AMERICAN ECONOMIC ASSOCIATION

ASSA 2021 Virtual Annual Meeting

Fiscal tools to reduce transition costs of climate change mitigation

Lorenzo Forni, Università degli Studi di Padova, Prometeia
Michele Catalano, Prometeia
Emilia Pezzolla, Prometeia

1222·2022 800 ANNI

UNIVERSITÀ DEGLI STUDI DI PADOVA

prometeia

How much the transition out of greenhouse gas emissions will cost to the economy?

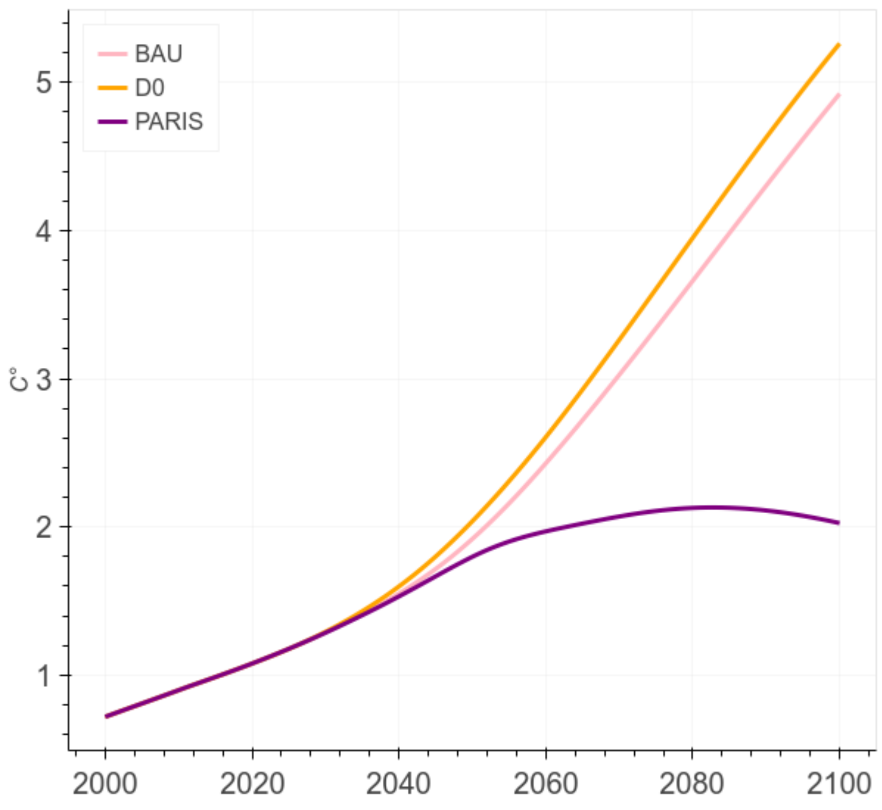
- **Current available estimates differ widely** (different methodologies; inherent uncertainty related to forecasting future greenhouse gas emissions and temperature increases).

- This is a serious problem, also in consideration of the fact that **climate scenario analysis is becoming a fundamental tool to assess the risks** due to global warming and climate change on real activities and on financial institutions.

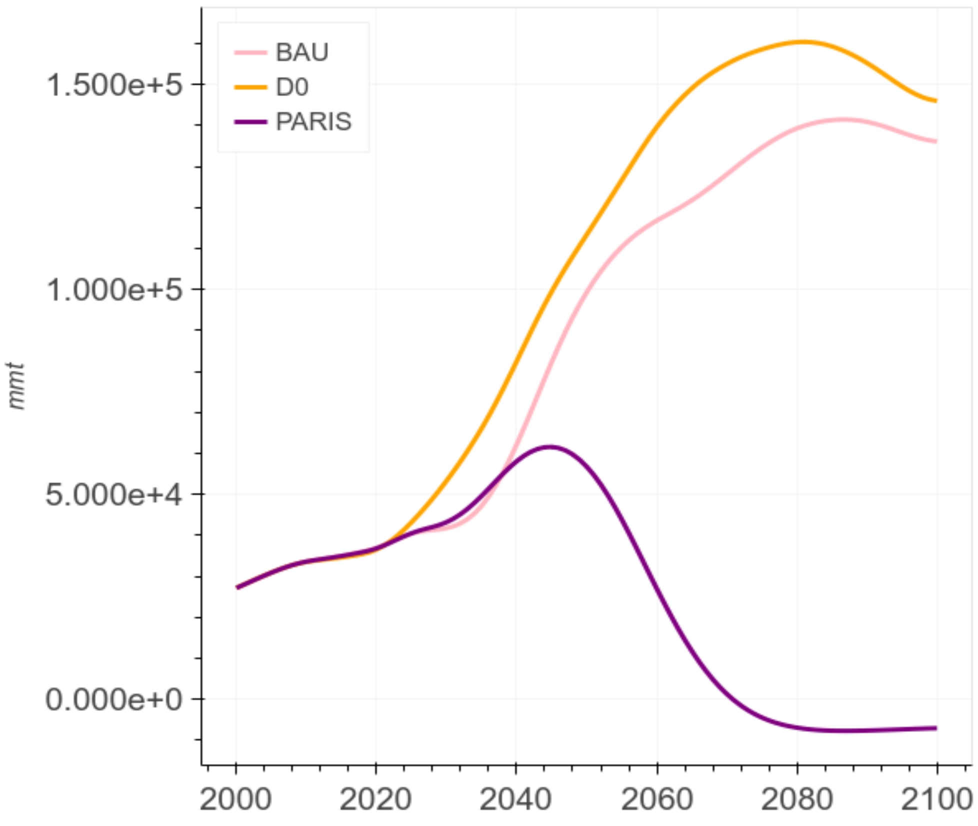
- Therefore, **our goal is** to contribute to the problem, seeking **to identify the cost of mitigation policies needed to implement widely-used scenarios** for future carbon emissions and temperature increases (such as the Paris Agreement path).

