EEIO in Sustainable Finance: Challenges and Opportunities

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Summary

I discuss the overlap of EEIO tools with **Sustainable Finance** applications

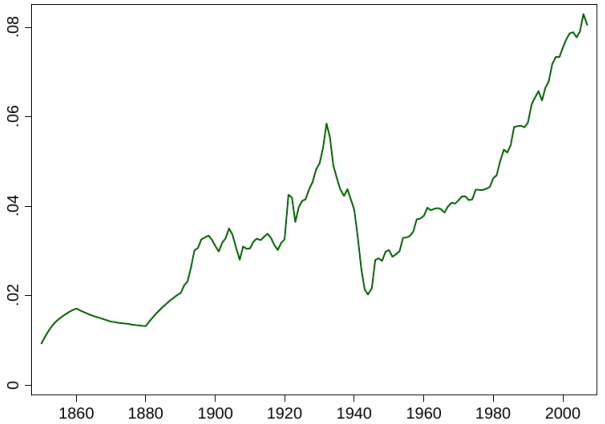
In particular their potential role in **Portfolio Management** and, more specifically,
a) the Attribution of environmental impact in financial portfolios and,
b) the Allocation of future financial resources and sustainability constraints

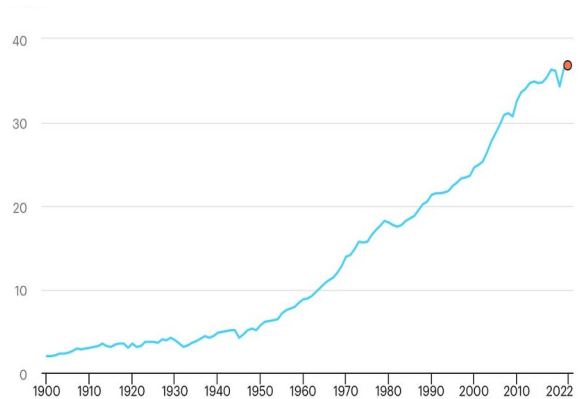
I sketch two proof-of-concept computer applications that highlight opportunities and challenges:
a) Attributing GHG emissions for a portfolio of *Public Procurement Contracts*
b) *Multi-Period Monte Carlo* simulations of EEIO systems towards new methods of capital allocation

Sustainability and Finance: a “Complex” Relation

- Financial Infrastructure (Auxiliary Services)
  - Monetary System / Payments
  - Accounting of Money and Contracts
- **Financial Intermediary** Function
  - Short Term Horizons
    - Liquidity Management
    - High Frequency Trading / Speculation
  - **Long Term Horizons (*)**
    - **Financing Contracts (*Sustainable Financing*)**
      - Equity / Debt
    - Risk Management Contracts
      - Insurance / Derivatives

(*) *The tragedy of the horizon* (M.Carney, Former BoE Governor) reflects how the typical time horizon in finance is too short to capture sustainability risks

