Pricing climate risks and opportunities in investors’ portfolios under uncertainty

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Professionals workshop

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An approach to price and manage climate-financial risk under uncertainty (*)

- 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

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

<table>
<thead>
<tr>
<th>What</th>
<th>Portfolio breakdown by instrument (equity, bonds, loans, etc.)</th>
<th>Contracts classification in <strong>climate policy relevant sectors (CPRS)</strong></th>
<th>Identification of relevant <strong>climate scenarios</strong> (physical, transition) by 2030/50</th>
<th>Climate shocks on green/brown energy firms’ <strong>market share</strong></th>
<th>Shock transmission to firm profitability and <strong>assets prices</strong></th>
<th>Portfolios’ losses/gain, <strong>default</strong> probability (investor, country)</th>
</tr>
</thead>
<tbody>
<tr>
<td>How</td>
<td>Financial macro-network analysis, exposure analysis</td>
<td>Scientific reports (IPCC, IEA)</td>
<td>Climate econ. models (IAM, SFC)</td>
<td>Climate financial pricing model</td>
<td>Climate Value at Risk (VaR)</td>
<td></td>
</tr>
</tbody>
</table>

**Risk identification and monitoring**

- **Data & source**: Firm financial, climate-relevant data (Scope123, Capex, etc.)
- **GHG emissions, temperature**
- **Value of fossil/renewal investments**

**Risk assessment and management**

- **Battiston & Monasterolo 2019**
- **Battiston ea. 2017**

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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. Price climate risks/opportunities under incomplete markets:
   - Need to *assess investors’ exposure* to climate risks (Climate policy relevant sectors (CPRS))
   - Need to *price climate risk* into financial contracts (climate spread)
Research questions

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

2. Can we price climate risks/opportunities in the value of individual contracts?
   - To what extent future climate policy shocks shift my probability of default?
   - What’s the price of climate risk (bonds’ 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?
Focus 1: understanding risk. This time it is different!
Climate change and financial stability: where risk comes from?

- **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
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

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Non-normal climate data evidence

- Western European summer 2003 was $5.4\sigma$ above mean temperature for 1864-2000
  - With normal distribution, $5.4\sigma$ 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
  - (You might have noticed the temperature here)
  - The “unknown unknowns” of climate change make risk pricing significantly more fuzzy in this arena

Picture source: Ackerman 2017
Risk type 1: (we assume) we know what we don’t know (i.e. the probabilities)

- **Value-at-Risk (VaR):** value to keep aside to avoid massive losses (95% cases)
- Why it matters: central banks use VaR to set capital requirements
- Traditional VaR stands on normal distribution of shocks, standard deviation as a risk measure
- Climate: fat-tailed risk thus volatility underestimates risk
- Financial economic models ignore this: linear shock transmission from climate to asset prices, with risk of large errors

![Diagram of Value-at-Risk (VaR) distribution](wikipedia)

**Picture source:** wikipedia
Risk type 2: when 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** doesn’t rely on probability distribution:
    - Decide what extreme climate scenarios could be feasible and relevant for your business/goals
    - Compute losses conditioned to each scenario
    - Identify portfolios’ rebalancing strategies to mitigate risk under each scenario

What is a scenario?

Picture source: Royal Dutch Shell
What climate transition scenarios?

We consider a country’s transition to the low-carbon economy to achieve the Paris Agreement (PA).

Evidence that countries aren’t aligning to their PA pledges (UNEP 2018). Thus, we consider a scenario of disorderly transition:

- **Orderly**: government introduces timely and coherent policies; investors can anticipate the policy introduction and price it in portfolio’s strategy (e.g. increase (decrease) exposure to bonds of climate-aligned (brown) countries)

- **Disorderly**: government delays the introduction of credible policies (then policies will be costlier); investors cannot anticipate the climate policy’s introduction (deep uncertainty) and thus cannot price it in.
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 **COP21 success** in reaching a climate agreement at came as a surprise to many.
- The **2017 US withdrawal** from the Paris Agreement would have not been predicted by most observers.
- **Investors didn’t price** these shocks in the value of assets that have fossil fuels (renewables) as underlying.

