Lecture 4: Public sector importance for mitigation and adaptation policy- Bending the carbon curve

4.1. Introduction

- Sustainable Macroeconomics: Dynamic model as guidance for policies of sustainable development and growth, as opposed to DICE or DSGE models
- Macroeconomic policy is necessary for decarbonization: the impact of setting standards, regulations, carbon pricing risk, phasing out fossil and phasing in renewables, and adaptation to climate risks
- Model-guided policies, in particular fiscal and monetary policies are needed to assess and promote the development of renewable energy sectors
- Yet in macroeconomics governments often have urgent and competing multiple policy objectives, and climate policies is only one of them
- Sustainable macroeconomics should also allow for studying other policies (Industrial policies, financial policies, income policies, sovereign debt, and goal conflicts)

Lecture 4.2 => Bending the carbon curve?

GDP per capita increase from 1880: 12 times higher; Is there a Kuznets Environmental Curve? See IMF papers, with Loungani et al. (2018), Data Source: Owid-CO_2

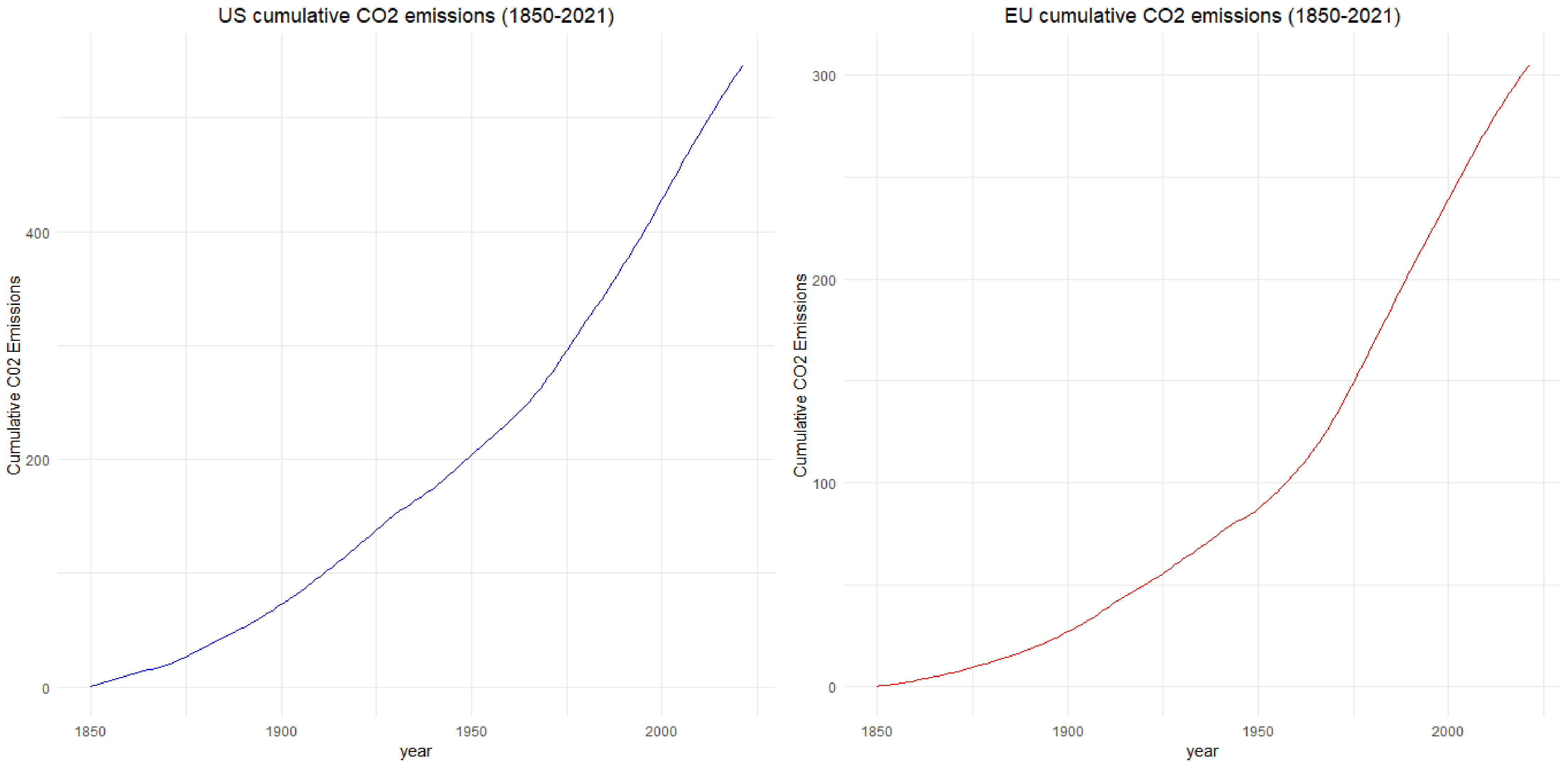
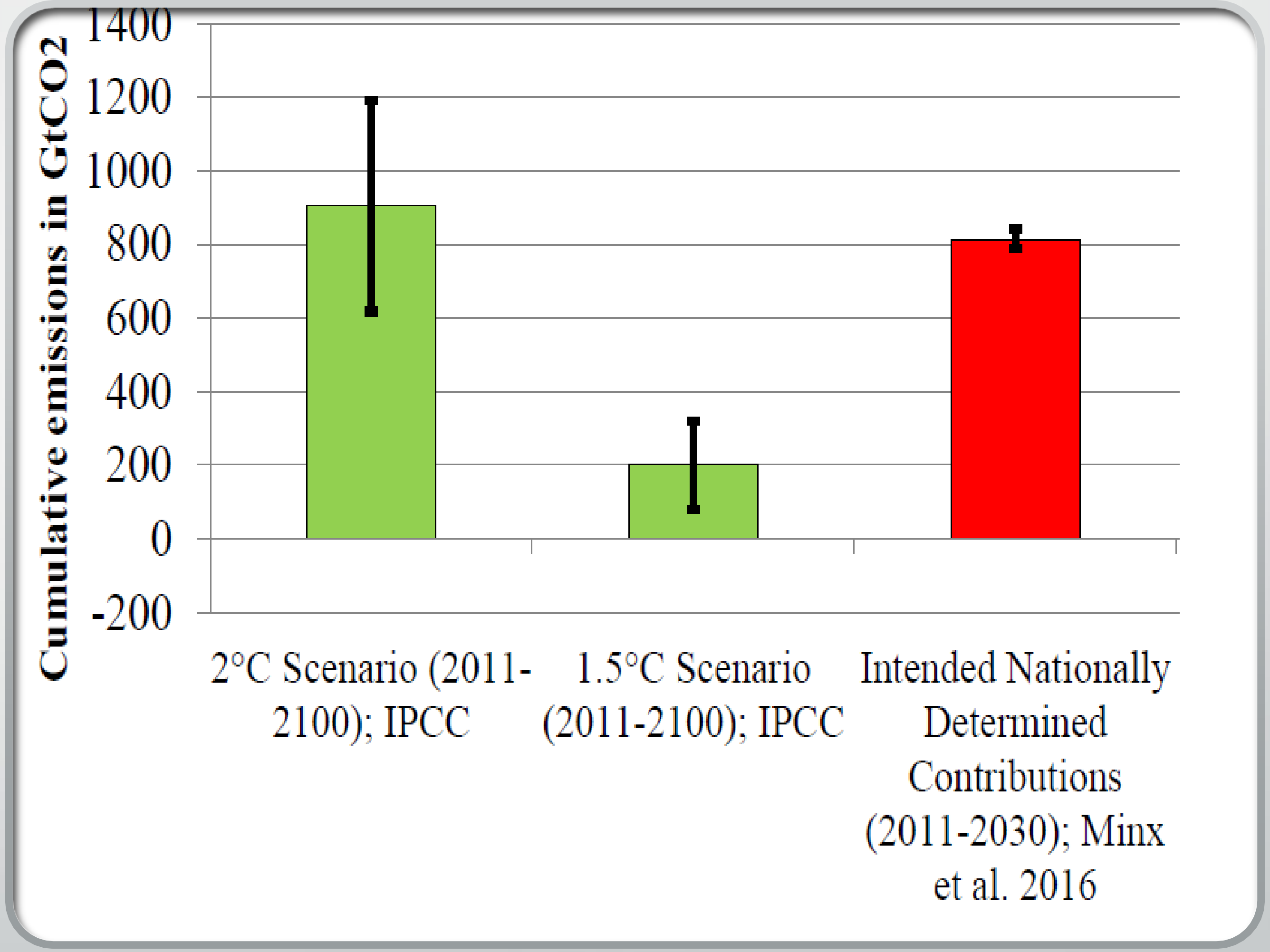


