

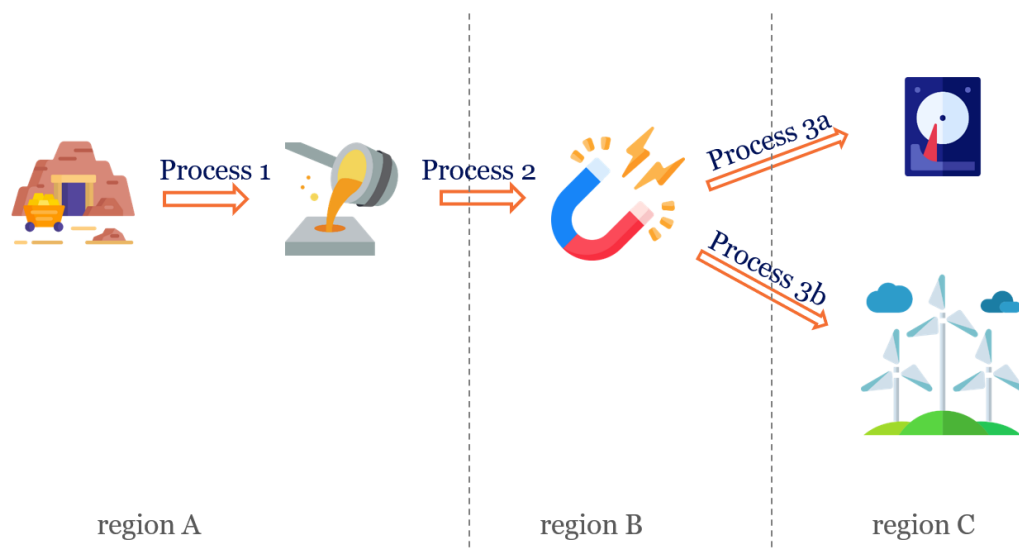
Week 9 Environmental footprints of the nations

Objectives

- Review and better understand the structure of MRIO
- Perform MRIO calculations in Python

Part 1:

This is a simplified international supply chain of Hard Disk Drive/ Wind Turbine. Please locate each process along the supply chain into the MRIO matrices.



	A	B	C	A	B	C
region A	Z_{AA}	Z_{AB}	Z_{AC}			
region B	Z_{BA}	Z_{BB}	Z_{BC}		Y	
region C	Z_{CA}	Z_{CB}	Z_{CC}			
		V				
		F				

Part 2: Python exercises

Background information

The world in 2015 is represented by three regions:

- R1 (OECD, i.e. 'developed' countries)
- R2 (BRICS, i.e. major emerging countries, including Brazil, Russia, India, China, and South Africa)
- R3 (ROW, countries in the *rest of the world* aggregated)

The economy of each region is classified into eight sectors according to the main purposes they contribute to:

- S1 Food, S2 Clothing, S3 Shelter, S4 Construction, S5 Manufactured products, S6 Mobility, S7 Trade, and S8. Services

The four final demand categories are:

- Final consumption expenditure by household
- Final consumption expenditure by NPISHs
- Final consumption expenditure by government
- Gross capital formation

Data of gross output (x), final demand (Y), and inter-industry transaction data (Z), in current million €, and 'environmental extension' (F) and household direct emissions and/or resource extractions (Fhh), and population data can be downloaded from BrightSpace (Week 9). They are also presented in this file (Page 3-5).

Tasks

1. Download and use the Python code (both Jupyter and Spyder available) from BrightSpace to import and convert all variables from .txt files to numpy arrays.

2. Create a series of "environmental intensity" vectors in a single array which contain information on different environmental (and non-environmental) variables, i.e. blue water consumption (million m³, or Mm³), CO₂ emissions (metric tons, or tonnes), value added (million €), and jobs (1000 people) per €1 million output.

3. Calculate the Leontief Inverse matrix: $L=(I-A)^{-1}$

(Note: calculate the Technical Coefficient Matrix A first, the Z matrix normalised by output.)

4. a. Calculate the carbon footprint of the three regions.

(Note: $EF = fLY + Fhh$)

b. Compare them with their territorial CO₂ emissions.

(Note: F and Fhh are constructed from territorial, production-based perspective)

c. Trace the regions' carbon footprints to producing sectors and regions.