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**MONASTEROLO, I.** "PRICING CLIMATE RISKS IN FINANCIAL PORTFOLIOS", EC JRC SUMMER SCHOOL, JULY 2019
Focus 2: assets’ classification into Climate Policy Relevant Sectors (CPRS)
1. Classify assets of individual investors’ portfolios into climate-policy relevant sectors (CPRS)

2. Investors’ portfolios’ exposures to CPRS and calculation of first and second round losses (network model).

3. Identify feasible forward-looking climate transition scenarios and assess the shock on fossil fuel/renewable energy firms and sectors’ market shares and GVA

4. Introduce forward-looking climate risks in pricing of individual contracts: e.g. sovereign bonds’ spread: change in GVA $\rightarrow$ change in tax revenues $\rightarrow$ change in contract value (e.g. climate spread)

5. Introduce climate into standard financial risk metrics (e.g. Climate VaR) and assess largest losses (gains) on investors’ portfolios
Assets’ classification into CPRS

• CPRS classification is based on NACE economic sectors (4-digit) to assess investors’ **exposure to climate risks and their relevance for climate change and policies** (PA, EU2030, etc.)

• **3 dimensions considered by CPRS:**
  • Contribution to Greenhouse Gases (GHG) **emissions** (info on Scope1,2,3, climate relevant data)
  • Role of the firm and sector in the **energy value chain** (e.g. mining and quarrying sector (B) has low direct emissions (3%) but high indirect/induced emissions in the value chain)
  • **Relevance for climate policy** and low-carbon transition (carbon leakage classification) and traditional policy areas (e.g. energy, transport)
CPRS: beyond green/brown classification to assess risk

- Fossil fuel,
- Utilities (fossil/renewable),
- energy-intensive,
- low-carbon/high carbon transportation,
- housing
Include emissions’ generation and transmission across sectors

- Fossil fuels (coal, oil, gas)
- Utility (fossil/renewable based)
- Energy intensive (manufacture)
- Housing
- Transport (high/low carbon)

Direct impact on emission
Induced impact on emission

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### NACE industrial classification of economic activities (1 digit)

<table>
<thead>
<tr>
<th>NACE Macro-sector code</th>
<th>CO2e (2016)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A - Agriculture, forestry and fishing</td>
<td>534,586,391.92</td>
</tr>
<tr>
<td>B - Mining and quarrying</td>
<td>77,860,862.01</td>
</tr>
<tr>
<td>C - Manufacturing</td>
<td>840,971,066.30</td>
</tr>
<tr>
<td>D - Electricity, gas, steam and air conditioning supply</td>
<td>1,098,083,546.14</td>
</tr>
<tr>
<td>E - Water supply; sewerage, waste management and remediation activities</td>
<td>161,564,425.09</td>
</tr>
<tr>
<td>F - Construction</td>
<td>57,811,284.18</td>
</tr>
<tr>
<td>G - Wholesale and retail trade; repair of motor vehicles and motorcycles</td>
<td>77,391,486.34</td>
</tr>
<tr>
<td>H - Transportation and storage</td>
<td>503,630,311.73</td>
</tr>
<tr>
<td>I - Accommodation and food service activities</td>
<td>18,598,937.77</td>
</tr>
<tr>
<td>J - Information and communication</td>
<td>10,346,281.06</td>
</tr>
<tr>
<td>K - Financial and insurance activities</td>
<td>7,035,014.10</td>
</tr>
<tr>
<td>L - Real estate activities</td>
<td>5,830,066.52</td>
</tr>
<tr>
<td>M - Professional, scientific and technical activities</td>
<td>19,439,533.18</td>
</tr>
<tr>
<td>N - Administrative and support service activities</td>
<td>23,549,820.72</td>
</tr>
<tr>
<td>O - Public administration and defence; compulsory social security</td>
<td>29,552,649.98</td>
</tr>
<tr>
<td>P - Education</td>
<td>17,999,543.73</td>
</tr>
<tr>
<td>Q - Human health and social work activities</td>
<td>30,093,334.93</td>
</tr>
<tr>
<td>R - Arts, entertainment and recreation</td>
<td>7,145,887.39</td>
</tr>
<tr>
<td>S - Other service activities</td>
<td>9,893,256.85</td>
</tr>
<tr>
<td>T - Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use</td>
<td>356,091.23</td>
</tr>
<tr>
<td>U - Activities of extraterritorial organisations and bodies</td>
<td>79,082.70</td>
</tr>
</tbody>
</table>