Temperatures and CO2 emissions

Temperatures anomalies (°C)



CO2 emissions (ton)



BAU: climate change impact on the economy, unchanged mitigation policy (status quo)
D0: no climate change impact on the economy
PARIS: carbon pricing to contain global temperatures at 2°C (in line with the Paris Agreement)

Our approach

→ The most widely used models among academics for assessing climate issues are **Integrated Assessment Models (IAM)** that integrate economic modules with climate modules, allowing for interactions between the two.

→ Nordhaus [2017] recognizes that the **economic projections are the least precise parts of IAMs**. This limitation extends to the issue of policies, **especially fiscal policy** (IAMs generally allow for carbon taxes but do not incorporate a fiscal module nor the effect of climate change on fiscal revenues).

→ This paper uses a **global overlapping generation (OLG) model** in the spirit of Kotlikoff et al. [2019] **augmented with a climate module** (FUND, Anthoff et al. [2014]) to assess the role of budget policies in estimating the economic costs related to the transition to lower greenhouse gasses emissions.

→ In particular, we focus on the **combination of carbon pricing measures and fiscal incentives for green investments**, considered one of the most effective policies to achieve a reduction in greenhouse gas emissions (Barrage [2020]).

Literature review

Most papers focus on integrated assessment models (IAMs) to quantify the damages caused by climate change and the cost of efforts to limit its extent:

- Nordhaus, W.D. (2007) The Challenge of Global Warming: Economic Models and Environmental Policy
- Nordhaus, W.D. (2008) A Question of Balance: weighting the options on global warming policies. New haven: Yale University press.
- Nordhaus , W.D. (2018) Projections and uncertainties about climate change in an era of minimal climate policies. American Economic Journal: Economic Policy, 10(3):333{60, 2018.
- Bonen A., P. Loungani, W. Semmler and S-. Koch (2016). "Investing to Mitigate and Adapt to Climate Change; A Framework Model," IMF Working Papers 16/164, International Monetary Fund.

Others use a multi-country overlapping generations approach:

- Heijdra, B. J., Kooiman, J. P., and Ligthart, J. E. (2006). Environmental quality, the macroeconomy, and intergenerational distribution. Resource and Energy Economics, 28(1):74-104
- Kotlikoff L.J., A. Polbin and A. Zubarev, (2016). Will the Paris Accord Accelerate Climate Change?", NBER Working Paper 22731, National Bureau of Economic Research.
- Kotlikoff L.J., F. Kubler, A. Polbin, J.D. Sachs, and S. Scheidegger. Making carbon taxation a generational win win. NBER Working Paper, (25760), 2019.
- Catalano, M, L. Forni, and E. Pezzolla. Climate-change adaptation: The role of fiscal policy. Resource and Energy Economics, 2019.

Main findings

- → To reduce temperatures to the target level of the Paris Agreement will require an **aggressive carbon pricing policy.**
- → In our analysis, this translates into **energy prices that will have to increase significantly.**
- → Using the **revenue from carbon pricing to fund low emissions (green) energy incentives would seem sufficient** to ensure global phase-out of fossil fuels and zero net emissions by 2070 but implies significant short- and medium-run economic costs.
- → To facilitate the transition to a low-carbon economy and achieve global carbon neutrality, **substantial public support for green investments will be needed**.