(Note: to retain the producing sector-region breakdown, diagonalize the intensity vector f)

5. Calculate each region's net CO₂ import (i.e. net emission displacement) through trade.

Data:

Gross output (**x**)
(unit: million €/year):

R1	S1	3.3E+6
	S2	5.3E+5
	S3	2.5E+6
	S4	4.8E+6
	S5	1.1E+7
	S6	4.0E+6
	S7	2.6E+6
	S8	3.3E+7
R2	S1	2.9E+6
	S2	1.3E+6
	S3	1.8E+6
	S4	4.2E+6
	S5	9.9E+6
	S6	1.8E+6
	S7	9.7E+5
	S8	8.1E+6
R3	S1	2.5E+6
	S2	3.6E+5
	S3	1.5E+6
	S4	3.1E+6
	S5	5.5E+6
	S6	1.9E+6
	S7	1.5E+6
	S8	8.9E+6

Final demand: four categories distinguished (**Y**)
(unit: million €/year):

		R1				R2				R3			
		HH	NPISHS	GOV	GCF	HH	NPISHS	GOV	GCF	HH	NPISHS	GOV	GCF
R1	S1	1.8E+6	1.6E+3	5.4E+3	4.6E+4	1.7E+4	1.9E+3	4.9E+2	2.3E+3	9.8E+4	8.8E+1	2.2E+2	1.9E+3
	S2	2.9E+5	1.3E+1	2.5E+3	1.2E+4	5.7E+3	3.8E+1	2.9E+1	1.6E+2	3.2E+4	2.1E+2	8.4E+1	1.3E+3
	S3	6.6E+5	1.9E+3	2.2E+4	1.2E+5	7.1E+3	1.2E+1	6.0E+1	2.5E+2	2.6E+3	2.6E+1	3.2E+2	1.4E+3
	S4	6.8E+4	1.3E+2	3.0E+3	3.1E+6	5.5E+2	7.8E+0	3.7E+1	5.9E+3	2.7E+3	8.9E-2	7.0E+0	1.3E+4
	S5	1.8E+6	4.6E+3	1.3E+5	2.1E+6	4.5E+4	3.6E+2	4.4E+2	2.0E+5	2.1E+5	6.0E+2	3.3E+3	3.0E+5
	S6	1.2E+6	9.8E+3	5.9E+4	2.8E+4	4.6E+3	1.5E+2	1.1E+3	3.8E+2	4.0E+4	3.8E+1	5.6E+2	2.0E+3
	S7	4.0E+5	2.7E+3	5.4E+3	6.0E+4	1.7E+4	1.7E+3	1.4E+3	1.9E+3	8.3E+3	2.0E+2	4.4E+2	3.7E+3
	S8	1.1E+7	3.0E+6	5.9E+6	1.2E+6	3.9E+4	8.0E+3	3.9E+3	4.0E+3	8.4E+4	3.1E+3	1.2E+4	3.1E+4
R2	S1	2.2E+4	1.4E+1	1.5E+2	6.4E+2	1.1E+6	2.7E+4	2.2E+4	7.8E+4	3.8E+4	1.3E+1	6.4E+1	4.7E+2
	S2	1.1E+5	2.5E-4	3.8E+1	1.0E+3	2.8E+5	3.2E+3	3.1E+3	1.8E+4	6.5E+4	1.4E+2	9.7E+1	2.0E+3
	S3	1.5E+4	2.5E+0	1.8E+1	2.3E+3	2.5E+5	4.5E+4	1.3E+5	7.6E+4	2.2E+3	8.6E+0	5.6E+1	2.7E+3
	S4	3.4E+3	1.2E-2	1.1E+2	1.9E+3	5.8E+4	1.3E+3	1.9E+3	2.5E+6	2.2E+3	2.7E-2	1.8E+0	4.1E+3
	S5	1.6E+5	4.0E+2	3.3E+3	1.7E+5	5.7E+5	1.1E+4	1.4E+4	1.7E+6	1.5E+5	3.1E+2	1.5E+3	1.8E+5
	S6	1.9E+4	2.5E+1	1.9E+2	8.9E+2	3.1E+5	5.3E+4	4.0E+4	2.4E+4	1.7E+4	6.3E+0	8.4E+1	2.3E+2
	S7	1.8E+2	3.1E+2	1.4E+2	5.6E+1	2.0E+5	2.3E+4	6.7E+3	1.4E+4	1.9E+3	4.5E+1	9.4E+1	8.2E+2
	S8	2.2E+4	9.8E+2	1.3E+3	4.3E+3	1.9E+6	1.0E+6	1.7E+6	3.5E+5	9.7E+3	2.9E+2	8.9E+2	5.6E+3
R3	S1	1.4E+5	1.1E+2	2.2E+3	3.8E+4	1.1E+3	4.2E+2	3.0E+3	1.0E+6	1.3E+3	3.7E+3	3.1E+4	
	S2	7.7E+4	7.1E-3	4.6E+1	8.1E+2	5.2E+3	4.5E+1	3.9E+1	1.5E+2	1.5E+5	5.0E+2	3.0E+2	8.8E+3
	S3	2.7E+4	2.5E+1	1.1E+2	9.5E+3	6.1E+3	1.6E+2	1.7E+2	1.7E+3	2.4E+5	1.3E+4	3.7E+4	3.2E+4
	S4	5.9E+3	1.7E-1	3.9E+2	5.8E+3	6.5E+2	3.6E+1	6.1E+1	7.0E+3	5.3E+4	2.3E+3	2.7E+3	2.0E+6
	S5	2.8E+5	2.1E+3	1.4E+4	2.4E+5	4.6E+4	6.5E+2	7.5E+2	9.3E+4	7.0E+5	2.9E+3	1.1E+4	8.1E+5
	S6	4.9E+4	2.5E+2	2.0E+3	9.3E+2	6.4E+3	2.1E+2	9.9E+2	5.8E+2	4.0E+5	1.0E+4	3.7E+4	4.7E+4
	S7	5.4E+2	9.2E+2	5.5E+2	1.3E+2	1.8E+3	5.4E+2	4.3E+2	2.2E+2	1.6E+5	1.9E+3	3.9E+3	5.9E+4
	S8	8.2E+4	2.2E+4	2.5E+4	1.3E+4	1.5E+4	3.6E+3	1.7E+3	1.5E+3	2.8E+6	1.0E+6	1.8E+6	3.2E+5

