IEooc_Methods5_Exercise2: Multi regional Input-Output modeling

Sample solution

1) **What are the dimensions of the MRIO-A-matrix and what do the dimensions mean? What are the units of A and what do they mean? Cell H10 value is 0.25787…, what does this number mean? Cell AE10 value is 0.012854…, what does this number mean?**

→The dimensions of A are 33 x 33. A contains information regarding the use of 11 products from 3 regions within 11 industrial sectors in 3 regions. Since all inter-industrial-flows in this system are in MEUR (million euros) all coefficients in A are in MEUR/MEUR. Hence A defines how many MEUR of product x from China are needed to produce product y within the EU.

For example: a_7_5 = 0.258, (cell H10) means that the food sector in the EU obtains 0.258 MEUR services from the EU per MEUR output.
A_7_5 = 0.0129, (cell AE10) means that energy providers in ROW (average of all countries except China and EU28) obtain 0.0129 MEUR of services from the EU per MEUR output.

2) **What are the dimensions of the MRIO-Y-matrix and what do the dimensions mean? What are the units of Y and what do they mean? Cell AN7 value is 1,348,186. …, what does this number mean? Cell AO32 value is 14718…, what does this number mean?**

→ the dimensions of Y are 33 x 3. Y contains information regarding the final consumption of 11 products from 3 regions within the 3 regions. All final-consumption-flows in this system are in MEUR (million euros). Hence Y defines how many MEUR of product x from China are consumed by final consumers within the EU.

For example: Y_4_1 = 1248186 MEUR, (cell AN7) means that the total domestic final consumer demand for consumer products within the EU was around 1350 billion Euros.

Y_29_2 = 0.0129, (cell AO32) means that the final consumer demand in China for services from ROW was 14 billion EUR.

3) **What are the dimensions of the MRIO-S-matrix and what do the dimensions mean? What are the units of S and what do they mean? Cell I39 value is 2,544,378. …, what does this number mean? Cell T62 value is 0.1392…, what does this number mean?**

→ the dimensions of S are 170 x 33. S contains information regarding the emission intensities of 170 types of emissions of 11 industrial sectors in 3 regions. All inter-industrial-flows in this system are in MEUR (million euros) and the emissions have varying units and are defined on the

sheet. Hence the units of the coefficients in S are [given unit]/MEUR. Hence S defines how many emissions of type x are emitted during the production of product y required in the EU.

For example: S_1_6 = 2544378 kg/MEUR, (cell I39) means that the energy supply sector in the EU emits 2540 t CO_2 into the air from combustion processes per MEUR output.

S_24_18 = 0.1392, (cell T62) means that the energy supply sector in China emits 0.14 kg mercury into the air from combustion processes per MEUR output.

4) **Tom buys a desk, an air journey and two Snickers. Susi buys 10 kg of potatoes and a car. How do you calculate the combined carbon footprints of the bundles of goods for Ralf and Susi?**
→ The Leontief IO-model is a linear model. This means that the carbon footprint of the combined bundles of goods of Ralf and Susi is the sum of all bundles of goods footprints from Ralf and Susi which are further the sum of all single goods within the bundles.

5) **Determine the total global industrial production x_EU28 needed to meet the total final demand of all consumers in EU28! What are the dimensions of vector x_EU28 and what does it mean? Compute a series expansion for the Leontief inverse and specify the first six summands x_0 to x_5 along with the final result (limit value x_infinity). Examine the results for the sectors 'landfill' and 'mining'! How do the total outputs behave within the three regions compared to final demands of goods 'agricultural products' and 'mining products'? How do the single steps of the value chain develop with increasing order of x_i and how can the development be explained?**

→ First, we build the IO-model [cf. Excel Sample solution *IEooc_Methods5_Exercise2_MRIO_ Solution.xlsx*]. To build the model we ideally create a new table (MRIO_Model) and define the unit matrix with the dimensions 33 x 33 using the function MUNIT(33). (Use the matrix equation functionality of Excel! First mark the cell for the solution, then enter the function and after that hit the keys CTRL-SHIFT-ENTER simultaneously!).

