Disaggregating and hybridizing the FIGARO EU-ICIOT to estimate material footprints

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Introduction
Calculation of material footprints for the EU

Material footprint: indicator used for monitoring the SDGs (goals related to sustainable economic growth and sustainable consumption and production)

Domestic extraction + Imports in Raw Material Equivalents (RME) – Exports in RME

Update and further development of the EU-RME model

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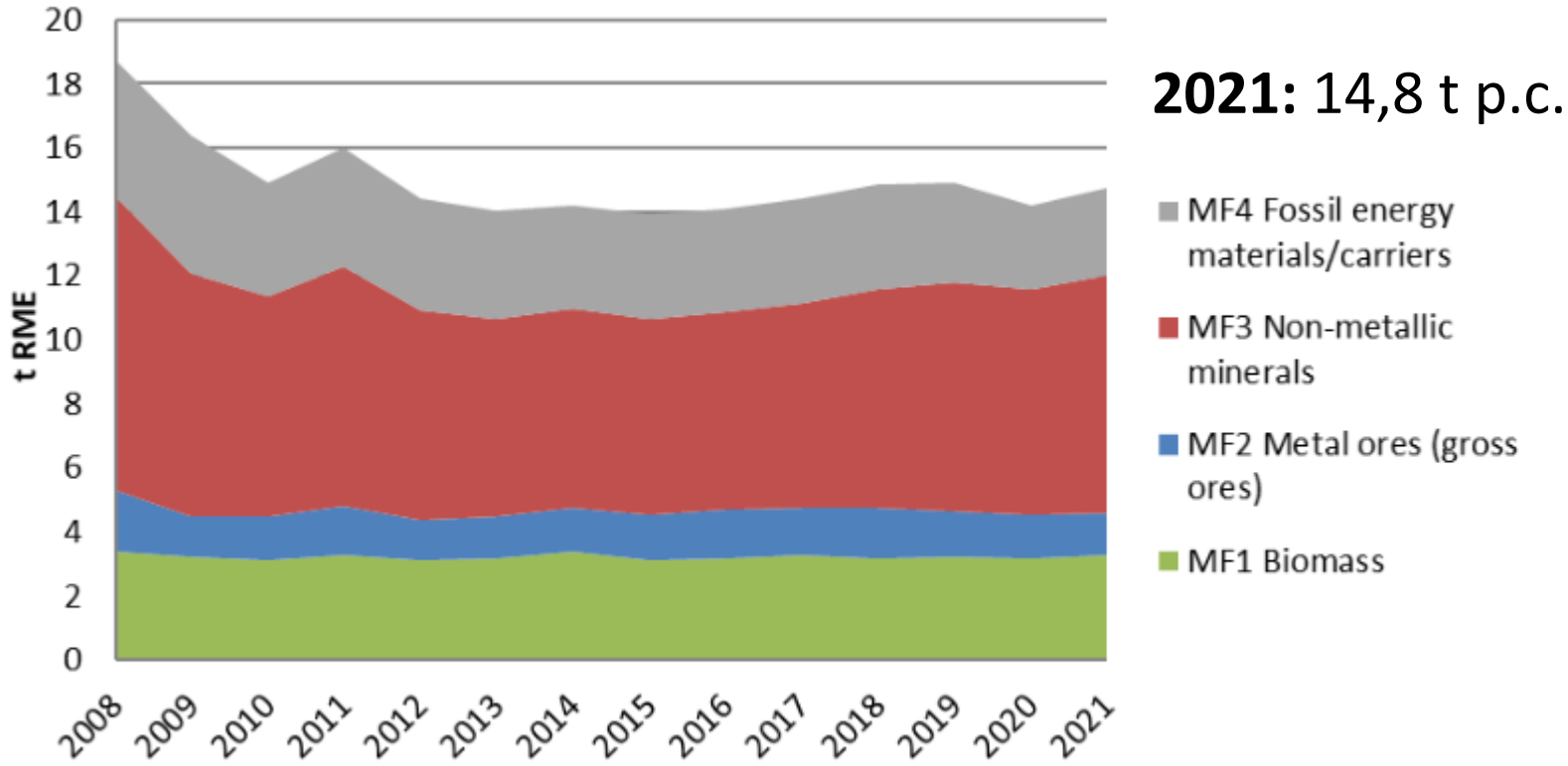
Project commissioned by: Eurostat, 2023-2026

Introduction
Calculation of material footprints for the EU

Material footprint (RMC) per capita in the EU



2021: 14,8 t p.c.