Final demand: four categories integrated (**Y_t**)
(unit: million €/year):

		R1	R2	R3
R1	S1	1.8E+6	2.2E+4	1.0E+5
	S2	3.0E+5	5.9E+3	3.4E+4
	S3	8.0E+5	7.4E+3	4.3E+3
	S4	3.1E+6	6.5E+3	1.6E+4
	S5	4.0E+6	2.5E+5	5.2E+5
	S6	1.3E+6	6.2E+3	4.3E+4
	S7	4.7E+5	2.2E+4	1.3E+4
	S8	2.1E+7	5.5E+4	1.3E+5
R2	S1	2.3E+4	1.2E+6	3.8E+4
	S2	1.1E+5	3.0E+5	6.7E+4
	S3	1.7E+4	5.0E+5	5.0E+3
	S4	5.4E+3	2.5E+6	6.3E+3
	S5	3.4E+5	2.3E+6	3.3E+5
	S6	2.0E+4	4.3E+5	1.7E+4
	S7	6.9E+2	2.5E+5	2.9E+3
	S8	2.9E+4	5.0E+6	1.6E+4
R3	S1	1.4E+5	4.2E+4	1.0E+6
	S2	7.7E+4	5.5E+3	1.6E+5
	S3	3.6E+4	8.1E+3	3.3E+5
	S4	1.2E+4	7.8E+3	2.0E+6
	S5	5.4E+5	1.4E+5	1.5E+6
	S6	5.2E+4	8.2E+3	5.0E+5
	S7	2.2E+3	3.0E+3	2.2E+5
	S8	1.4E+5	2.2E+4	5.9E+6

Household direct emissions or resource extractions (**F_{hh}**)

	R1	R2	R3
CO ₂ emissions (tonnes)	2.6E+9	1.1E+9	1.4E+9
Water consumption (Mm ³)	1.3E+4	2.6E+4	3.3E+4
Value added (million €)	0.0E+0	0.0E+0	0.0E+0
Employment (1000 people)	0.0E+0	0.0E+0	0.0E+0