Below we then create the fields for the first five powers starting with A, A^2, A^3, A^4 and A^5. The powers we then obtain gradually from A by simply applying successive multiplication processes (MMULT, matrix function!). By clicking on the single cells in A^x you can inspect the applied formulas.
Eventually we determine L using the known function.
Using the values for A through A^5 as well as L we can evaluate the results.

6) **Determine the total emissions of 'CO2-combustion, air', CH4-combustion, air', CO2-non-combustion, air', 'CH4-non-combustion, air', and 'Hg-combustion, air' for the first six summands for x_EU28 and the total output x_EU28! How big is the share of a) emission of zeroth order and b) steps 1-5 of the supply chain compared to total CO2 emissions? What's the explanation for these results?**

➔ We create a new sheet (Model_Evaluation_Fullscale) and copy the final demand matrix for Y into this table. Then we determine the varying values

$x\_0 = A^0.y$
$x\_1 = A^1.y$
…
$x\_5 = A^5.y$
$x\_full = L.y$

These results are shown in table 'Total emissions for EU final demand, iteration'. Next, we multiply the rows of the stress matrix S with the values of x accordingly. 'CO2-Combustion, Air' applies to the first row of S, 'Hg-combustion-air' applies to the 24th row. The results of this calculation can be found in table 'Total emissions for EU final demand'.

Discussion: The emissions of the zeroth order CO2 combustion emissions account for only a quarter of total emissions, the other 70 % are also not emitted during production of the consumed goods but further up the supply chain. The zeroth order emissions for methane (non-combustion) are especially low with only 5 %. Most of the emissions (95 %) are emitted during higher stages of the supply chain. This makes sense since non-combustion methane are produced especially in agriculture and natural gas production which are both sectors that supply little directly to final demand.
It's the opposite with Hg emissions. Here the contribution of the order 0 is almost 55 % which can be traced back to electricity production emissions.

7) **Determine the emissions of 'CO2-combustion, air' for each sector and region of x_EU28. Do your calculations in appropriate units (ex. Mt). What are the sector-region pairs that contribute the most emissions to total CO2 emissions? How do CO2 emissions split up among the three regions?**
➔ We remain with the sheet (Model_Evaluation_Fullscale). We copy and transpose the corresponding rows of the S matrix (row 1) into column L.
Then we can simply multiply total output x with process and region-specific entries of S and further also convert from kg to Mt (factor 1e9). The results can be found in column N.

Discussion: The total consumption-based CO_2 emissions in EU28 in 2007 were 4.78 Gt. Of this 57 % can be allotted to the EU, 13 % to China and 30 % to ROW. The biggest share of emissions come from energy supply in the EU (1300 Mt), service sector of the EU (920 Mt), energy supply in ROW (700 Mt) as well as material production sector in ROW (370 Mt).

8) **Determine the global CO2 and fine particulate matter (PM2.5 combustion air) emissions of one EU citizen generated through combustion processes using the average annual consumption of goods of 30,000 Euros (basic price w/o sales tax or other levy and taxes). How do the emissions split up among a) the three regions and b) the 11 sectors?**

➔ This calculation we perform on a different sheet ‚Unit Demand'. First we determine the average bundle of good for 30,000 Euros by taking the associated raw data from total consumption in the EU and then downscale with the help of the rule of three to 30,000 EURO = 0.03 MEUR (column D top).
Then we determine total output x for this demand (column D, bottom). As in task 7 we copy and transpose the relevant rows from S (row 1 and 18), column H and I. Through simple multiplication of x with S we receive the final result (column E and F). In total sum we incur 12 tons of CO2 and 4.2 kg PM2.5 emissions.

The share of emissions for the EU is 55-60 %, China 13-14 % and 25-30 % for ROW. The biggest share for CO2, just like in exercise 7 (linear model!), stems from the energy supply sector in the EU (3.3 t), the service sector of the EU (2.4 Mt), the energy supply in ROW (1.8 t) as well as the material production sector in ROW (1 t).
The biggest emitter of particulate matter in the personal supply chain is the service sector (transport!) with 1.63 kg, followed by material production in ROW (0.43 kg) and the energy supply in the EU (0.35 kg).