Python work

- Groups are composed of **4 students**.

- The file with your solutions must be **submitted via Moodle by December 12th of 2021, 23h59 (Portuguese time)**. Submit one .py file per work group. The name of the file should be the student number of the student submitting the file, for instance, 12345.py.

- The file must have the following structure:

```
# Group: <student number1, student number2; … >

# a)
<code>

# b)
<code>

# c)
<code>

# d)
<code>
```

- General criteria included in the grade:
    - Code does not run: 0 points
    - Submission after due date: 0 points
    - Generality of code
    - Clean and organized code
    - Efficiency of code
    - Clever or creative solutions

1. Leontief input-output with greenhouse gas (GHG) emissions

The Office of National Statistics (ONS) of the United Kingdom produces input-output summary tables with 10 sectors. The sectors considered are: Agriculture [A], Production [B-E], Construction [F], Distribution, transport, hotels and restaurants [G-I], Information and communication [J], Financial and insurance [K], Real estate [L], Professional and support activities [M-N], Government, health & education [O-Q], and Other services [R-T]. Inside square brackets are the sector codes that show how the data was aggregated in the 10 sectors.

From the link:

https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/inputoutputsupplyandusetablessummarytables

the file 'bb21a10summarytables.xlsx' can be downloaded. This file contains input output data for the UK, from the year 1997 to 2019, measured in £ million.

Download the file and import the data to work with Python. You can adapt the code below. This code uses the module Pandas to import, from the file, data regarding the intermediate consumption by sector for 2019, and create two array objects: a 2D array object with the input-output table, `z`, and the vector (1D array) with the total output of each sector, `x`.[1] Change the variable `path`, to have the correct path to the file downloaded into your computer. An example for Windows is,

`path = 'C:/Users/somename/Downloads/bb21a10summarytables.xlsx'`.

```
>>> import pandas as pd
>>> import numpy as np
>>> path = '/Users/somename/Downloads/bb21a10summarytables.xlsx'
>>> # Input output table
>>> df = pd.read_excel(path,
                       sheet_name = 22,
                       usecols = "C:L",
                       header = None,
                       skiprows = 52,
                       nrows = 10)
>>> z = np.array(df,dtype = float) # £ million

>>> # Output per sector
>>> dfx = pd.read_excel(path,
                          sheet_name = 22,
                          usecols = "C:L",
                          header = None,
                          skiprows = 75,
                          nrows = 1)
>>> x = np.array(dfx, dtype = float)[0] # £ million
```

In many cases, the monetary value of each sector's gross output may not ultimately be the most important measure of the economic impact following a change in demands. In this workgroup we are also interested in the impacts in terms of greenhouse gas (GHG) emissions,

[1] See the link (https://pandas.pydata.org/docs/reference/api/pandas.read_excel.html) for a description of the options of the `read_excel` function.

measured as CO2 emissions. These emissions can be included in the input-output model by knowing the GHG intensity of each sector, i.e. the amount of CO2 emitted by each sector per unit of output. The ONS presents data of GHG intensity in thousand tonnes of CO2 / £ million.[2] The GHG intensity data relevant for this workgroup is organized in the file 'ghgintensity_uk.xlsx' that can be downloaded from Moodle. This contains GHG intensity for the years 1997 to 2019 for the sectors mentioned above, and was prepared from the file obtained from the link in footnote 2. You can adapt the code below to import the data.

```
>>> pathe = '/Users/somename/Downloads/ghgintensity_uk.xlsx'
>>> dfem = pd.read_excel(pathe,
                         sheet_name = 0,
                         usecols = "B:X",
                         skiprows = 1,
                         header = None,
                         nrows = 10)
>>> E = np.array(dfem, dtype = float) #Thousand tonnes CO2 /£ million
```

Write code to support your answers to the questions below. Write your code so that it also works properly with other input-output data, for instance, different number of sectors.

