

## IEooc\_Application3\_Exercise1: Consumption Taxation of CO<sub>2</sub>-intensive Materials

### Sample solution

*Goal: Systems understanding of material markets, material content of merchandise groups, error propagation, Monte-Carlo-Simulation*

#### Questions:

- 1) Draft the system definition for the production, trade and consumption of a random merchandise group! Name all processes, flows and stocks! Which ones of your processes provide a balanced equation for the product flows for the merchandise chosen and which ones don't? Why or why not?

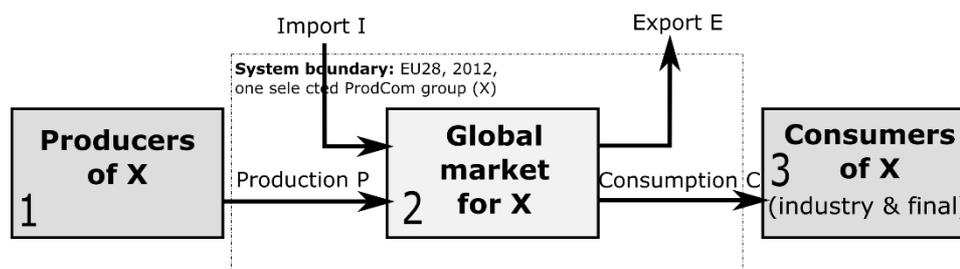


Fig. 1: System definition

We describe three processes: production (1), trade (2) and consumption (3). Four flows: production P, import I, export E and consumption C. Inventories/Stocks are not considered. Since producers and consumers create or consume respectively, there can be no trade balance established. Consequently, we place the system boundary around process 2, the market.

- 2) Why are all production related excise taxes for steel (or any other material) counted more than once when applying simple addition of all charges across commodity groups?

Materials are part of the value chain for consumer goods. Materials turn into components which then further become part of the product ex. steel → rim → motor vehicle. Every single one of these products contain the same steel and hence also the excise tax for it. Consequently, if you simply add the excise tax for steel, rim and motor vehicle the steel is accounted for three times instead of only once.

**3) Determine the quantity of steel flowing into the final consumption inventories for all 100 merchandise groups (commodity group 3)**

The calculations are shown in the excel file IEooc\_Application3\_Exercise1\_IoC\_Solution.xlsx, sheet "sample\_solution". The mass flows for production (column H), import (column I) and export (column J) are multiplied with the respective steel content (column L). Then you sum up the column to obtain the total steel flow. To consider flows only from group 3 we use SUMIFS. The results for P, I and E are then shown in cell T104 to V104.

The apparent consumption of steel is

$$\text{Apparent consumption} = \text{production} + \text{import} - \text{export}$$

The result is **36 Mt steel** (cell T106).

**4) For all 4 materials, determine total CO<sub>2</sub> taxes and fees final consumers in the EU 28 must pay. Only consider the merchandise groups that eventually flow into the consumer inventories (commodity group 3)!**

Besides the steel content, we now also determine the content of aluminum, plastic and cement. For this we follow the same steps as in number 3 with the only difference that we use columns M, N and O instead of L.

After that we multiply embedded material flows with the respective bench marks (cells R8 through R11) and CO<sub>2</sub> costs (R3).

The taxes for all four materials are then added up and, just like in number 3, firstly get filtered into final consumption commodity groups (group3, SUMIFS) before we can determine the associated taxes relative to the apparent consumption (cell AS 106).

The result is **3.6 billion Euros** (cell AS106).

**5) For which merchandise group are the fees (fee/kg per EUR/g) highest for import?**

First, we determine relative taxes (change in price) RP as

$$RP = 100 * \text{total taxes} / \text{total monetary flow}$$

This formula applies to all merchandise groups as well as P, I and E flows.

The result you receive in column AW, AX and AY.

Through search and sort, you can find the groups with the highest relative taxes for imports:

*Aluminum doors, thresholds for doors, windows and their frames, 25121050, with a price change of 54 %.*

This result however appears very high since the aluminum content changes by only 18 % and the degree of processing for aluminum doors is higher than that of aluminum metal and hence the relative share of Al for doors should be lower than for Al metal itself. There may be an error within the ProdCom data base.

- 6) Calculate the error propagation for the relative tax/fee (change of price) for steel contained in a manufactured good!
- a) Present your results as formulas. Consider the production flow of any random merchandise group.