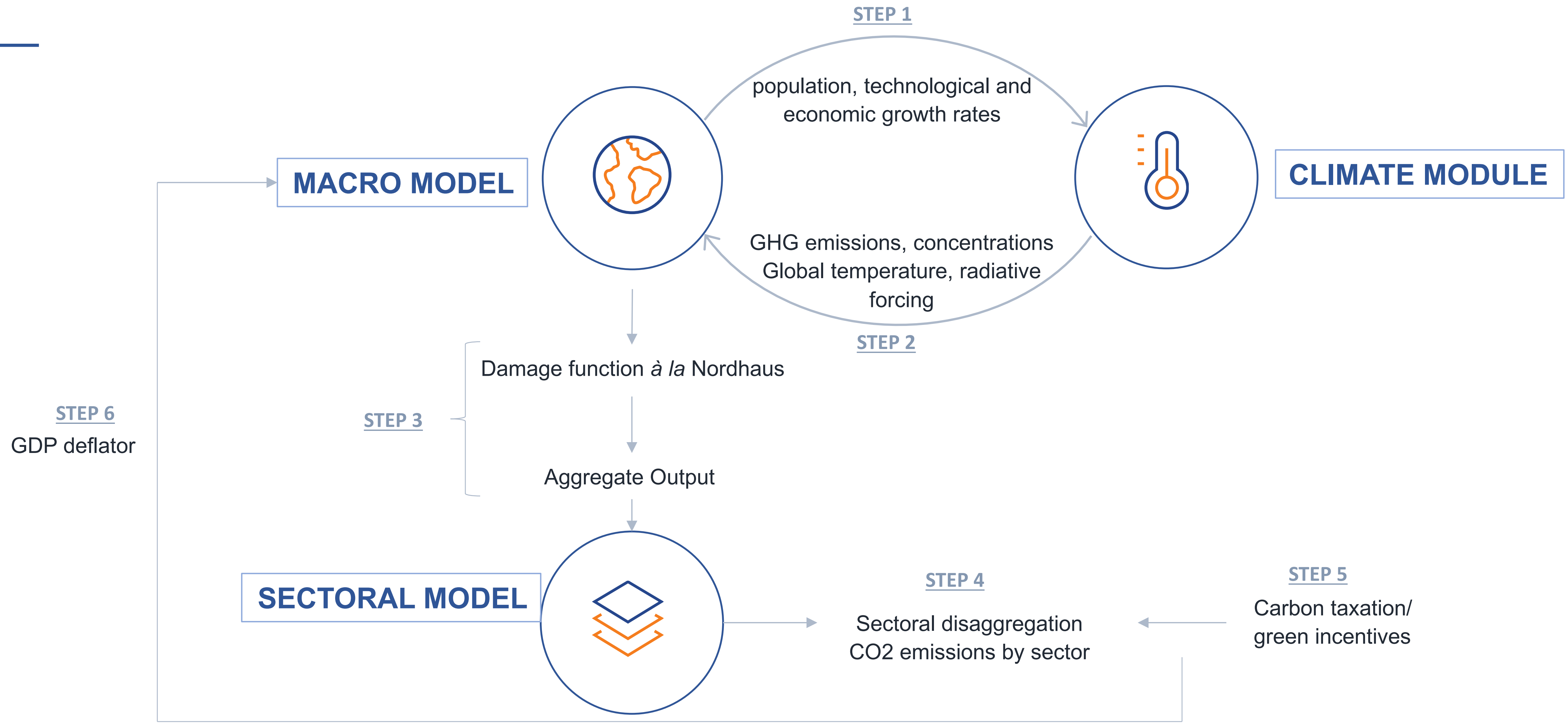
The model: the economic and climate modules

1. **Macro multi-country overlapping generations (OLG) model with:**
   - 8 regions/countries: Europe (Germany, France, Italy), US, China, India e Africa and the rest of the world
   - 4 core sectors: Households, Firms, Government and Financial Markets

2. **Sectoral model with:**
   - 8 sectors: Brown energy sector, Green energy sector, Negative emissions sector, Heavy manufacturing, Light manufacturing, Crops, Livestock, Services

3. **Climate module which computes:**
   - GHG emissions: CO_2, CH_4, N_2O, SF_6 and SO_2
   - Global average temperatures
   - Radiative forcing

The model: how it works



The model: the OLG multi-country (macro level)

Households:

- set life-cycle consumption *C* and leisure (labour supply *L*) decision under the perfect foresight hypothesis
- save and hold financial assets *A*
- retire at age 66 receiving pension *T*, and are assumed neither to leave bequests nor to receive inheritances

Aggregate budget constraint (*)

$$A_{t+1} = (1 + r_t - \tau_{a,t})A_t + (1 - \tau_{l,t})w_t L_t - (1 - \tau_{c,t})p_t C_t + pens_t + \pi_t$$

- r_t: real interest rate prevailing on the financial market
- A_t: real aggregate savings
- $p_t C_t$: real consumption
- $\tau_{a,t}\ \tau_{l,t},\ \tau_{c,t}$ denote the tax rates on wealth, labour income and consumption, respectively
- $(1 - \tau_{l,t})w_t L_t$: post-tax labour income
- $pens_t$: pensions
- π_t: profits from the sectoral model