a) Create a function `coef_mat(z, x)`, that given an array with an input-output table `z` and an array `x`, with a vector of total output of each sector, returns an array with the associated matrix of technical coefficients. Find the matrix of technical coefficients for the UK for the year 2019. Below is an example of an economy with two sectors.

```
>>> z = np.array([[3, 2],
                  [1, 4]])  # £ million
>>> x = np.array([10, 10]) # £ million
>>> coef_mat(z, x)
array([[0.3, 0.2],
       [0.1, 0.4]])
```

b) If A is the matrix of technical coefficients, the Leontief inverse matrix can be approximated by the power series,

$$I + A + A^2 + A^3 + \cdots + A^m.$$

As m increases, A^m approaches the zero matrix and the series converges to the Leontief inverse matrix. Create a function `leon(a, dif = 1e-6)`, that, for an array with the matrix of technical coefficients `a`, returns an array that is an approximation of the Leontief inverse matrix. The desired matrix is obtained when, by adding one more term to the power series, the change in each entry of the array is smaller than `dif`. Apply the function `leon` with `dif = 1e-6`, and find the Leontief inverse matrix for the UK for the year 2019.

Create a function `impact_output(a)` that given the coefficient matrix `a`, returns a list where each element is the change in production of the whole economy from a

[2] https://www.ons.gov.uk/economy/environmentalaccounts/datasets/ukenvironmentalaccountsatmosphericemissionsgreenhousegasemissionsintensitybyeconomicsectorunitedkingdom

unitary demand change of each good. What is the sector, for which, a unitary demand change for its good, has the largest impacts in the production of the whole economy?

```
>>> a = coef_mat(z, x)
>>> np.round(leon(a), 2)
array([[1.5 , 0.5 ],
       [0.25, 1.75]])

>>> np.round(impact_output(a), 2)
array([1.75, 2.25])

>>> # What is the sector with largest impact?
>>> maximp(a)
'Sector 2'
```

In the above example, we have created the function `maximp(a)`, that given a matrix of technical coefficients `a`, returns the sector with the largest impact.

c) Create a function `impact_ghg(a, ghg)`, that, given an array with a matrix of technical coefficients `a`, and a vector `ghg` with the GHG intensity of each sector measured in thousand tonnes of CO2 / £ million, returns a list (in tonnes of CO2 / £) with the increase in emissions of the economy, from a unitary demand increase of each good. From the example below, an increase of 1 £ in the final demand for good 1, results in the increase of 0.003 tonnes of CO2 emissions of the economy.

```
>>> np.round(impact_ghg(a, E),3)
array([0.003, 0.009])
```

d) Define the contribution of each sector to the wellbeing of the population as the output of a sector minus the cost of its GHG emissions. Let the cost of a tonne of GHG emissions be the price of a tonne of CO2 on the UK Emissions Trading System (UK ETS). This market started on the 1st of January 2021 and CO2 has been traded at a price around 50 £ / tonne[3].

Create a function `wellbeing(a, ghg, p = 50)`, that given an array with the matrix of technical coefficients `a`, an array, `ghg`, with the GHG intensity of each sector, and a price, `p`, of CO2 (in £ / tonne), returns a list with the contribution of each sector to wellbeing (in £), from a unitary demand change of each good. Which sector most contributes to wellbeing? What is the range of prices of CO2 for which the previous answer does not change? Assume prices are integer numbers and the maximum price is 200 £ / tonne.

```
>>> E = np.array([1, 5]) # Thousand tonnes CO2 / £ million
>>> np.round(wellbeing(a, E), 2)
array([1.61, 1.79])

>>> # Which sector contributes most to wellbeing?
>>> maxwell(a, E)
```

[3] ht>>> tps://www.ft.com/content/56e02d3d-8c31-4937-be50-60d4bf9342f7

```
'Sector 2'

>>> # What is the range of CO2 prices for which the previous answer does
not change?
>>> price_range(a, E)
[0, 76]

>>> # Just checking...
>>> maxwell(a, E, p = 77)
'Sector 1'
```

In the example above we have created a function `maxwell(a, ghg, p = 50)`, that given an array with the matrix of technical coefficients, a vector with the GHG emissions per sector and the price of CO2 of 50 £ / tonne, returns the sector or good, whose unitary demand change most contributes to wellbeing. We have also created a function `price_range(a, ghg)`, to return a list with the required price range.

From the example, we see that a unitary increase in the final demand for good 2, results in the increase of 1.79 £ in the wellbeing. We can also see that, sector 2 is the sector with the largest contribution for wellbeing if the price of CO2 is smaller than 77 £ / tonne. When the price of CO2 is 77 £ / tonne, or larger, the sector with the largest contribution to wellbeing is sector 1.