Source: Eurostat (env_ac_rme)

Introduction
Calculation of material footprints for the EU

EU-RME Model
Single-region hybrid IOT model (182 product groups)
ADTA assumption

RME indicators for the EU

RME Country tool
Coefficient approach

RME indicators for EU countries

Source: Schoer et al. (2024): Documentation of the EU RME model, Eurostat.

Introduction
Objective

EU-RME Model
Single-region hybrid IOT model (182 product groups)
ADTA assumption

RME indicators for the EU

RME Country tool
Coefficient approach

RME indicators for EU countries

FIGARO EU-ICIOT
64 product groups
27 EU countries
18 non-EU countries
1 RoW region

Disaggregation and hybridization

1) EU countries using data from Eurostat

2) Non-EU countries using data from international sources

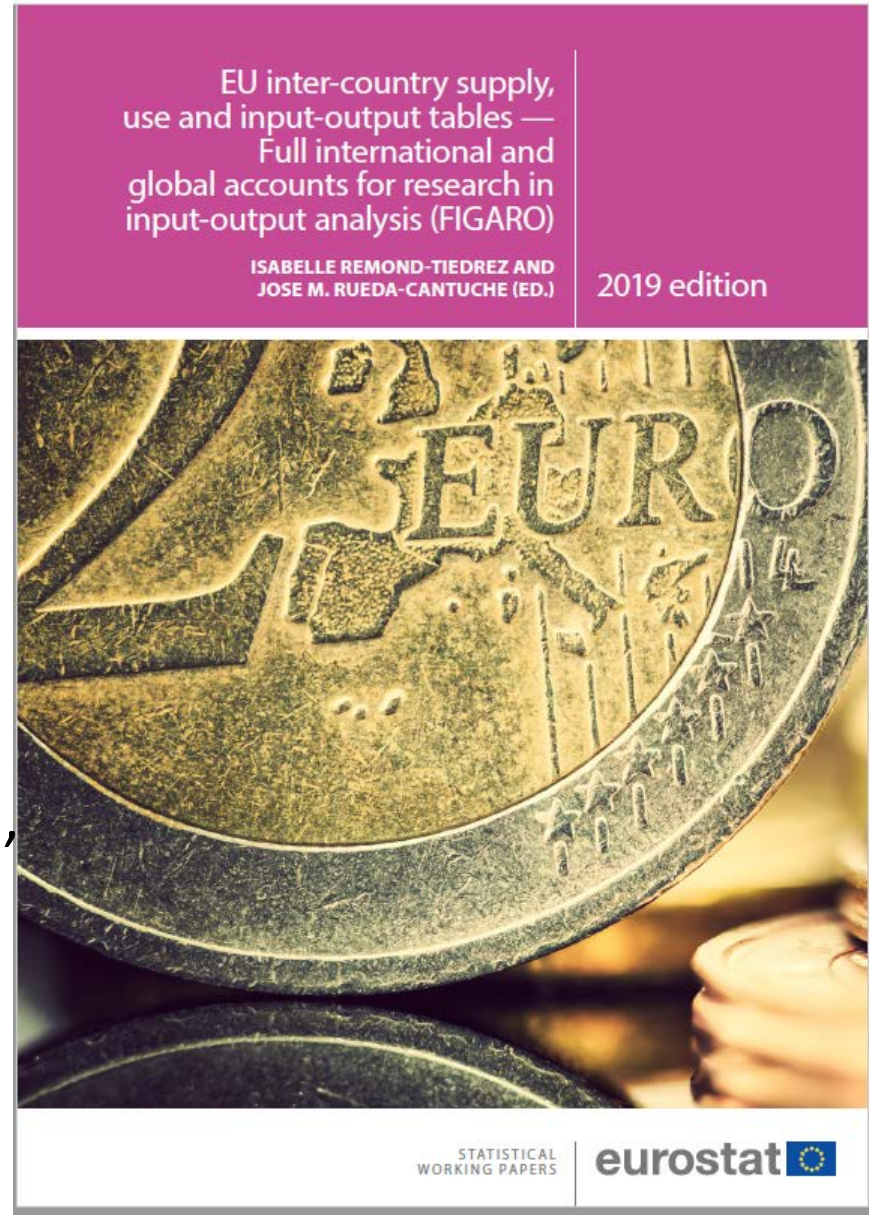
Future MRIO EU-RME Model
Disaggregated hybrid Model
Based on the EU-ICIOT