(*) *All variables in the model are defined in real terms by using the export price of the US as numeraire.*

The model: the OLG multi-country (macro level)

Firms:

- produce an aggregate output *Y* with physical capital *K*, effective units of labor *L*, and technology Z, which is the endogenous TFP net of climate damage *D*
- effective labour *L* is given by *NH*, with *N* labor input and *H* human capital
- Endogenous TFP increases due to both capital/labor ratio *K/N* and human capital per worker *H*

Production function

$$Y_t = Z_t K_t^{\alpha} (H_t N_t)^{1-\alpha}$$

Technology

$$Z_t = (1 - D_t) TFP_t$$

Endogenous productivity

$$TFP_t = \left(\frac{K_t}{N_t}\right)^{g} H_t^{z}$$

Climate damage à la Nordhaus

$$D_t = 1 - \frac{1}{1 + \pi_1 T_t^A + \pi_2 (T_t^A)^2}$$

- g: contribution of the capital/labour ratio to the TFP
- z: contribution of the human capital to the TFP
- α: capital share, i.e. the share of income spent on capital
- I_t and I_t^*: private and public investment in physical capital
- T_t^A denotes the change, since 1900, in global mean surface temperature measured in Celsius.

The model: the OLG multi-country (macro level)

Government:

- raises taxation on consumption, labor, wealth and CO2 emissions
- uses revenues from carbon tax to finance green incentives
- uses other revenues to finance social transfers (*pens*) and the education systems (*sg)*
- issues new debt *B* to finance the deficit

Public budget

$$\Delta B_t = r_t B_t - \tau_{l,t} w_t L_t - \tau_{c,t} p_t C_t - \tau_{a,t} A_t + sg_t + \zeta_t pens_t + G_t - rev_{co2,t} + inv_t$$

- $\tau_{a,t}$ denote the tax rate on wealth A_t, $\tau_{l,t}$, $\tau_{c,t}$ denote the tax rates on labour income and consumption, respectively
- ζ denote the number of retired people
- $w_t L_t$ labour income, pC_t households' consumption
- $pens_t$ and sg_t denote transfers and schooling expenditure, respectively
- $G_t = \gamma Y_t$ public spending as fraction of GDP
- $rev_{co2,t}$ revenues from carbon taxation
- inv_t exogenous public investment

The model: the OLG multi-country (macro level)

Financial markets

- The Net Foreign Asset (NFA) in each region is defined as:

Net Foreign Asset

$$NFA_t = A_t - q_t K_t - B_t$$

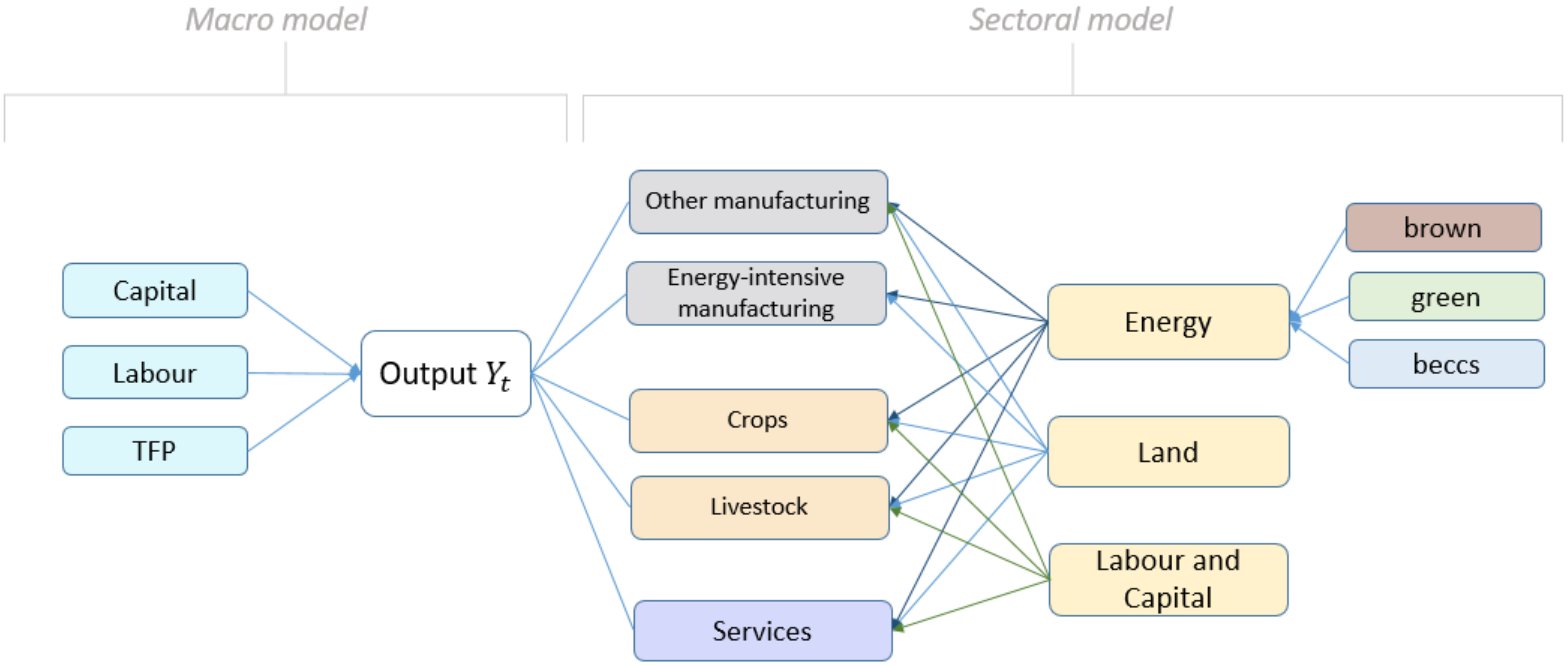
- A_t aggregate saving
- K_t capital stock
- B_t public debt
- q_t is the **Tobin's q** that is defined through an intermediate financial sector that disaggregates the capital of the firm at macro-level (K_t) in capital stocks $K_{j,t}$ used for the j-sector production of the sectoral model. The financial intermediate firm buys at price q_t the investment goods I_t , and sells a disaggregated investments goods, $I_{j,t}$ at the different sectors j at price $q_{j,t}$. Therefore, the value of aggregate capital is given by the following CES function, with γ_{jt} and η_t denoting the share and the elasticity of the CES function respectively:

Value of aggregate capital

$$q_t = \left[\sum_j \gamma_{j,t} q_{j,t}^{1-\eta}\right]^{1/(1-\eta)}$$

The model: the sectoral level

A dual system approach: while the macro-model defines output Y_t in terms of aggregate macro-inputs and from a supply side perspective, the CGE model defines the same quantity at the sectoral level taking into account the disaggregated economic structure. General equilibrium conditions are satisfied in each sector matching supply and demand through price determination



The model: the sectoral level

CO2 emissions

- Emissions from sector j are defined as follows:

CO2 emissions

$$CO2(j)_{k,t} = \frac{1}{A(j)_t} \gamma_{k,t} \theta_{k,t}^{\sigma_j - 1} \left(\frac{p(j)_{k,t} + \tau_{CO2,t}}{p(j)_t} \right)^{-\sigma_j} Q(j)_t$$

- We assume an exogenous emission dynamic constraint on total actual emissions $\overline{CO2}_t$:

Emissions constraint

$$\sum_j CO2(j)_t = CO2_t \leq \overline{CO2}_t$$

Macro-climate scenarios

1. No climate change impact scenario (**D0**)
    - temperature rise > 5°C to 2100;

2. Baseline scenario (**BAU**)
    - weak and different mitigation by area (stronger in EU, less in US and CHN);
    - temperature rise > 4°C to 2100;

3. Paris Agreement scenario (**PARIS**)
    - strong and different mitigation between areas;
    - temperature increase to 2°C by 2100;

4. Paris Agreement scenario (**PARIS1**)
    - compared to the "Paris" scenario, in this scenario we considered an expansive fiscal policy with green public investment (1% of GDP for 5 years) to facilitate the transition to “carbon neutrality”: with the same emissions we want to minimize the economic cost and find a sustainable path in terms of growth and public finances.

