Assignment week 3: Input-Output Analysis of impacts of an energy efficiency programme

Teachers

Thomas Guibentif, Julien Michellod, Martin Patel

Targets

- Conduct literature research on economy-related subjects.
- Get hands-on experience with input-output analysis and its applications.
- Understand the possibilities and limitations of input-output analysis.

Final report

The final report should contain answers to all questions of the exercise. You are encouraged to do some background research beyond the provided literature for this assignment. **Make sure that you properly quote and refer to your sources**. We also recommend you proofread your work.
Parts 1 and 2 will be graded based on your EXCEL file, with a filled-in table in "Answers" sheet **containing formulas** and links to other sheets that allowed you to get answers. Make sure that it is well-organised and easy to check by using titles, providing the units and providing additional information when necessary. Clever use of excel functionalities is encouraged (avoid copy-pasting by values and use "$" wherever possible).
Part 3 will be graded on the sole basis of your report. This should be provided in WORD or PDF, not longer than 8 pages (excluding tables), and be self-supporting, thus without links to Excel. Please check the language carefully (you may submit in English or French).

Deadline

Wednesday, March 13th 2024, 17:00
Send your WORD/PDF and EXCEL documents on Moodle. In case of technical problems you can e-mail them to thomas.guibentif@unige.ch and julien.michellod@unige.ch.

Background literature

- Kornelis Blok and Evert Nieuwlaar, Introduction to Energy Analysis. Routledge editors, 3rd Edition, 2020
- Yushchenko, A.; Patel, M.K.: Contributing to a green energy economy? A macroeconomic analysis of an energy efficiency program operated by a Swiss utility. Applied Energy 179 (2016), pp. 1304–1320

Task

In this assignment we will estimate the impacts at a macro-economic level of an energy efficiency programme (EEP). More precisely, we will compute the economy-wide impact on electricity consumption of subsidizing the installation of efficient light bulbs in common areas of buildings.

Description and data

Since 2009, the EEP "éco21", operated by the utility SIG (Services Industriels de Genève) in the canton of Geneva, has been supporting energy efficiency in common areas of buildings. It has encouraged the replacement of fluorescent tubes in common areas of buildings (traditionally lit 24/7) with LED light sources equipped with presence detectors, as well as the installation of efficient laundry machines and

hot water circulation pumps. Éco21 works with partner electricians and providers who encourage their clients to install the newer technology in exchange for a subsidy provided by the programme.

The expenditure required for the measure implementation is thus shared between the programme and the beneficiary (see slide 34 of the lecture). It comprises purchase of the equipment; installation of the equipment; and wholesale margins. The programme further incurs administration costs and IT development costs, namely for the application processing platform. We consider the expenses incurred in the year 2014, as summarized in Table 1. We assume that all goods and services are produced in Switzerland **except for the appliances,** which are imported at the expense of a 5% transport margin.

The EEP action in 2014 is estimated to have enabled savings of 3.57GWh/year, representing less demand from the energy supply sector. This amounts to a net decrease in total output from this sector of 624 kCHF/year. We further assume that these annual savings, extended over the entire lifetime of the measures (10 years), are incurred in 2014 by using their net present value: $NPV = \sum_{t=0}^{L} \frac{Annual\ savings}{(1+d)^t}$, i.e. the impact of avoided expenses is assumed to be lowered each year by a discount factor $d=2.5\%$. The resulting NPV is provided in Table 1.

Table 1 Expenses and savings resulting from the deployment of measures in 2014, in consumer prices (adapted from [Yushenko & Patel, 2016], figs 11&12 suppl. mat., for the purpose of this exercise)

Expenditure [kCHF]	
Equipment*	1'358
Administration of the programme	538
Other business services	43
IT spending by the programme (website, simulator…)	62
Wholesale margin on equipment	1'378
Electricians and heat installers	1'563
Energy cost savings (NPV, excl. taxes)	-5'598

* Imported, a transport margin of 5% applies.

Input-Output Analysis

As first step, open the **Excel file** and study its content. Description of tabs and data sources can be found in Table 2. The base year for this exercise is 2017.

Table 2. Description of Excel file content and data sources

Sheet name	Description	Data source
Expenditure	2014 expenditure on goods and services for measure implementation and programme operation	Yushchenko, Alisa, and Martin K. Patel. "Contributing to a Green Energy Economy? A Macroeconomic Analysis of an Energy Efficiency Program Operated by a Swiss Utility." Applied Energy 179 (October 2016): 1304–20. https://doi.org/10.1016/j.apenergy.2015.12.028
SIOT	Swiss input-output table for 2017	SFSO. Swiss Input-Output Table 2017. Bern: Swiss Federal Statistical Office; 2018.
$(I-A)^{-1}$	Inverse input-output matrix	Calculated from Swiss input-output table.
Electricity	Swiss electricity consumption by sector in 2017	SFSO. Energy flow accounts by economic activity, aggregated by sections and energy sources, in TJ. Bern: Swiss Federal Statistical Office; 2021.
Emissions	Swiss total GHG emissions by sector	Air emissions accounts of the economy and households, SFSO, 2021
Matrix exercise	A matrix example to perform the matrix inverse calculations	Kornelis Blok and Evert Nieuwlaar, Introduction to Energy Analysis. Routledge editors, 2020
NCT	Net commodity taxes	Calculated from the Swiss input-output table

You are expected to perform a preliminary input-output analysis of the programme operation from a macroeconomic perspective, focussing in particular on GHG emissions. The sections below guide you

through a typical research process: Experimenting with the method, application to the study data and writing of a report. We expect you to provide at least the filled "Answers" sheet of the Excel file and a brief research report. The report should be self-standing and not rely on the Excel file for comprehension.