Aim: Estimation of material footprint indicators

Introduction
Objective

FIGARO EU-ICIOT

- **MRIO** published by Eurostat
- Annual update, current time series: 2010-2021
- 64 product groups
- **Regions:**
  - EU27, Switzerland, Norway
  - G20: United Kingdom, Russia, Argentina, Brazil, Canada, Mexico, United States, South Africa, China, Indonesia, India, Japan, South Korea, Saudi Arabia, Turkey, Australia
  - RoW region



Sources: Remond-Tiedrez & Rueda-Cantuche (eds.) (2019): EU inter-country supply, use and input output tables.

Development of a harmonized hybrid EU-RME MRIO model
Characteristics

MRIO model optimized for material footprint calculations

- **46 regions** (EU27, 18 non-EU countries, 1 RoW region), **2010-2022**
- **Differentiation of 163 product groups** to reduce aggregation error
  - Mining: disaggregated into 30 separate product groups
  - Agriculture: … 20 product groups
  - Minerals: … 8 product groups
  - Metals & metal products: … 22 product groups
- **Hybrid model** (mixed monetary & physical units, 67 products in physical units)
  - Agriculture/Fishery/Forestry/Minerals in kt
  - Energy carriers in ktoe
  - Metals and metal ores in kt metal content
  - Minerals in kt

Development of a harmonized hybrid EU-RME MRIO model
Characteristics

Rationale for hybridization

- **Aim:** improve the allocation of embodied raw materials to consumers

Criteria for selecting product groups for hybridization:

- High degree of raw material intensity
- High degree of homogeneity
- Availability of information on output in physical terms
- Availability of information on the sales structure in physical terms (energy/agriculture)

Development of a harmonized hybrid EU-RME MRIO model
Methods

1. **Preparation of input data**
   - **EU:** Eurostat (Structural Business Statistics, Prodcom, MFA, Agricultural Accounts, Energy Balance), balanced ITGS trade dataset, BGS Mining
   - **Non-EU:** UN-IRP Material Flows, IEA/UNSD Energy balance, FAO Agricultural statistics, UNIDO Industry Statistics, USGS/BGS Mining and Metal production and BACI Balanced trade data
2. **Disaggregation of the monetary EU-ICIOT**
   - Country-by-country approach
3. **Hybridization of the disaggregated EU-ICIOT**
4. **Calculation of material footprints**

→ **feasible** only because we have the EU-ICIOT as a basis for the disaggregation,

Development of a harmonized hybrid EU-RME MRIO model

Methods: Data sources for non-EU countries

Data	Monetary data	Data in physical units
Agriculture, forestry and fishing (output)	• FAO Agricultural statistics	• UN-IRP Material flows • FAO Agricultural statistics • FAO Fishery statistics
Mining and metals, minerals (output)	• UNIDO MinStat • UNIDO IndStat (ISIC Rev. 3/4) • Data in physical units and conversion with prices	• UN-IRP Material flows • USGS Mineral yearbooks • BGS World Mineral Production • Austrian World Mining Data
Manufacturing (output)	• UNIDO IndStat (ISIC Rev. 3/4)	• Wood: FAO
Energy (output)	• Data in phyiscal units and conversion to prices	• UN-IRP Material flows • IEA energy balances • (UNSD energy balances)

Development of a harmonized hybrid EU-RME MRIO model

Methods: Data sources for non-EU countries

Data	Monetary data	Data in physical units
EU-ICIOT for 2010-2021	• FIGARO EU-ICIOT, 2023 edition	
Bilateral trade (all product groups)	• ITGS trade dataset at HS6 level	• BACI trade dataset at HS6 level *(probably)*
Domestic extraction (extension)		• UN-IRP Domestic extraction
Generic input coefficients	• Input coefficients from German 3R-model RoW region	

Development of a harmonized hybrid EU-RME MRIO model

Methods: Disaggregation of the monetary EU-ICIOT

Country-by-country approach

- We separate the EU-ICIOT into country blocks and apply the disaggregation algorithm separately for each country.
  - Total imports and exports (by 163 product groups) between two regions are fixed beforehand.
  - The disaggregated MRIO is balanced using GRAS to match the original aggregated EU-ICIOT.