Macro-climate scenarios

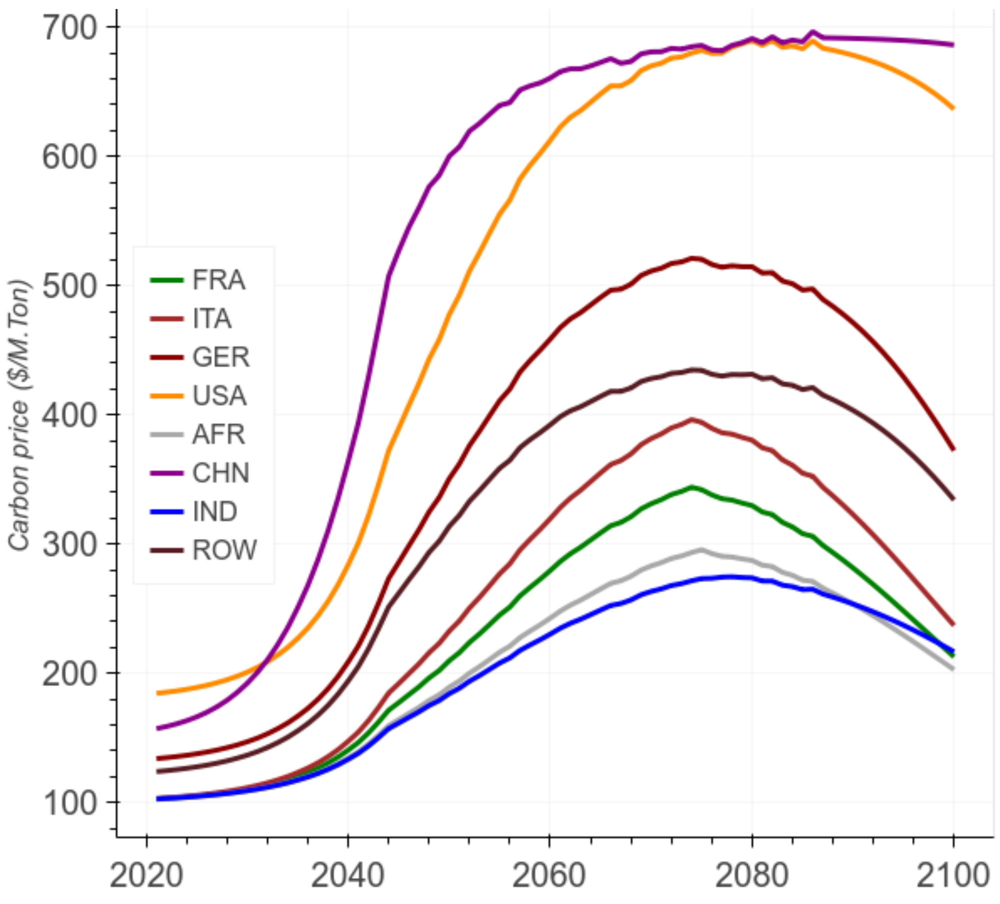
- The mitigation action is implemented with an **increase in the cost of emissions** (which would occur with carbon pricing instruments)
- This results in an **increase in the cost of energy produced from fossil fuels** (which in the model are coal, oil and natural gas) and encourages the use of green sources
- We have assumed that the **revenue** generated by carbon pricing is used to **increase incentives/investments for the use of green sources** ("Paris" and "Paris1").
- In addition to green incentives, in the “Paris1” scenario we have introduced **green public investment for 5 years**
- Unlike the BAU scenario, in the Paris1 and Paris scenarios the level of CO2 emissions is “targeted” to reach **zero net emissions in 2070**.

Macro-climate scenarios

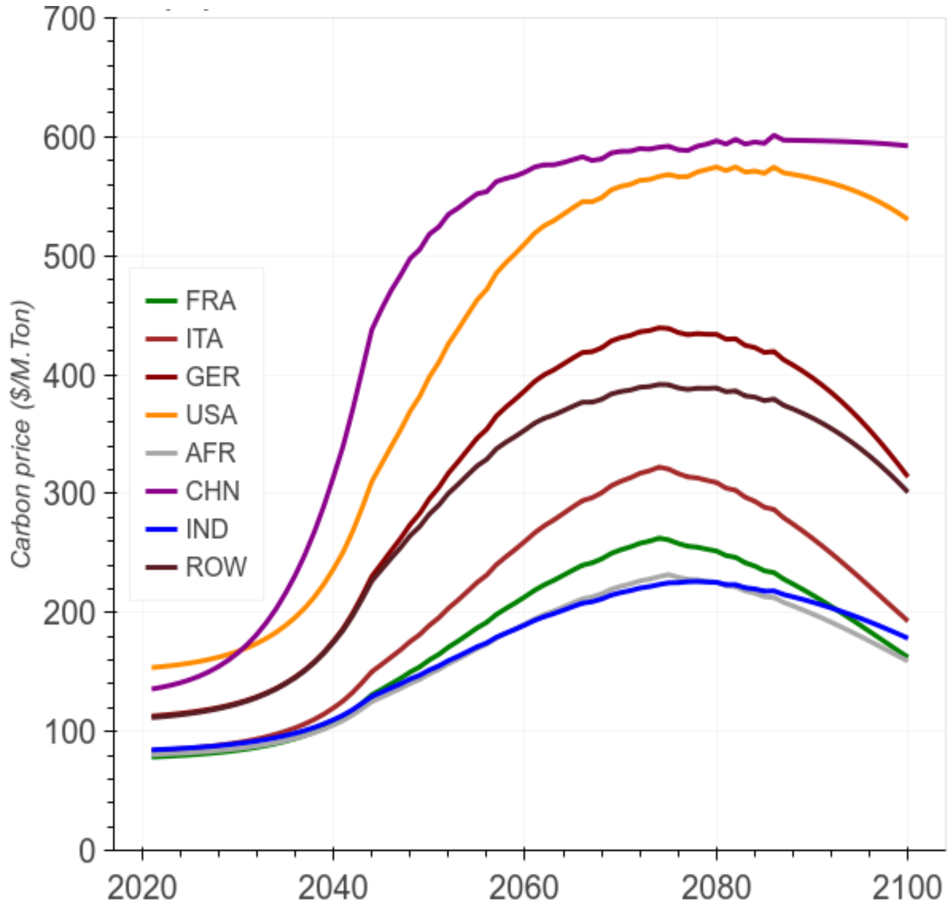
	Climate damage to the economy	Carbon pricing	Green incentives	Public green investment	Net emissions (carbon neutrality 2070)
D0					
BAU	✓				
Paris	✓	✓	✓		✓
Paris1	✓	✓	✓	✓	✓