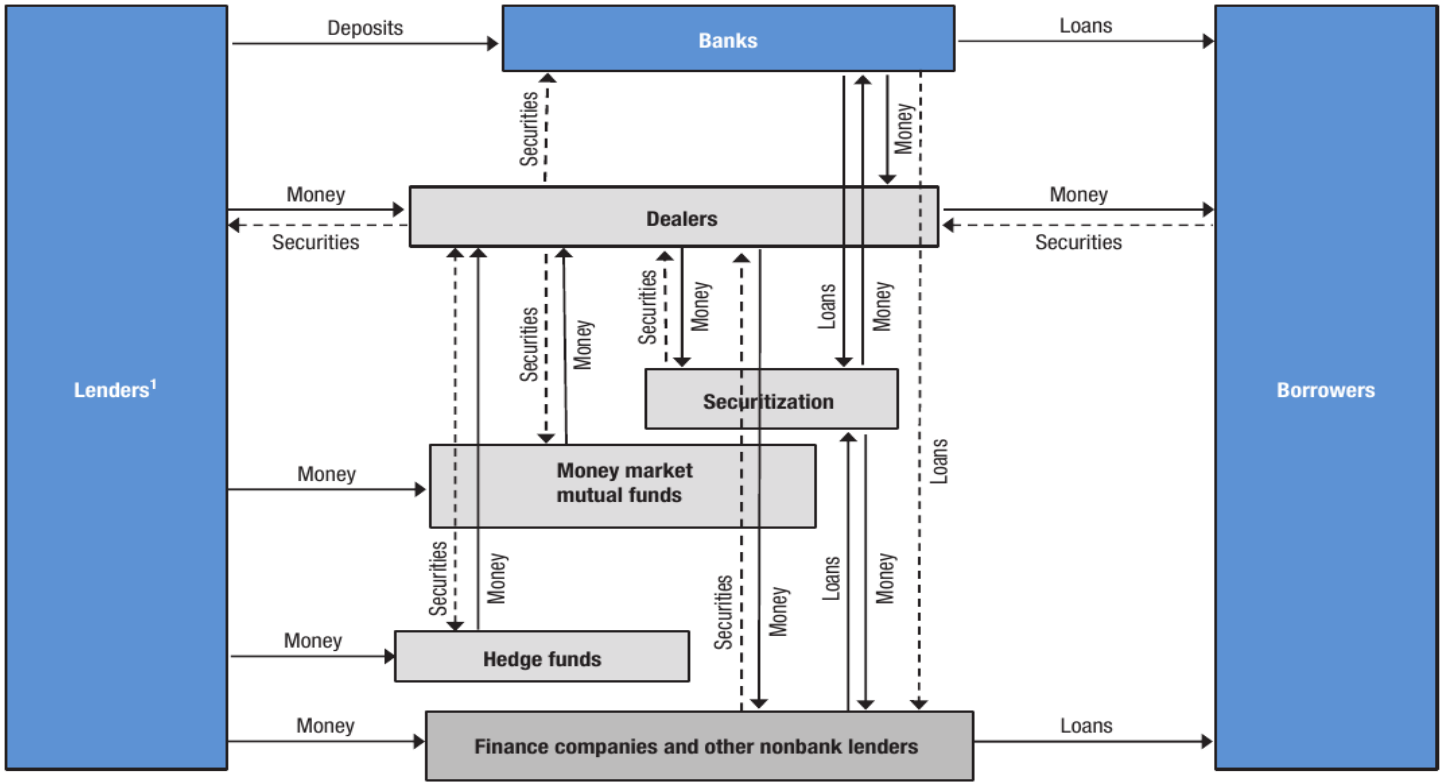




Source: T.Philippon, IEA

Sustainability and Finance: a “Complex” Relation

Figure 2.3. Traditional versus Shadow Banking Intermediation



Source: IMF, *Shadow banking around the globe, how large and how risky?*, 2014

Sustainable Finance initiatives: Multiplying and Maturing

Classify by aggregation or geographical scope

- Global Scope (UN-led, IPCC, IEA, NGO's, Regulators)
  - TCFD, TNFD, CDP, GRI, WRI
  - IFRS, ISSB
  - NGFS
- European Scope
  - EU Taxonomy
  - CSRD, NFRD, ESRS
- National Scope
  - Dutch Energy Efficient Mortgages
- Sub-national (Cities)
  - Green Public Procurement Criteria

Classify by legal status and implications

- Legally binding regulations
- Voluntary (self-regulatory) codes of conduct

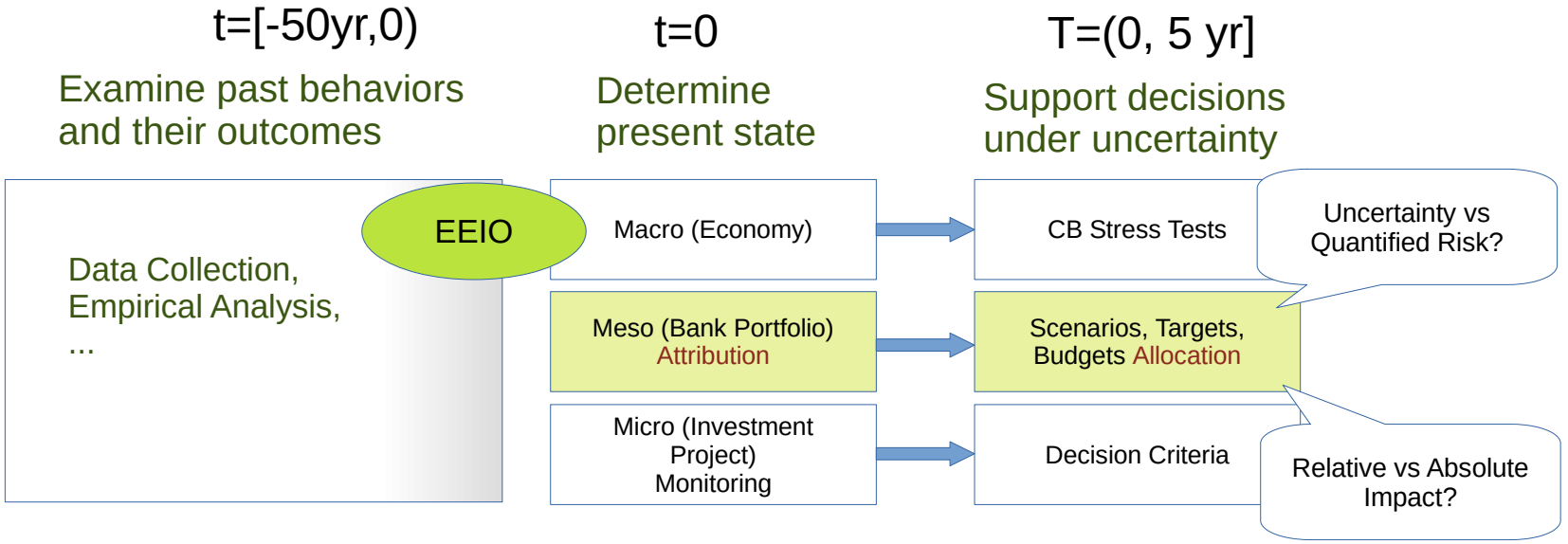
Classify by the type of economic agent x financial product

