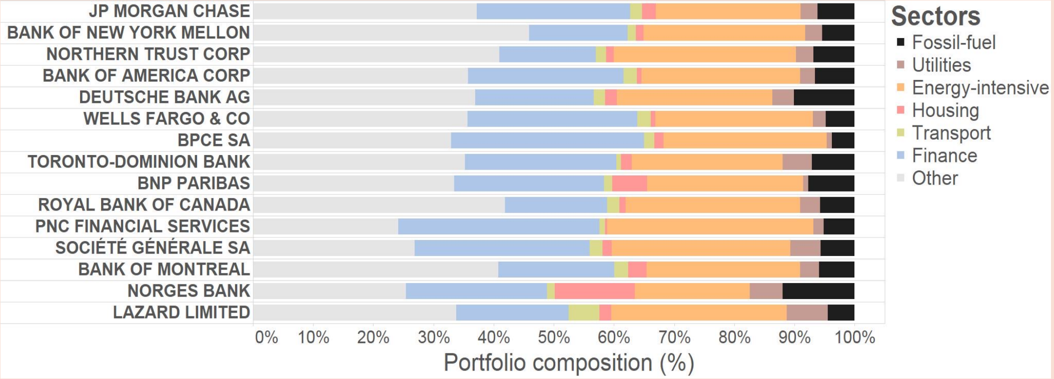




Economic scenarios (sector output, IAM)

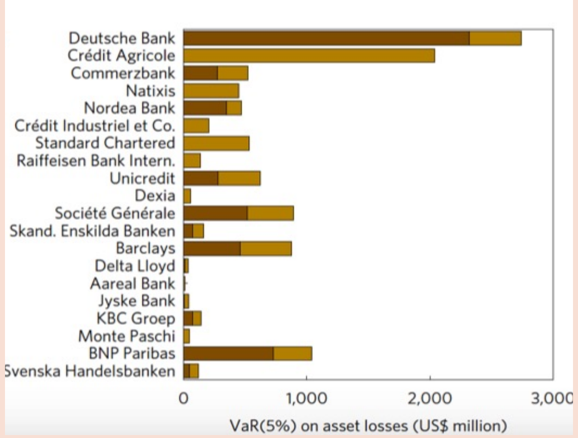


Climate risk exposures *(disclosure)*



Battiston ea (2017)

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



Battiston ea (2017)

Missing!

New investments and capital reallocation

Missing!

Appendix

Enabling or hampering role?

Enabling:

Investors perceive high physical risk from missed transition/high opportunities successful transition (**credible climate policies,** Rogge ea. 2018*)*

→ They reallocate capital into low-carbon investments early and gradually and even anticipate policy impact: **climate sentiments** (*Dunz ea. 2021)*

Hampering:

Investors interpret "orderly transition" as high-carbon firms only slightly more risky than low-carbon: expect firms to adjust tech mix and spread stranded assets over time because **climate policy not credible**

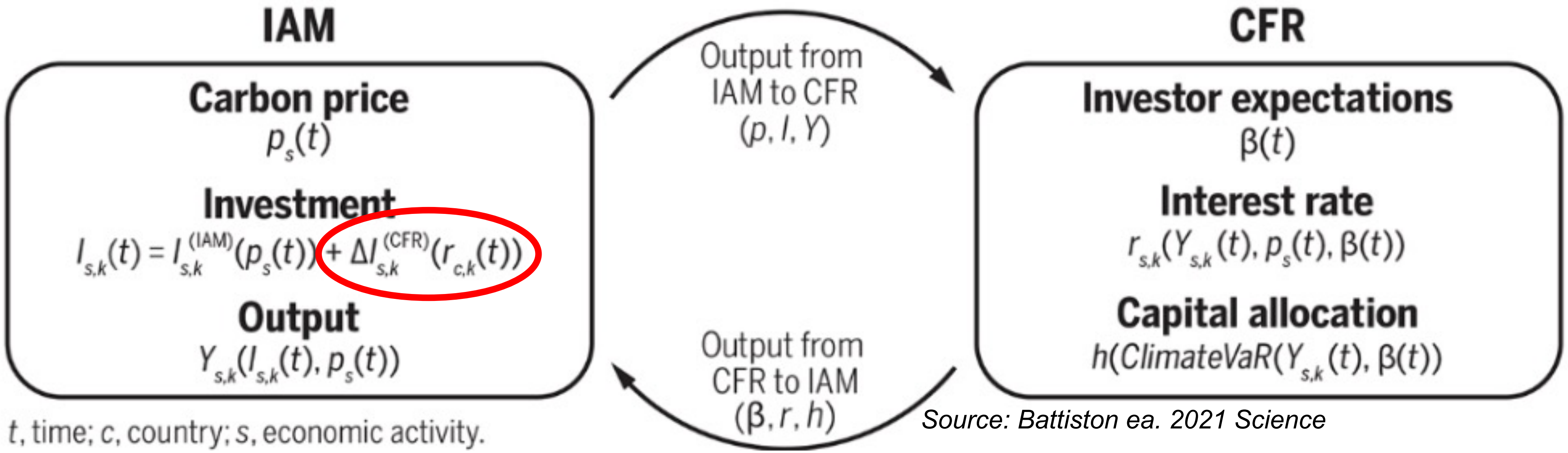
→ Capital reallocation not sufficient to fund investments assumed in scenario. Transition more costly for society due to abrupt reallocations of capital and price adjustments.