Results

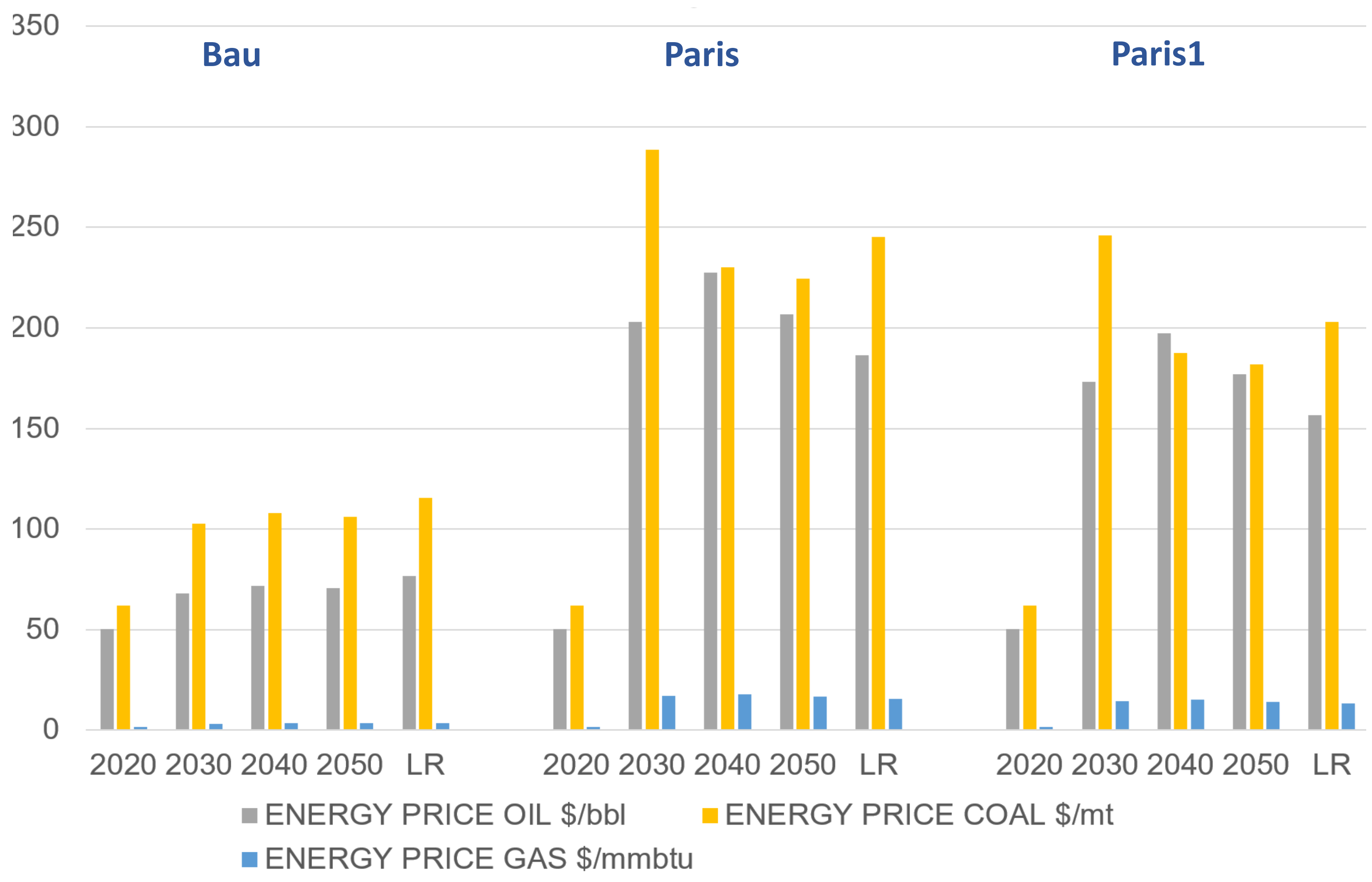
Paris: carbon price ($/MT)



Paris1: carbon price ($/MT)