- Banks
- Asset Managers
- Insurance
- Public Sector

Classify by the objective of financial agent

- Attribution of impact (PCAF)
- Allocation of budget (SBTi, PACTA)

Portfolio Management and EEIO: The Big Picture



- PM must pursue the optimisation of a collection of financial positions while recognizing and integrating all relevant sustainability constraints
- Most of the theoretical and practical tools for sustainable PM are still missing (which is not WISE)
- Attribution is more mature than Allocation.
- EEIO fits into PM as a top-down, holistic toolkit, complementing bottom-up or project-focused tools

Current use of EEIO tools in Sustainable Finance (*)

GHG Attribution Methodologies

- GHG Corporate Protocol **(2013)**: Technical Guidance for Calculating Scope 3 Emissions. In particular, Category 15, greenhouse gas emissions associated with investments (Financed Emissions).
- TCFD, SBTi, PCAF: **Financed Emissions**: Attribution Option 3: Economic activity-based emissions. Economic activity data of the investee or borrower (e.g., turnover or asset values) are converted to emissions, using official statistical data and/or acknowledged EEIO.
- IFRS S2 Sustainability Disclosure Standard: Scope 3 greenhouse gas emissions, in accordance with the Scope 3 categories described in the Greenhouse Gas Protocol Corporate Value Chain...

(*) Based on public disclosures

- **Diverse Corporate (Voluntary) Sustainability Reports**
  - Amazon (2022)
  - Fairphone (2022)
  - Starbucks (2023)
  - TSMC (2022)
  - Bayer (2021)
  - ...
- **Financial Sector Non-Financial Reporting**
  - PCAF Banks (464 Members, 165 Disclosures as of 2023)
  - ...

Current use of EEIO tools in Sustainable Finance

EEIO tools are used for Attribution:

- Diverse databases (reflecting regional focus)
- Used commonly for attributing GHG Emissions (Financed Emissions) but also other impacts
- Used in various combinations with other approaches (LCA)
- **Considered the fall-back option in the absence of more specific data sources**

The general approach of applicable attribution methodologies is a linear formula:

Financed Emissions = Attribution Factor x Investment Entity Emissions

Where:

- the *attribution factor* aims to capture the materiality of the financing (e.g. percentage of capital structure financed)
- the *investment emissions* are computed on the basis of regional/sectoral average emissions factors expressed per economic activity (e.g., tCO2e/€ of revenue) and applied to revenue figures of the investment entity
- the nature of the emissions (producer, consumer responsibility) is directly inherited from the emission factor used. Fine grained views (Scope 2, downstream Scope 3 etc) may not be available.

GHG Attribution in Public Procurement Portfolios

Motivation: Public Procurement is a large slice of economic activity: up to 1/6 of global GDP

Objective: Calculate emissions by the *contractors* of public sector entities, screening of “hot spots” etc.

Proposed at the 2022 EU Datathon (Publications Office) to improve Transparency in Public Procurement: to build a new tool to integrate **procurement contract data** of the TED (Tenders Electronic Daily) database with regional/sectoral impact metrics provided by **EEIO frameworks**.

Granular Open Data! Availability of a very large, Europe-wide repository of contractual information about public procurement.

Towards a Public Procurement Emissions Landscape

- **TED data processed:** Initial focus was the 2017-2022 universe. Circa 53 GB / 3 million forms.
- **Data Model Richness:** 8 core classes (Project, Procurement Entity, Contractor, Contract, Emissions Source etc) and many auxiliary models (Reference Data, Dictionaries etc). Mapping all relevant TED data and supporting multiple environmental accounts
- **EEIO Data:** Currently the main dataset used is Eurostat *emission intensities* per CPA/NACE sector