*Macro-sector selected based on emissions*

*Macro-sector selected based on enabling*

*Macro-sector to be considered after TEG mandate*
From NACE to CPRS: advantages

- Different CPRS classification (e.g. fossil-fuel, energy intensive) for activities included in the same NACE (example: NACE B Mining and Quarrying)

<table>
<thead>
<tr>
<th>NACE</th>
<th>NACE1</th>
<th>NACE2</th>
<th>NACE3</th>
<th>Description</th>
<th>climate relevance</th>
<th>Relevance to Climate action</th>
<th>CPRS1</th>
<th>CPRS2</th>
<th>CarbLeak</th>
</tr>
</thead>
<tbody>
<tr>
<td>05.1</td>
<td>B-MINING AND QUARRYING</td>
<td>05-Mining of coal and lignite</td>
<td>05.1-Mining of hard coal</td>
<td>Mining of hard coal</td>
<td>H</td>
<td>Extraction of fossil fuels is main cause of direct GHG emissions</td>
<td>1-fossil-fuel</td>
<td>1-fossil</td>
<td>coal</td>
</tr>
<tr>
<td>05.10</td>
<td>B-MINING AND QUARRYING</td>
<td>05-Mining of coal and lignite</td>
<td>05.1-Mining of hard coal</td>
<td>Mining of hard coal</td>
<td>H</td>
<td>Extraction of fossil fuels is main cause of direct GHG emissions</td>
<td>1-fossil-fuel</td>
<td>1-fossil</td>
<td>coal</td>
</tr>
<tr>
<td>08.9</td>
<td>B-MINING AND QUARRYING</td>
<td>08-Other mining and quarrying</td>
<td>08.9-Mining and quarrying n.e.c.</td>
<td>Mining and quarrying n.e.c.</td>
<td>H</td>
<td>This sector does not share business model of 3-energy-intensive</td>
<td>3-energy-intensive</td>
<td>3-energy-intensive</td>
<td>C</td>
</tr>
<tr>
<td>08.91</td>
<td>B-MINING AND QUARRYING</td>
<td>08-Other mining and quarrying</td>
<td>08.9-Mining and quarrying n.e.c.</td>
<td>Mining of chemical and fertiliser minerals</td>
<td>H</td>
<td>This sector does not share business model of 3-energy-intensive</td>
<td>3-energy-intensive</td>
<td>3-energy-intensive</td>
<td>C</td>
</tr>
<tr>
<td>08.92</td>
<td>B-MINING AND QUARRYING</td>
<td>08-Other mining and quarrying</td>
<td>08.9-Mining and quarrying n.e.c.</td>
<td>Extraction of peat</td>
<td>H</td>
<td>Extraction of fossil fuels is main cause of direct GHG emissions</td>
<td>1-fossil-fuel</td>
<td>1-fossil</td>
<td>coal</td>
</tr>
<tr>
<td>08.93</td>
<td>B-MINING AND QUARRYING</td>
<td>08-Other mining and quarrying</td>
<td>08.9-Mining and quarrying n.e.c.</td>
<td>Extraction of salt</td>
<td>H</td>
<td>This sector does not share business model of 3-energy-intensive</td>
<td>3-energy-intensive</td>
<td>3-energy-intensive</td>
<td>A</td>
</tr>
<tr>
<td>08.99</td>
<td>B-MINING AND QUARRYING</td>
<td>08-Other mining and quarrying</td>
<td>08.9-Mining and quarrying n.e.c.</td>
<td>Other mining and quarrying n.e.c.</td>
<td>H</td>
<td>This sector does not share business model of 3-energy-intensive</td>
<td>3-energy-intensive</td>
<td>3-energy-intensive</td>
<td>A,C</td>
</tr>
</tbody>
</table>

- **Beyond NACE**: we consider exposure to climate risks and relevance for climate action (Battiston ea. 2017)
- **Indirect contribution of fossil fuel** firms to emissions along the chain (induced)
- **Business model** of the issuer to define its carbon intensity (emissions/revenue)
• Activities classified based on contribution to **6 EU sustainability policy objectives**:

1. Climate change mitigation (**67 activities across 8 sectors**)  
2. Climate change adaptation (methodology and worked examples for evaluating substantial contribution)  
3. Sustainable use and protection of water and marine resources  
4. Transition to a circular economy, waste prevention and recycling  
5. Pollution prevention and control  
6. Protection of healthy ecosystems  

• Guidance and case studies for **investors preparing to use the taxonomy**.
EU taxonomy: is an economic activity environmentally sustainable?