Population (**pop**)
(unit: people)

R1	R2	R3
1.00E+9	3.04E+9	3.22E+9

Inter-industry transactions (Z)

unit: million €/year):

		R1								R2								R3							
		S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8
R1	S1	9.0E+5	7.1E+3	2.9E+3	1.3E+4	4.7E+4	2.9E+3	1.9E+3	2.7E+5	2.3E+4	3.1E+3	4.0E+3	5.2E+2	5.2E+3	3.6E+3	3.4E+1	1.2E+4	5.4E+4	2.7E+3	2.8E+3	2.0E+3	2.4E+4	1.6E+3	1.3E+3	2.6E+4
	S2	1.7E+3	9.3E+4	6.8E+2	4.4E+3	2.2E+4	2.6E+2	2.6E+2	1.8E+4	3.1E+1	8.5E+3	8.1E+1	1.2E+2	1.3E+3	3.0E+1	3.3E+0	8.5E+2	1.0E+3	1.5E+4	6.2E+2	1.1E+3	1.2E+4	4.6E+2	1.1E+3	4.2E+3
	S3	6.0E+4	2.4E+4	3.9E+5	1.6E+5	3.4E+5	2.0E+5	4.4E+3	4.1E+5	1.0E+3	2.9E+2	3.3E+3	2.2E+3	9.4E+3	4.2E+3	1.2E+2	1.4E+3	1.6E+3	1.0E+3	8.5E+3	5.9E+3	1.0E+4	5.4E+3	4.6E+2	6.0E+3
	S4	2.5E+4	3.5E+3	5.9E+4	7.4E+5	2.3E+5	2.4E+4	2.8E+3	4.5E+5	2.0E+2	2.4E+1	2.0E+2	1.2E+4	1.2E+4	2.1E+2	2.3E+1	1.1E+3	1.2E+3	5.3E+2	1.2E+3	1.8E+4	1.4E+4	7.9E+2	3.7E+2	5.9E+3
	S5	1.6E+5	4.4E+4	8.9E+4	4.7E+5	3.5E+6	7.1E+4	2.6E+4	1.0E+6	1.1E+4	7.7E+3	1.1E+4	2.3E+4	2.8E+5	6.3E+3	1.1E+3	3.3E+4	2.8E+4	4.9E+3	2.5E+4	1.1E+5	5.1E+5	3.0E+4	2.4E+4	1.3E+5
	S6	1.6E+5	2.6E+4	1.1E+5	1.6E+5	3.9E+5	8.5E+5	4.4E+4	7.7E+5	3.5E+3	8.6E+2	1.2E+4	1.0E+4	1.3E+4	1.4E+4	1.3E+3	7.5E+3	1.0E+4	1.4E+3	1.1E+4	1.4E+4	1.3E+4	5.1E+4	6.2E+3	2.7E+4
	S7	2.5E+5	4.5E+4	1.2E+5	1.5E+5	6.4E+5	1.9E+5	1.1E+5	5.2E+5	2.8E+3	2.6E+2	1.9E+3	8.9E+2	3.3E+3	7.4E+2	1.3E+2	3.1E+3	3.1E+3	1.8E+3	2.0E+3	3.6E+3	1.0E+4	4.6E+3	3.7E+3	1.5E+4
	S8	5.1E+5	6.4E+4	2.8E+5	6.5E+5	1.5E+6	4.4E+5	8.8E+4	8.4E+6	1.1E+4	4.5E+3	8.6E+3	3.3E+4	4.9E+4	1.4E+4	3.8E+3	9.7E+4	5.5E+3	2.6E+3	1.3E+4	1.4E+4	2.6E+4	9.1E+3	1.2E+4	1.3E+5
R2	S1	1.9E+4	3.9E+2	1.8E+2	6.5E+2	2.2E+3	1.2E+2	6.4E+1	6.8E+3	9.5E+5	1.0E+5	2.0E+4	2.4E+4	9.1E+4	4.9E+4	1.5E+3	3.0E+5	3.1E+4	1.4E+3	2.5E+3	1.8E+3	2.2E+4	1.2E+3	8.2E+2	1.6E+4
	S2	3.3E+2	1.2E+4	2.1E+2	9.9E+2	6.8E+3	1.4E+2	2.9E+1	4.4E+3	3.3E+3	5.2E+5	5.8E+3	1.1E+4	9.1E+4	6.2E+3	4.1E+2	7.7E+4	2.3E+3	2.4E+4	9.3E+2	2.7E+3	1.9E+4	9.3E+2	3.6E+3	9.4E+3
	S3	6.0E+2	4.1E+2	1.6E+4	1.3E+4	6.7E+3	1.2E+4	4.9E+1	2.0E+3	3.2E+4	2.5E+4	3.5E+5	1.2E+5	4.1E+5	1.7E+5	1.2E+3	9.7E+4	8.8E+2	9.4E+2	8.1E+3	4.9E+3	1.1E+4	1.4E+4	4.3E+2	2.8E+3