We define the relative taxes RP as quantity of goods M, steel content s, CO<sub>2</sub> threshold B, CO<sub>2</sub> costs C, and total value W. Hence the formula and derivatives are as follow:

$$RP = 100 \cdot M \cdot s \cdot B \cdot C / W$$

$$\frac{\partial RP}{\partial M} = 100 \cdot s \cdot B \cdot C / W$$

$$\frac{\partial RP}{\partial s} = 100 \cdot M \cdot B \cdot C / W$$

$$\frac{\partial RP}{\partial W} = -100 \cdot M \cdot s \cdot B \cdot C / W^2$$

B and C are constant either because they are a set values fixed by the state or arbitrary assumed while not containing any errors. The analytical result for the global error is:

$$\Delta RP = 100 \cdot B \cdot C \cdot \left( \left| \frac{s}{W} \right| \cdot |\Delta M| + \left| \frac{M}{W} \right| \cdot |\Delta s| + \left| \frac{M \cdot s}{W^2} \right| \cdot |\Delta W| \right)$$

- b) Determine the numerical value for the absolute and relative maximal error for the prices change of steel for the EU28 production volume group , 29102230 €, , Motor vehicles with a petrol engine > 1500 cm<sup>3</sup>

The calculation can be found in table "error propagation". With a relative error of +/- 10 % for M and W we can calculate the absolute change ΔM and ΔW (cell E17 and E21). The same is true for steel content (relative error 33 %).

These values we insert into the formula above and receive following results:

<b>Price change of steel and motor vehicles produced, group 29102230:</b>	<b>0.22 % (cell J9).</b>
<b>Absolute maximal error for all price changes:</b>	<b>0.11 % (cell J17).</b>
<b>Relative maximal error for change of price:</b>	<b>53 % (cell J21).</b>

7) Conduct a Monte-Carlo-Simulation of the relative change of price for steel tax based on the EU28 production volume , 29102230 ‘ , , Motor vehicles with a petrol engine > 1500 cm<sup>3</sup> (minimum 1000 MC cycles)

- a. Assume all data is distributed normally!
- b. Assume all data is distributed uniformly!

Assess your results using histograms. Determine mean and standard deviation relative to change of price distribution. How does the mean value compare to the mean value calculated in task 4? How reasonable are the assumptions about the distribution of the random values?

Assume following parameters for the error ranges for the uncertain variables. The absolute values are for task 7a, the standard deviations for task 7b.

- ProdCom absolute value: +/- 10 %, standard deviation: 10 % of mean value
- ProdCom absolute mass: +/- 10 %, standard deviation: 10 % of mean value.
- Absolute material content: see color code in excel table and table 1. Standard deviation 1/3 of mean value.
- CO<sub>2</sub> threshold and CO<sub>2</sub> price: no deviation since fixed parameters/assumptions

The MC simulation can be found in table ‘MC\_simulation’. Using the random number function for excel we generate more than 1000 uniformly distributed random values for mass, value and steel content (column A, B, C) and RP column F. In column E we find the interval bins for the histogram (fig. 2). Column G shows the results for mean value (~ 0.21), standard deviation (~ 0.046) and relative standard deviation (~ 21 %).

Results for the same calculations for another random normal deviation you can find in column J-P. A substantially bigger standard deviation can be noted using this normal distribution. The reason for this is that other than the uniform distribution, normal distributions have constant spreading on both sides and hence result, based on the squared formula, on disproportional deviation.

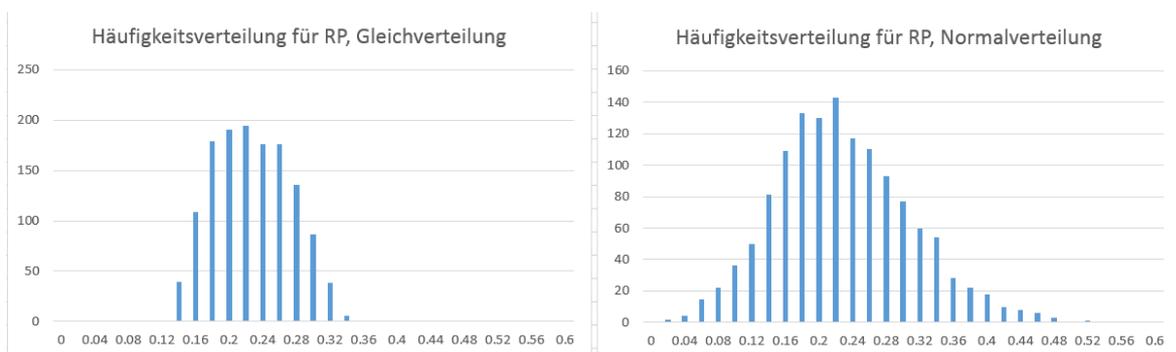


Fig. 2: Frequency distribution (histogramm) for RP (x-axis) for group 29102230

It becomes clear that the overlap of various uniform distributions does not result in uniform distribution of the result.

The mean values calculated using the MC simulation coincide very well with the expected values from the table column 'error propagation' (0.2157). The method of using a high number of samples leads to a high reliability of the MC simulation.

The relative errors of 10 % for M and W are rather small and hence indicate that either uniform as well as normal distribution are good choices. It's a different case with s. The relative error of 33 % is very big and the normal distribution comes up with values bigger than 1 which is impossible. Hence, using normal distribution for s is problematic and a different distribution (ex. truncated normal distribution) should be preferred.