Used Datasets	Purpose
TED Data (R2.0.9 filter)	The backbone for reconstructing economic activity due to public procurement
Eurostat Emission Intensities	The principal source of environmental impact attribution (tonnes CO2 per EUR)
ECB FXR Dataflow	FX reference rates for harmonizing contact values across the EU
SIMAP, Eurostat, RAMON	CPV / CPA / NACE Classifications and Correspondences
Eurostat NUTS3	Geospatial contours and point locations of NUTS3 regions

Planned Additional Datasets	Purpose
Older and Newer TED Data (R2.0.8, eForms)	Reach the full scope in terms of temporal window and contractual information that is integrated in the platform
Eurostat Environmental Accounts	Test alternative attribution methodologies (territorial, production vs consumption based etc)
ECB/Eurostat Economic Data	Provide further macro-economic indicators to normalize data (e.g. by GDP per capita etc)
EEA ETS Data	Introduce carbon price views from ETS System

Identification Issues: the quirky CPV Classification

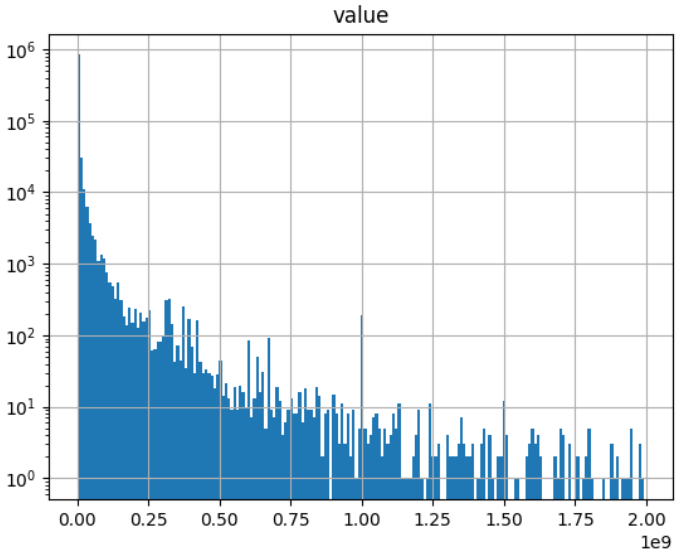
How to link a procurement contract to an economy sector and its activities / footprint?

- The CPV Classification (Common Procurement Vocabulary)
  - Legally binding and widely used, aligns with public procurement practices
  - Does not have semantic definition (category labels are all the meaning there is)
  - Does not have a clear economic activity mapping. Partially compatible mappings between the statistical open data universes (e.g. CPV vs CPA/NACE)
- CPV Categories:
  - Goods (Supply) Contracts
  - Services Contracts
  - Works Contracts
- Current solution: a manual map of top (~80) level CPV categories to Eurostat AEA Categories via CPA codes

CPV Code	CPV Description	CPA Code	CPA Description
77	Agricultural, forestry, horticultural, aquacultural and apicultural services	CPA_A01	Products of agriculture, hunting and related services
03	Agricultural, farming, fishing, forestry and related products	CPA_A01	Products of agriculture, hunting and related services
772	Forestry Services	CPA_A02	Products of forestry, logging and related services

Sample of the manual identification table

Identification / Data Quality Issues: Accuracy of Financials



Histogram of contract values in EUR (log scale)

The statistical distribution of (reported) contract values (log plot) indicates potential “outlier” buckets at > 1.00 bln procurement values.

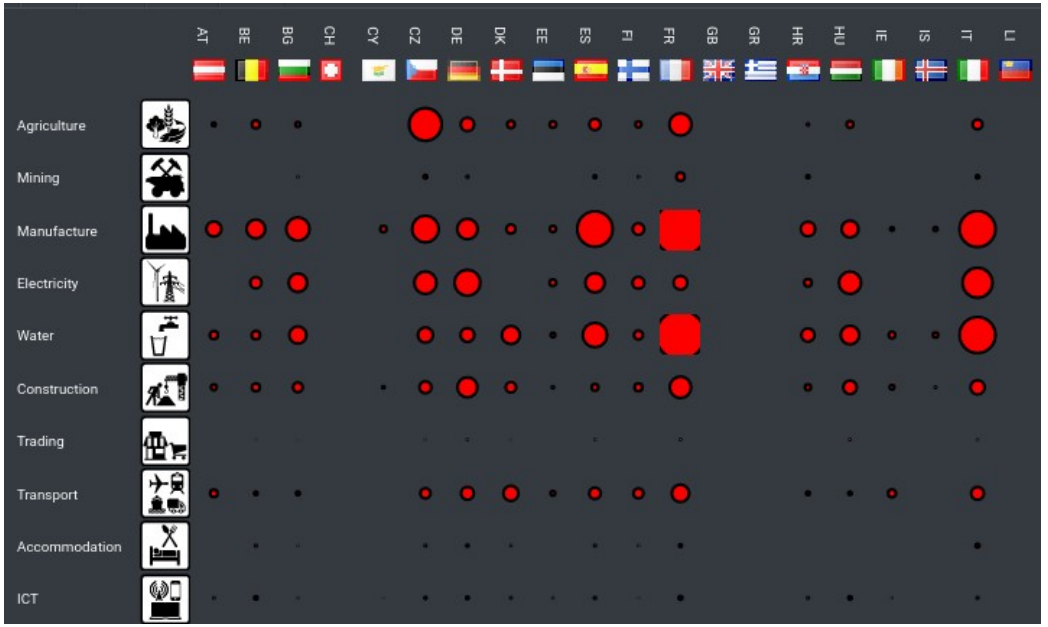
People are filling the forms with random contract values to preserve secrecy.