	S4	8.4E+2	5.8E+1	5.6E+2	6.4E+3	1.0E+4	4.4E+2	9.2E+1	3.1E+3	1.1E+4	5.2E+3	4.0E+4	9.1E+5	5.2E+5	1.0E+4	1.2E+3	8.5E+4	1.2E+3	2.5E+2	9.3E+2	1.8E+4	1.5E+4	3.7E+2	3.1E+2	4.6E+3
	S5	7.8E+3	3.0E+3	5.3E+3	2.7E+4	2.0E+5	3.7E+3	1.5E+3	6.0E+4	8.0E+4	1.1E+5	1.5E+5	6.9E+5	4.5E+6	8.4E+4	7.2E+3	5.0E+5	2.0E+4	3.0E+3	1.6E+4	8.9E+4	3.3E+5	1.5E+4	2.0E+4	7.6E+4
	S6	4.0E+3	5.1E+2	5.8E+3	5.8E+3	8.1E+3	2.9E+4	2.0E+3	1.6E+4	7.4E+4	2.9E+4	8.0E+4	2.7E+5	2.7E+5	2.2E+5	9.4E+3	2.5E+5	6.2E+3	6.9E+2	7.3E+3	9.6E+3	9.5E+3	2.4E+4	3.8E+3	1.3E+4
	S7	1.3E+3	1.6E+2	1.0E+3	6.9E+2	2.8E+3	3.7E+2	6.7E+2	2.4E+3	8.4E+4	3.9E+4	6.0E+4	1.1E+5	2.3E+5	4.2E+4	6.5E+3	1.2E+5	6.4E+2	4.3E+2	4.1E+2	7.9E+2	2.2E+3	9.1E+2	7.4E+2	3.4E+3
	S8	3.3E+3	4.1E+2	4.5E+3	4.7E+3	1.0E+4	3.9E+3	2.0E+3	3.9E+4	9.2E+4	7.6E+4	1.6E+5	3.0E+5	7.9E+5	1.6E+5	1.9E+4	1.4E+6	7.3E+2	3.0E+2	1.6E+3	1.8E+3	3.6E+3	1.1E+3	1.1E+3	1.4E+4
R3	S1	8.7E+4	1.8E+3	8.1E+2	1.7E+3	4.7E+3	3.9E+2	4.2E+2	2.6E+4	5.4E+4	2.5E+3	3.7E+3	1.6E+3	1.0E+4	2.7E+3	1.9E+2	1.8E+4	6.8E+5	1.6E+4	2.8E+4	2.0E+4	6.5E+4	1.5E+4	1.3E+4	2.3E+5
	S2	2.7E+2	1.3E+4	2.3E+2	8.6E+2	7.2E+3	9.5E+1	5.8E+1	3.8E+3	6.4E+1	1.0E+4	5.8E+1	7.6E+1	1.4E+3	4.6E+1	7.4E+0	9.1E+2	1.9E+3	4.9E+4	1.3E+3	2.2E+3	1.8E+4	8.1E+2	1.6E+3	1.1E+4
	S3	2.0E+3	1.6E+3	4.1E+4	1.6E+4	1.7E+4	1.4E+5	2.8E+2	5.9E+3	1.5E+3	6.3E+3	3.7E+4	5.2E+3	2.3E+4	1.3E+5	1.1E+2	3.0E+3	1.6E+4	7.4E+3	1.7E+5	5.9E+4	1.4E+5	1.7E+5	7.2E+3	1.5E+5
	S4	1.6E+3	1.4E+2	1.8E+3	1.8E+4	2.7E+4	1.0E+3	1.9E+2	8.5E+3	5.4E+2	4.7E+1	3.1E+2	3.8E+4	5.1E+4	3.3E+2	4.1E+1	1.5E+3	2.1E+4	5.1E+3	2.3E+4	4.4E+5	2.0E+5	1.5E+4	4.0E+3	1.8E+5
	S5	1.7E+4	8.7E+3	1.2E+4	5.1E+4	3.8E+5	1.1E+4	4.1E+3	1.2E+5	9.9E+3	1.3E+4	7.4E+3	2.5E+4	2.5E+5	5.3E+3	1.3E+3	4.5E+4	4.9E+4	2.0E+4	4.7E+4	3.2E+5	1.5E+6	4.0E+4	2.1E+4	2.9E+5
	S6	1.3E+4	1.5E+3	1.1E+4	1.3E+4	2.8E+4	8.3E+4	1.0E+4	5.4E+4	3.2E+3	7.2E+2	6.7E+3	1.0E+4	1.2E+4	1.7E+4	1.1E+3	9.1E+3	6.7E+4	1.5E+4	5.4E+4	1.2E+5	1.4E+5	3.3E+5	6.4E+4	2.5E+5
	S7	2.9E+3	4.4E+2	2.7E+3	1.7E+3	7.1E+3	9.4E+2	1.7E+3	5.4E+3	6.7E+2	7.3E+1	3.5E+2	2.5E+2	8.0E+2	3.7E+2	7.5E+1	1.2E+3	1.2E+5	2.6E+4	5.6E+4	1.6E+5	2.4E+5	1.1E+5	9.4E+4	3.8E+5
	S8	1.1E+4	1.6E+3	1.5E+4	1.5E+4	3.8E+4	1.3E+4	6.5E+3	1.5E+5	3.6E+3	1.2E+3	2.6E+3	8.2E+3	1.2E+4	5.3E+3	1.4E+3	2.6E+4	7.1E+4	2.4E+4	5.6E+4	1.9E+5	2.9E+5	1.2E+5	7.1E+4	1.8E+6