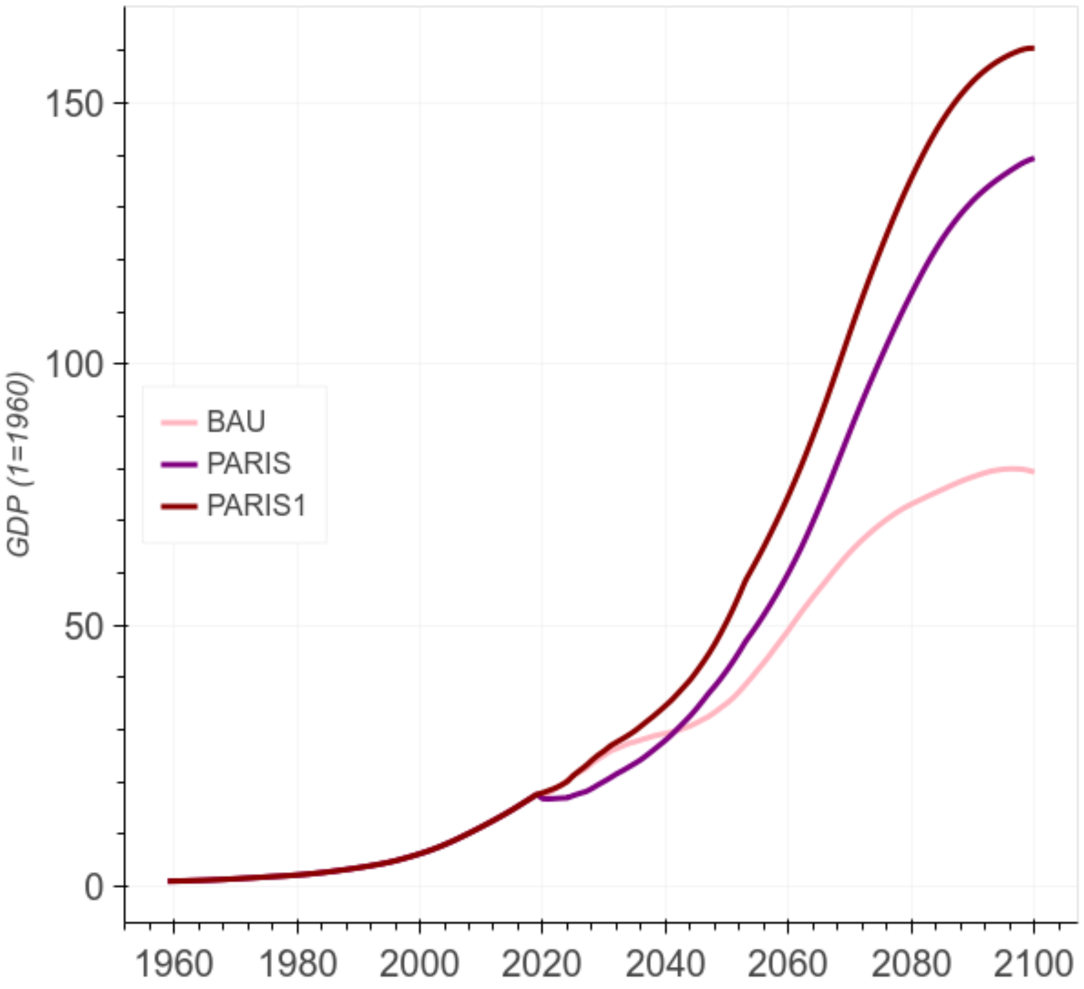


Results


350
300
250
200
150
100
50
0
Bau
Paris
Paris1
2020 2030 2040 2050 LR
2020 2030 2040 2050 LR
2020 2030 2040 2050 LR
ENERGY PRICE OIL $/bbl
ENERGY PRICE COAL $/mt
ENERGY PRICE GAS $/mmbtu

Results

WORLD GDP



- The carbon pricing policy in the “Paris” scenario would imply economic costs in the short-run compared to the BAU scenario, but significant benefits in the long run (55% as deviation from BAU)

- These benefits would be higher (88%) in the presence of public green investment in the “Paris1” scenario that limits the increase in carbon price and foster the transition to a low-carbon economy

Conclusion

- → In order to achieve the Paris Agreement targets, the various policies under consideration mainly examine the possibility to increase carbon pricing, in addition to incentives for green investments.
- → We have built a model that falls within the framework of the Integrated Assessment Models (IAM) à la Nordhaus to analyze the impact of climate change and mitigation policies on economic growth
- → The carbon pricing policy with global zero emissions targeted by 2070, allows the temperature increase to be kept within 2°C, but at the cost of a recession in the short term which is not foreseen in the business-as-usual scenario.
- → Public green investments can help to contain the short-run recessionary pressure while at the same time limiting the magnitude of the carbon price increase.

Thanks for your attention!