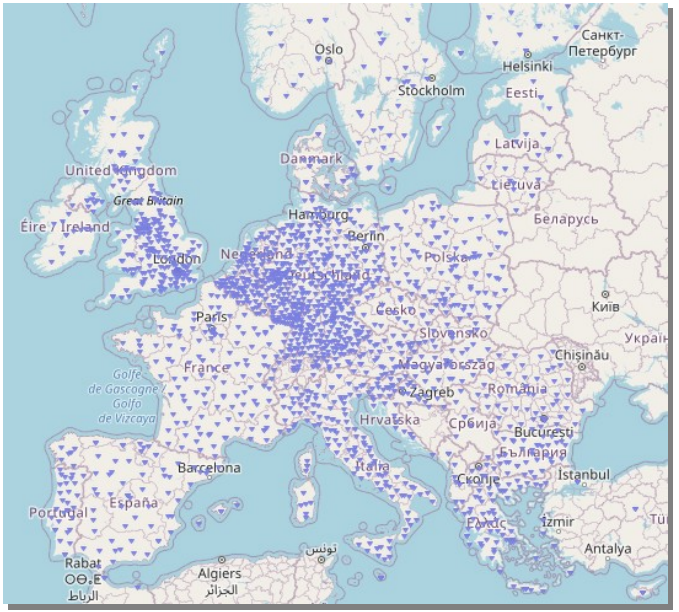
Also large number of “zero value” contracts.

Multiple CPV codes per contract without value breakdowns

Values must at least be be annualized to be compared to sectoral averages.

An Europe-wide overview of Procurement Emissions





Data driven visualizations help create overviews and heat-maps. This example uses the entire TED procurement dataset and pictograms to illustrate a Sector x Country grid of attributed GHG emissions.

TED data are extremely granular by location and CPV – the main constraint is the currently *limited granularity of environmental accounts*

NUTS3 level data is sometimes available or can be inferred from address information of the procurement entities.

Portfolio Management of Public Procurement Emissions

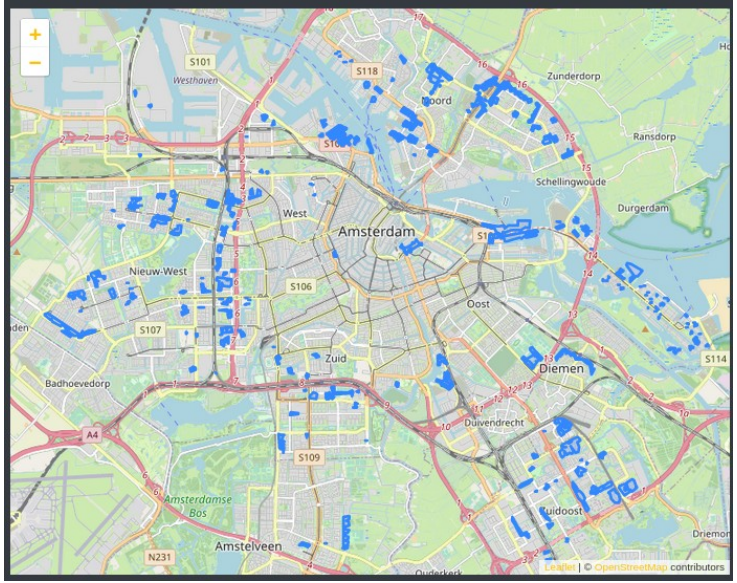
Report of Procurement Portfolio Emissions