Part 1 – Sandbox (6 points)

A (2 points). In order to gain practical insight into the construction of the Leontief inverse matrix, you are requested to perform the calculations illustrated in the lecture (slide 20 onwards). On the "Matrix exercise" tab, calculate the technology matrix *A* and the Leontief inverse matrix $P=(I-A)^{-1}$. You might want to use the matrices *I* and (*I-A*). Add these tables with Excel formulae in the "Matrix exercise" tab.
Tip: To calculate the inverse matrix, use the function "MINVERSE" ("INVERSEMAT" in the French version) after selecting the entire result range, and validating the formula with Ctrl+Shift+Enter. For a tutorial: https://youtu.be/G8w-d9U3PJM?t=127 (from sec 2:07)

B (2 points). Compute total output multipliers from this basic example (see slide 26 onwards). Then use the energy consumption vector provided in the class to compute the vector of energy intensities (see slide 28 onwards) and that of energy multipliers (see slide 32 onwards).
Tip: Energy intensity is the ratio between the electricity consumed by a sector and the output of that sector. Then the row vector of *Energy intensities* can be multiplied by the *P matrix* using the Excel function "MMULT" ("PRODUITMAT" in the French version). You can use the "TRANSPOSE" function to transform column vectors into row vectors.
NB: Matrix multiplication is not commutative, check this website for a detailed description of matrix multiplication: https://www.mathsisfun.com/algebra/matrix-multiplying.html.

C (2 points). Consider the purchase of a 1CHF light bulb, as in the class. To which sector would you assign that 1CHF? Build the vector of final demand change due to this purchase. Compute the electricity consumed across the economy due to the purchase of the light bulb, using the electricity multipliers.

Part 2 – Application to data (18 points)

A (2 points)**.** Calculate *total output multipliers*, representing the total of direct and indirect activities generated by 1 CHF of final demand from a sector based on data provided in "(I-A)-1" tab (i.e. the *P matrix*). Write down your results in the "Answers" tab.

B (3 points). Calculate the GHG intensity vector, showing *GHG emissions* per unit of total output (MWh/MCHF) of each sector, based on data provided in "SIOT" and "Emissions" tab. Write down your results in the "Answers" tab.

C (3 points)**.** Calculate *GHG multipliers*, based on the *P matrix* provided in the "(I-A)-1" tab and the vector of *GHG intensities*. Write down your results in the "Answers" tab

D (4 points)**.** Calculate the vector of change in *final demand for domestic goods and services in basic prices* due to the operation of the programme in 2014 based on data provided in "Expenditure" and "NCT" tabs. Write down your results in the "Answers" tab.
Tip: *Basic price* is equal to *consumer price minus trade and transport price* and *net commodity taxes (NCT)*. It therefore includes the added value of the products (wages, operational surplus etc.). We assume that equipment is purchased locally directly from *producers* so we assume that trade and transport margins are negligible, except for part of the lighting equipment (see above). You need to assign each expenditure to one sector. For details on sectoral classification, see:
https://www.bfs.admin.ch/bfs/en/home/statistics/industry-services/nomenclatures/noga.html

E (6 points) Calculate **change** in the following indicators due to the implementation of the programme, using the vector of final demand change and multipliers computed previously and write them down in the "Answers" sheet:

- Total output (in total and by sector), million CHF
- Direct GHG emissions change (in total and by sector), tons
- Total (direct and indirect) GHG emissions change, tons

Part 3 – Report writing (36 points)

You are expected to write a short report using the following sections:

A. Introduction (2 points)

Present your work and the layout of the report in a couple of sentences.

B. Concepts and methodology (12 points)

Explain in your own words the procedure that you followed, illustrating from the example computed in Part 1. You should at least define the following terms and explain how you used or calculated them in your analysis. Please, do not restrain yourself to information from the slides of the course but be careful to properly quote and refer to your sources if any (see https://www.unige.ch/universite/politique-generale/plagiat/):

a. Final and intermediate demand
b. Input-output table and Leontief inverse matrix
c. GHG intensity and GHG multipliers
d. Direct, indirect and induced impacts (which did you calculate ?)
e. Gross and net impacts (which of both did you calculate ?)
f. Basic price and net commodity taxes

C. Results (4 points)

Provide the answers table along with at least one graph that you find of interest. Briefly introduce them so you can refer to them in the discussion.

D. Discussion (16 points)

Answer at least the following questions:

a. At the macroeconomic level, where do the main impacts of the EEP implementation seem to come from in terms of GHG emissions? Are they due to volume or multiplier effects? Provide a description of real-world processes to explain your numerical results.
b. One plausible induced effect of the programme implementation is that energy cost savings would be re-invested, generating further GHG emissions. How could you model this mechanism with an input-output approach[1] ? What other induced effects can you think of?
c. What are the major advantages and disadvantages of the analysis you performed? Cite at least two of each. You can reflect on the methodology as well as the assumptions made. Specify how you could address the disadvantages.
d. What further analysis could you perform to evaluate whether energy efficiency programmes are beneficial from a macroeconomic perspective? Suggest at least two possibilities and mention how they differ from and/or complement the methodology you used.

E. Conclusion and future research (2 points)

Conclude on the relevance and limitations of your work in a couple of sentences.
What other subjects would you imagine exploring with input-output analysis?

[1] You may keep it simple. For inspiration, see e.g. Freire-González, Jaume. 2011. "Methods to Empirically Estimate Direct and Indirect Rebound Effect of Energy-Saving Technological Changes in Households." Ecological Modelling, 223 (1): 32–40. https://doi.org/10.1016/j.ecolmodel.2011.09.001.

.