If a risk scenario is associate with too low-risk perception can make the scenario unfeasible

IAM-CFR framework

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 climate targets.

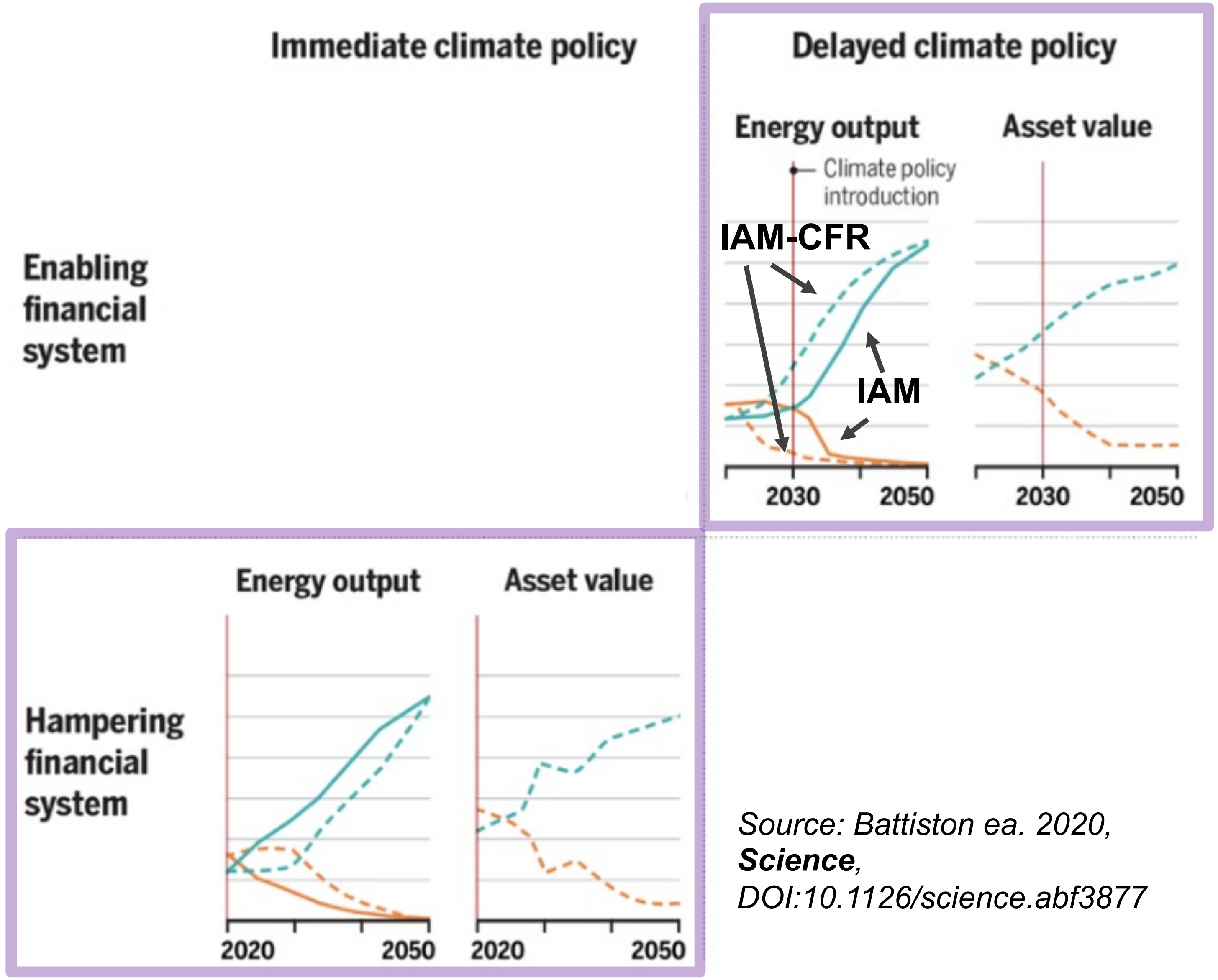


Source: Battiston ea. 2021 Science

- 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

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

IAM-CFR framework



Orderly/disorderly are endogeneous

- An immediate transition to 2° C classified in NGFS scenarios as orderly. But in hampering case: delayed transition, large and sudden financial value adjustments as in a disorderly scenario.
- A delayed transition to 2° C classified disorderly. But in enabling case gradual price adjustments more consistent with orderly
- In hampering role: disorderly transition could also lead to higher risk than in NGFS disorderly

Source: Battiston ea. 2020, ***Science****, DOI:10.1126/science.abf3877*

Legend

Policy implications

Policy signal and policy credibility

Role of policy credibility well-known in economics. Here: highlight its crucial role for low-carbon transition dynamics and for financial stability

Fiscal policies

Neglecting role of finance implies **carbon price projections** could miss **emissions target** because mitigation scenario does not necessarily imply a risk perception by the financial system that leads to investment reallocation assumed by the scenario. Similarly, for carbon subsidies phasing out.

Thus, IAM-CFR framework could help IPCC community and NGFS to revise carbon price projections from climate mitigation models to be more consistent with role of financial system

Financial policies

IAM-CFR could support financial authorities, within financial stability mandate, in encouraging investors' assessment of climate-related financial risk.

– Limit underestimation of financial risk in climate stress-test exercises.

Implications for asset eligibility criteria in central banks' collateral frameworks and asset purchasing programs (e.g. Quantitative Easing)