Show 50 entries

Project Title	Budget (EUR)	CPV	CO2 (Tonnes)
(MAT 11) dostawa koncentratów kompotów	3263125	15332100	224.8
(MAT 21) Dostawa sucharów specjalnych SU-2	300013	15820000	20.7
035 ISE Freiburg 755 907 Neubau G Forschungsgebäude ZhS_04 Rohbauarbeiten	3187747	45262310	536.2
1/DLII5/IV220_EleBAT	2937247	39121100	202.4
18O30354; TU C, Inst.f.Strukturleichtbau (MERGE) 2.BA Labore	93392	45321000	15.7
19O30008 TU BAF, Fakultät f. Maschinenbau, Neubau Hallenkomplex 2. BA	26827	45420000	4.5
19O30032 FA ANA, bedarfsgerechte Unterbringung	300006	45410000	50.5
19O30034 TU BAF, Infrastruktur, 4. TBM, Wissenschaftskorridor	610948	45112500	102.8
19O30041 TU C, Inst.f.Strukturleichtbau (MERGE) 2.BA Labore	53190	45262320	8.9
19O30043 TU BAF, Neubau Universitätsbibliothek/Hörsaalzentrum	329200	42416120	22.7
19O70009; Sächs. Krankenhaus Altscherbitz, Haus 19,20,21, Umbau und Sanierung	140539	45215100	23.6
2 Rammeaftaler på henholdsvis Fødevarer og Fisk, Fjerkræ, Salater/dressinger samt Juice/Saft	29033006	15000000	2000.4

Conventional (tabular) reports are the bread-and-butter of portfolio management. The constructed database can be filtered using standard queries.

Map of Area Sources



Where applicable emissions sources can be associated with a geospatial object (point, polygon) and can be placed on a map.

The data for achieving this mapping are not in TED and must be sourced elsewhere

Enablers and challenges of using EEIO in this use case

Enablers:

- Comprehensive coverage and (relative) standardization of the TED database of procurement contracts as open data
- The open availability of EEIO data of some granularity from Eurostat
- A vibrant open source data science ecosystem (numpy, pandas) and cost effective deployment of geospatial web apps via open source databases and web platform (postgis, geodjango)

Challenges:

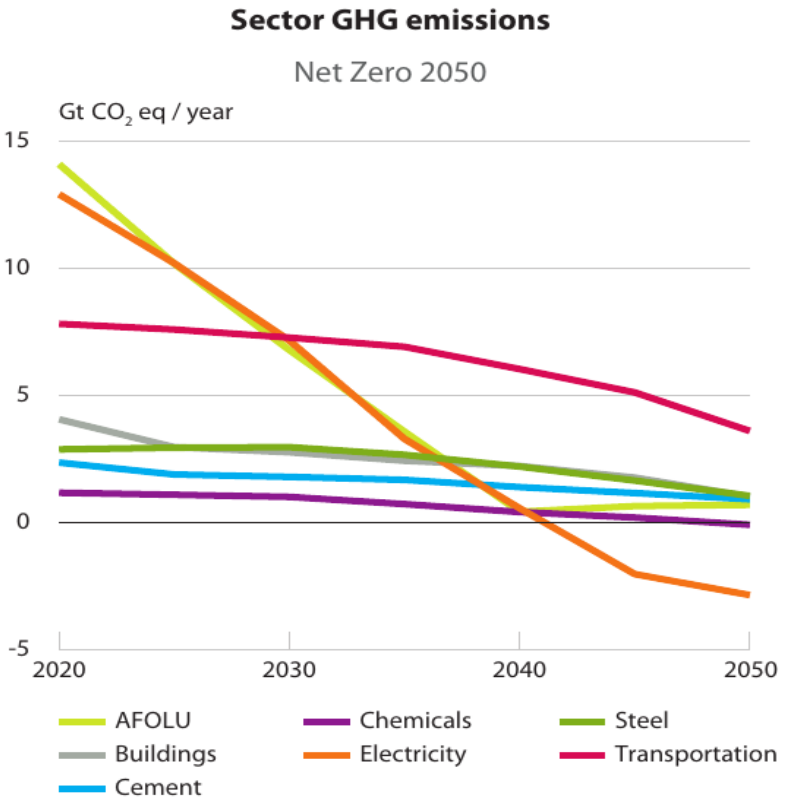
- ***Semantic Universe Silos***:
  - Only partially compatible mappings between the various official statistical universes (e.g. CPV vs NACE)
  - Aligning the meaning of monetary figures on procurement contracts versus EEIO tables
- Data Quality: Inaccurate contractual amounts complicate and potentially bias results
- Multilingual nature of textual information
- ***Granularity Level:*** Linking average sectoral footprints to individual contracts does not recognize e.g., any GPP criteria

Monte Carlo analysis of Future Portfolio Emissions

Objective: Calculate *future* financed emissions, the likelihood of meeting targets, of non-compliance with limits etc.

Propagating environmental impacts provided by EEIO frameworks for the current portfolio into the future, taking into account external and internal information (scenarios, available budgets, limits and financial objectives) *and uncertainties*.

