ECONOMETRIC MODELS OF CLIMATE CHANGE:
THE GLOBAL CARBON BUDGET
CASE A

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1. Introduction

One of the key drivers of the greenhouse effect, by which long-wave radiation from Earth that would otherwise escape into space is absorbed in the atmosphere and thus remains within the Earth system, is carbon dioxide (CO_2).

Since the beginning of the industrial era in the middle of the 18th century, carbon dioxide emissions from human activity have been steadily increasing. Even though they still comprise only a small part of total carbon dioxide emissions that move continuously through Earth's carbon cycle (the larger part stemming from plant respiration and decomposition), these so-called anthropogenic emissions upset the long-term equilibrium this cycle had settled in before the industrialization. This equilibrium was dynamic, with atmospheric carbon dioxide concentrations oscillating during the last 800,000 years between roughly 180 ppm (parts per million) during ice ages and 280 ppm during warm periods. Since about the 1920s, the majority of anthropogenic emissions have been from fossil fuel combustion, and they have been growing roughly exponentially (Le Quéré et al. 2018). Latest measurements record atmospheric carbon dioxide concentrations at more than 400 ppm, about 100 ppm above the current maximum over the last 800,000 years.

The aim of the Global Carbon Project [1] is to collect and homogenize attempts at quantifying the anthropogenic carbon equilibrium upset. The group publishes the annual Global Carbon Budget and the corresponding data. [2]

The main data objects that are collated and maintained are anthropogenic carbon dioxide emissions from fossil fuels (E_FF) and from land-use change (E_LUC) (deforestation, afforestation, and others), different estimates of how much of these emissions are absorbed by the terrestrial biosphere (land sink S_LND), and different estimates of the amount absorbed by the ocean (ocean sink S_OCN). By necessity, all emissions not absorbed by Earth's carbon sinks must end up in the atmosphere, and so the final object of interest is the growth in atmospheric concentrations (G_ATM).

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[1] www.globalcarbonproject.org

[2] http://www.icos-cp.eu/GCP/2018

The Global Carbon Budget Equation is thus

$$G\_ATM_t = E\_FF_t + E\_LUC_t - S\_LND_t - S\_OCN_t + e_t, \tag{1}$$

where e_t is an error term that accounts for all the measurement and estimation errors that accumulate in the process of collecting the data.

The data set made available for this case is the Excel file `Global_Carbon_Budget_2018v1.0.xlsx` from the web site in Footnote 2. The second tab "Global Carbon Budget" has annual global time series from 1959 to 2017 for all elements in Equation (1), measured in GtC/year. The error term e_t is dubbed "budget imbalance". The data set is described in detail in Le Quéré et al. (2018).

Case Research Questions

Main modelling challenge: Specify a model that relates the Global Carbon Budget time series in the second tab of the spreadsheet `Global_Carbon_Budget_2018v1.0.xlsx`, using the budget equation (1) as the basic guidance for the model's structure. You have to use all the data in this tab, but you are not limited to them.

Main policy challenge: Consider the scenarios of the Representative Concentration Pathways initiative (Meinshausen et al. 2011), denoted RCP2.6, RCP4.5, RCP6, and RCP8.5, which consider global surface temperature scenarios between 1.5 degrees warming above pre-industrial levels (RCP2.6) to 4.5 degrees warming (RCP8.5) by the year 2100. In the RCP2.6 scenario, for example, a maximum of 440 ppm atmospheric carbon dioxide concentration is reached in 2050, followed by a reduction to about 360 ppm in the long run thereafter.[3] Using your model, explore what the RCP concentration scenarios imply for admissible global emission paths and formulate requirements for global emission reductions corresponding to the different scenarios.

Le Quéré, C. et al., 2018, The Global Carbon Budget 2018, *Earth System Science Data* 10: 2141-2194.

https://doi.org/10.5194/essd-10-2141-2018

Meinshausen, M. et al., 2011, The RCP greenhouse gas concentrations and their extensions from 1765 to 2300, *Climatic Change* 109: 213–241.

[3] I provide the annual CO_2 concentration scenario time series of the RCPs in the period 2019–2100 in units of ppm in the file `RCP_CO2_concentrations_2019_2100.csv`. They are obtained from http://www.iiasa.ac.at/web-apps/tnt/RcpDb/.

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