- Sources: e.g. Junius & Oosterhaven (2003): The solution of updating or regionalizing a matrix with both positive and negative entries. Economic Systems Research, 15(1), Temurshoev et al. (2013): A note on the GRAS method, Economic Systems Research 25(3).

Development of a harmonized hybrid EU-RME MRIO model

Methods: Disaggregation of the monetary EU-ICIOT

Generalized RAS algorithm (GRAS/iterative scaling)

- **Purpose:** balance input-output tables to ensure that constraints are met
- for IOTs with negative entries (e.g. in changes in inventories)
- Positive entries are multiplied and negative entries are divided by correction factor
- In our case, **constraints** are:
  - Total domestic use (row sum)
  - Total output (column sum)
  - Original EU-ICIOT with 64 product groups

- Sources: e.g. Junius & Oosterhaven (2003): The solution of updating or regionalizing a matrix with both positive and negative entries. Economic Systems Research, 15(1), Temurshoev et al. (2013): A note on the GRAS method, Economic Systems Research 25(3).

Development of a harmonized hybrid EU-RME MRIO model

Methods: Disaggregation of the monetary EU-ICIOT

Simplified example: three regions (A/B/C), two product groups (P1/P2) in aggregated form, one final demand category

		C. A		C. B		C. C		C. A	C. B	C. C
		P1	P2	P1	P2	P1	P2	fd	fd	fd
C. A	P1									
	P2									
C. B	P1									
	P2									
C. C	P1									
	P2									
TVA										

Development of a harmonized hybrid EU-RME MRIO model

Methods: Disaggregation of the monetary EU-ICIOT

Simplified example: separate country blocks, aggregation of imports and domestic production to a single IOT, Here: region C.A

		C. A		C. A	Total C. A cons	Export	Total output
		P1	P2	fd			
C. A	P1						
	P2						
Total IMC input							
TVA							
Total input							

Development of a harmonized hybrid EU-RME MRIO model

Methods: Disaggregation of the monetary EU-ICIOT

Simplified example: disaggregation at the product level for region C.A

		C. A					C. A	Total C. A cons	Export	Total output
		P1a	P1b	P1c	P2a	P2b	fd			
C. A	P1a									
	P1b									
	P1c									
	P2a									
	P2b									
Total IMC input										
TVA										
Total input										

Development of a harmonized hybrid EU-RME MRIO model

Methods: Disaggregation of the monetary EU-ICIOT

Simplified example: adding a regional disaggregation for imports

		C. A					C. A	Total C. A cons	Export	Total output
		P1a	P1b	P1c	P2a	P2b	fd			
C. A	P1a									
	P1b									
	P1c									
	P2a									
	P2b									
C. B	P1a									
	P1b									
	P1c									
	P2a									
	P2b									
C. C	P1a									
	P1b									
	P1c									
	P2a									
	P2b									
Total IMC input										
TVA										
Total input										