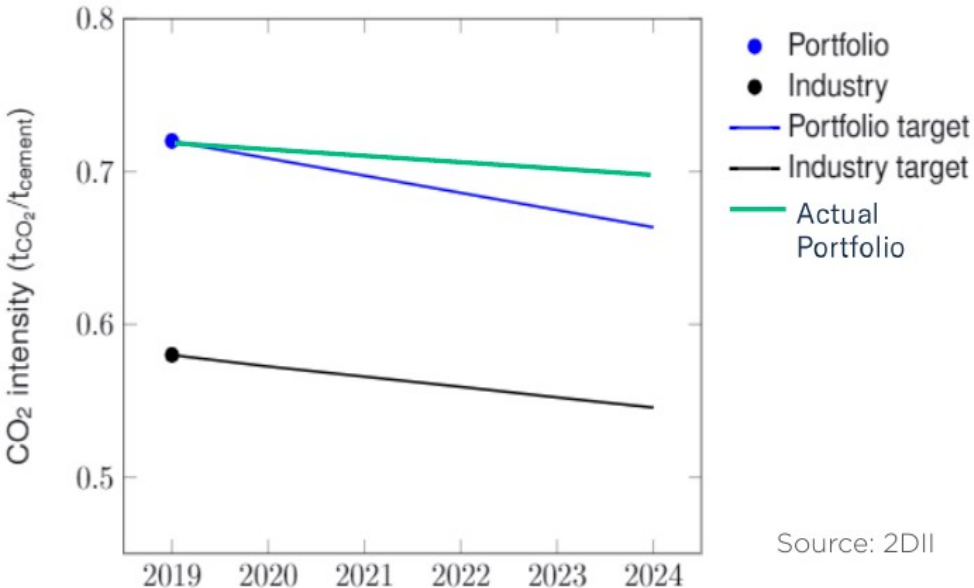
NGFS Scenarios (2021): Used in Cental Bank stress testing (Network for Greening the Financial System)



Source: IIASA NGFS Climate Scenarios Database, GCAM model.
AFOLU is agriculture, forestry and other land use.

Methodologies for Portfolio Alignment with Paris Targets

- Financial industry is building on IPCC / IEA Pathways. E.g., SBTi Sector Decarbonisation Approach (Intensity paths for key sectors)
- Paris Agreement Capital Transition Assessment (PACTA) methodology (Open Source)
  - 5 year horizon
  - Sectors with/without technology transition paths
  - A “market” benchmark
- Portfolio Alignment is as a process that requires:
  - Measuring Impact (must be consistent with Attribution)
  - Setting Targets (Define portfolio alignment indicators: absolute, relative)
  - Steering capital allocation (extending classic financial objectives)
  - Monitoring and tracking progress



Portfolio Management Tools: Past and Future

Best Practices of the Past

- Focus on financial capital
  - Markowitz Portfolio Theory
  - Capital Asset Pricing Models
  - Factor Models
  - Volatility / Covariance / Correlations
- Data mostly from public equity markets
  - “Cleaning” / filtering with assumptions
  - Structural models of the firm

$$E\left(R_i\right) = R_f + b_i\left(E\left(R_m\right) - R_f\right)$$

Future Best Practices?

- Consistency with **Attributed** footprint of current portfolio
  - Methodologies adopted for attribution must be projected
  - EEIO at future times under various scenarios
  - Take into account accepted, defendable scenarios and both market and technological market uncertainty
- Assert that Budgets, Targets and Limit Frameworks with both monetary and impact dimensions are sound
- On ongoing basis (once implemented), provide a running *explanation* of developments
  - Is there a causal explanation that links the current (updated) portfolio state with the previous state? Which shock realizations contributed to and explain the outcome?
  - The explain process assumes that, e.g., footprint **changes** can be verified
- Slicing and dicing the new relevant dimensions
  - Producer, Consumer, Income Responsibility, Different types of environmental impact

Why Monte Carlo in EEIO Context?

Previous MC applications in EEIO literature

- Standard technique going back decades (*)
- Used to assess uncertainty from data pipeline and methodology choices
- Parametrization of uncertainty reflects e.g., empirical data quality profiles
- Helps study the propagation of errors and the confidence intervals around estimates

(*) *Monte Carlo Sensitivity Analysis of Input-Output Models*, Bullard Sebald, 1988

A different point of view on Monte Carlo:

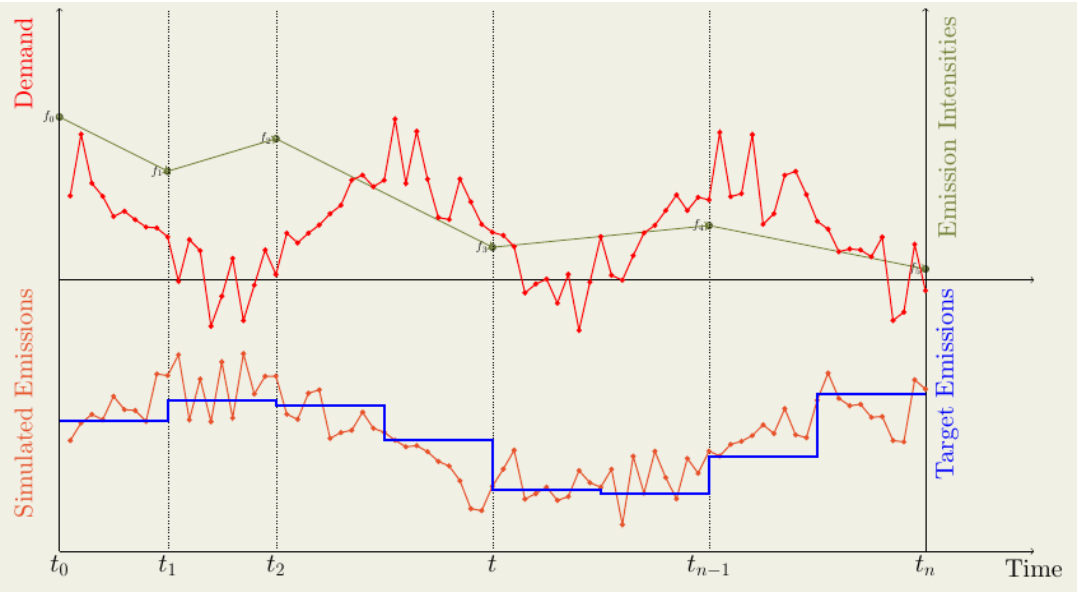
- We assume an EEIO framework is accurate as of time zero.
- We approach Monte Carlo simulation of EEIO elements as a generic way to establish "**what-if" and uncertainty of future outcomes**
- The multi-dimensional nature of financial factors and sustainability objectives, the diverse underlying drivers (and statistical distribution) and possible non-linear evaluations means a significant amount of computation is involved
- Not a specific new model, rather a computational technology and building block.
- This type of Monte Carlo very common in classic financial portfolio / risk management.

Monte Carlo Simulation of Portfolio Impact using an EEIO system

- A general purpose, multi-period, Simulation Framework spanning the target setting period (e.g., 5 years)
  - Y(t) models uncertain and fast moving market demand (which drives production volume).
  - f(t) models emission intensity paths (and uncertainties). Slower moving / expert based.
  - A(t) models economic structure development (and uncertainties). Slower moving or static.
  - U(t) footprint vector of the economy
- Portfolio Metrics
  - w(t) are portfolio exposure allocation weights to sectors
  - P(t) are projected portfolio sectoral contributions
  - L(t) might be target emissions of limit (max emissions)
- Calculate metrics such as likelihood of meeting targets (exceedance probability) per sector and in total

$$U_t^E = f_t \left(I - A_t \right)^{-1} Y_t$$

$$P_t = w_t U_t^E$$



MC Timing Experiments using C++ libraries (Eigen)

Matrix Size	Single Run (in sec)	Run X 1000 (in min)	Run X 1000000 (in hr)
10	0.0002	0.003	0.0
25	0.0005	0.008	0.1
50	0.0019	0.031	0.5
100	0.0093	0.155	2.6
200	0.0330	0.549	9.2
300	0.0948	1.580	26.3
500	0.2949	4.915	81.9
700	0.7491	12.484	208.1
800	1.0690	17.817	296.9
900	1.4085	23.476	391.3
1000	1.8707	31.178	519.6
1300	3.2737	54.561	909.4
1400	3.9717	66.195	1103.2
1500	4.8209	80.349	1339.1
2000	10.8740	181.233	3020.6
2500	18.3311	305.518	5092.0
3000	29.8149	496.915	8281.9
4000	62.2094	1036.823	17280.4
5000	112.3530	1872.550	31209.2
10000	757.4750	12624.583	210409.7

How long does it take?

Instant (~sec)

Check Socials (~min)

Write Email (~hr)

Sleep Over it (~day)

Table with timing results for a C++ implementation of an EEIO solver (Solstice), running on a 16-core CPU, 32GB RAM. The size of IO matrix (vertical) is from 10x10 to 10Kx10K, versus number of times calculated (horizontal) – from single run, to 1K simulations, to 1M simulations. **There is definitely a window of opportunity!**

Open Source Tools towards Sustainable Portfolio Management

Code and Data

Equinox

Web Application / Database
[Live at sustainability.town]

Solstice

Flexible MC Simulation of Economic Networks
[Under Construction]

Knowledge and Training

A wiki for all things risk management

Open Risk Academy

Features several tutorials
Sustainable Finance

THANK YOU!