‘Environmental’ extensions (*F*)

	R1								R2								R3							
	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8
CO ₂ emissions (tonnes)	9.0E+5	7.1E+3	2.9E+3	1.3E+4	4.7E+4	2.9E+3	1.9E+3	2.7E+5	2.3E+4	3.1E+3	4.0E+3	5.2E+2	5.2E+3	3.6E+3	3.4E+1	1.2E+4	5.4E+4	2.7E+3	2.8E+3	2.0E+3	2.4E+4	1.6E+3	1.3E+3	2.6E+4
Water consumption (Mm ³)	1.7E+3	9.3E+4	6.8E+2	4.4E+3	2.2E+4	2.6E+2	2.6E+2	1.8E+4	3.1E+1	8.5E+3	8.1E+1	1.2E+2	1.3E+3	3.0E+1	3.3E+0	8.5E+2	1.0E+3	1.5E+4	6.2E+2	1.1E+3	1.2E+4	4.6E+2	1.1E+3	4.2E+3
Value added (million €)	6.0E+4	2.4E+4	3.9E+5	1.6E+5	3.4E+5	2.0E+5	4.4E+3	4.1E+5	1.0E+3	2.9E+2	3.3E+3	2.2E+3	9.4E+3	4.2E+3	1.2E+2	1.4E+3	1.6E+3	1.0E+3	8.5E+3	5.9E+3	1.0E+4	5.4E+3	4.6E+2	6.0E+3
Employment (1000 people)	2.5E+4	3.5E+3	5.9E+4	7.4E+5	2.3E+5	2.4E+4	2.8E+3	4.5E+5	2.0E+2	2.4E+1	2.0E+2	1.2E+4	1.2E+4	2.1E+2	2.3E+1	1.1E+3	1.2E+3	5.3E+2	1.2E+3	1.8E+4	1.4E+4	7.9E+2	3.7E+2	5.9E+3