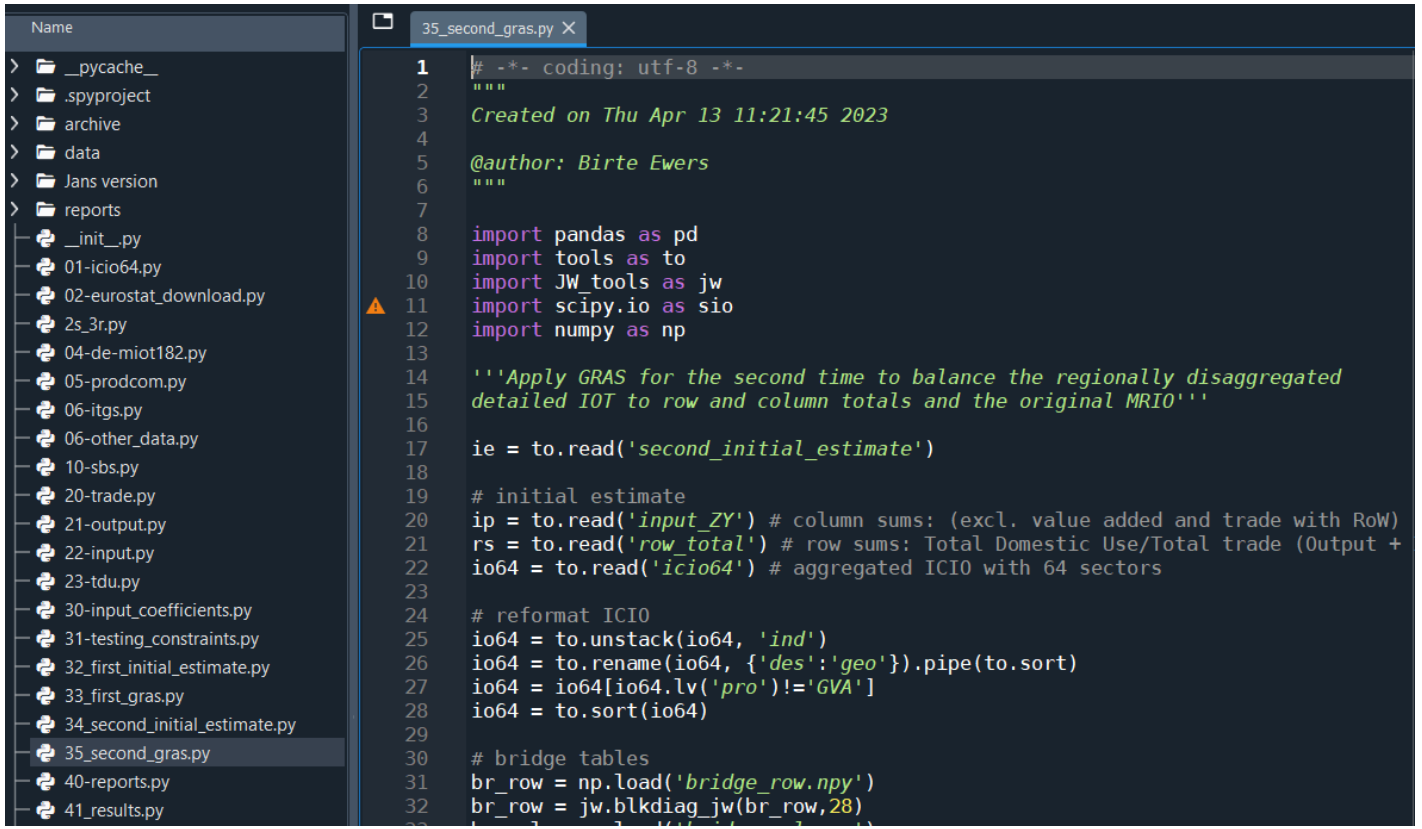
Development of a harmonized hybrid EU-RME MRIO model
Methods: Disaggregation of the monetary EU-ICIOT

Summary of the disaggregation algorithm

- Aggregate the EU-ICIOT into separate country IOTs
- Derive a **first initial estimate** based on **input coefficients** and the **column total** for each product group
- Apply **GRAS** to balance the initial estimate
  - Constraints: EU-ICIOT, row total (Total domestic use), column total
- Derive a **second initial estimate** adding the international dimension by splitting the rows according to the region of origin
  - Assumption: internationally traded products have the same sales structures as products of domestic origin
- Apply **GRAS** to balance the second initial estimate
  - Constraints: EU-ICIOT, row total (Domestic use of domestic products, imports), column total
- Move residuals to ‘Changes in inventories’
- Combine the country blocks to create the disaggregated MRIO

Development of a harmonized hybrid EU-RME MRIO model
Technical implementation

- Set of **Python** scripts
- Use of the **Numpy** package for the actual iterative algorithm
- Use of **Pandas** for data processing
- Currently: 2000 lines of code
- Many checks for validating the internal consistency of data processing



Harmonized hybrid EU-RME MRIO model
Challenges and open issues

- very large datasets to handle
- missing and confidential data at the detailed product level
- negative numbers at unexpected places in the original EU-ICIOT
- Changes in inventories are used as residual during the original creation of the EU-ICIOT and during our own balancing
- Many of the international data sources need to be downloaded manually which increases the effort for a possible annual update of the model

Harmonized hybrid EU-RME MRIO model
Ongoing work

1. **Preparation of input data** → completed for EU countries
2. **Disaggregation of the monetary EU-ICIOT** → completed for EU countries
3. **Hybridization of the disaggregated EU-ICIOT** → spring 2024
4. **Calculation of material footprints** → summer 2024

Thank you for your attention.

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