- To be considered Taxonomy-eligible, an action must:
  - Contribute substantially to one or more of the environmental objectives
  - Do no significant harm to any other environmental objective
  - Comply with minimum social safeguards (defined as ILO core labour conventions).
  - Comply with the technical screening criteria

- Thus, climate-aligned economic activities will not be eligible if they could significant harm other environmental objectives

- A sector is eligible if it passes a threshold for the sector, i.e. the sector decreases the avg emissions (according to ETS) produced from the sector
EC taxonomy aims to identify economic activities that are environmentally sustainable (activities that positively contribute to climate mitigation, adaptation, do not do harm)

Thus, it is more restrictive than CPRS.

CPRS and taxonomy depart from NACE framework and complements it

CPRS: climate risk dimension

Taxonomy: sustainability

CPSR are complementary to the taxonomy
Challenges for moving from NACE to CRPS

- **NACE 4-digit level of granularity often NOT sufficient to identify the climate risk exposure of the individual firm/issuer.** Thus, it needs to be completed with additional information→CPRS

- **Challenge:** assigning the right (business point of view) NACE 4-digit level for individual issuer requires sector-specific knowledge of the business model and emissions’ role in the value chain
  
  - This challenge arises in particular for climate relevant sectors (e.g. car manufacturing, gas transmission, railways, utility,..)
  
  - NACE Classification Trust (from TR) see correspondence in NACEtoCPRS

- Let’s look at the example of the **ECB Corporate Sector Purchase Program (CSPP)**

Challenges: example

- Let’s take a very climate-relevant sector, i.e. automotive
- Example - **Volkswagen**:
  - Parent: Porsche family thus NACE assigned to the Parent is M (same as for Ferrero, food producer in IT)
  - But we know that Porsche is car manufacturing (C) thus we need to reclassify the NACE sector based on the real economy activity of the subsidiary, i.e. Volkswagen
  - But the bonds are issued by Volkswagen N.V., which is classifies as a Trust (64.30 (M))
  - Thus we need to look down in the subsidiaries to the activity of Volkswagen A.G. car manufacturing (29.10)
- When to stop? Example 2, look at Madrilena gas
<table>
<thead>
<tr>
<th>ISIN</th>
<th>Issuer</th>
<th>LEI</th>
<th>NACE Classification</th>
<th>Issuer Consolidated Parent</th>
<th>NACE Descr</th>
<th>NACE Sector/CPR52</th>
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</thead>
<tbody>
<tr>
<td>XS1586555515 VOLKSWAGEN INTERNATIONAL FINANCE NV</td>
<td>52990C Trusts, funds and similar financial entities (NACE) (64.30)</td>
<td>Volkswagen AG FAMILIEN PORSCHE, Manufacture of motor vehicles 29.10</td>
<td>carbon-intensive transportation</td>
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<tr>
<td>XS1589806907 HEIDELBERGCEMENT FINANCE LUXEMBOURG</td>
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<tr>
<td>XS1590568132 NATURGY CAPITAL MARKETS SA</td>
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<td>Naturgy Energy Naturgy Energy Grol, Manufacture of refined petro 19.20</td>
<td>fossil-fuel</td>
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<tr>
<td>XS1595739356 MADRILENA RED DE GAS FINANCE BV</td>
<td>72450C Trusts, funds and similar financial entities (NACE) (64.30)</td>
<td>Madrilena Red I IUISANDRA SPAIN II, Distribution of gaseous fue 35.22</td>
<td>fossil-fuel</td>
<td></td>
<td></td>
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</table>
Guided exercise

1. Open the excel file Exercise CSPP that includes all the issuances of corporate bonds that qualified for the CSPP and where purchased by the National Central Banks under the ECB’s QE

2. Select one national central bank and select all the issuances purchased under the CSPP (e.g. Banca d’Italia)

3. Assign the issuer to **CPRS considering the level of the group that is relevant for CPRS**. Explain the rationale for the classification (e.g. emissions, policy relevance, risk exposure, question, etc).

4. Identify an example

5. Discuss relation between **green bonds field and CPRS**

6. **Plot** the exposures of your sample to individual CPRS (pie chart)

7. Discuss your results (ppt slide) in class (5 min)