Figure 2: Cumulative Emissions in Giga Tones Plotted from 1850 to 2021, source: Owid-CO2

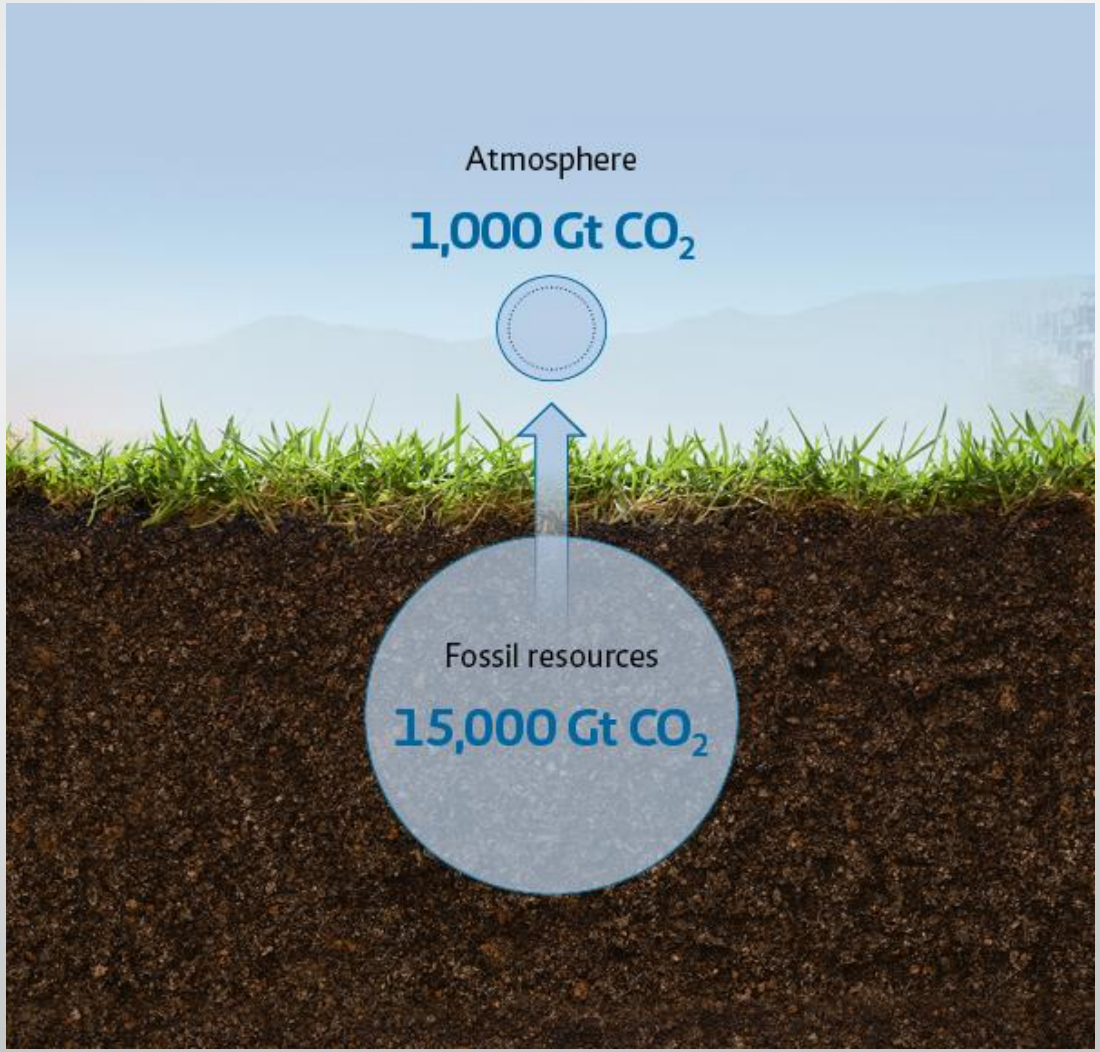
Lecture 4.2. Carbon curve and Carbon Budget? Paris (2015) policy targets, see Edenhofer et al. (2014), PIK research

=> Paris (2015) Target:

- Reduction of 50 % (65%) of net emissions until 2030
- Zero net emission by 2050

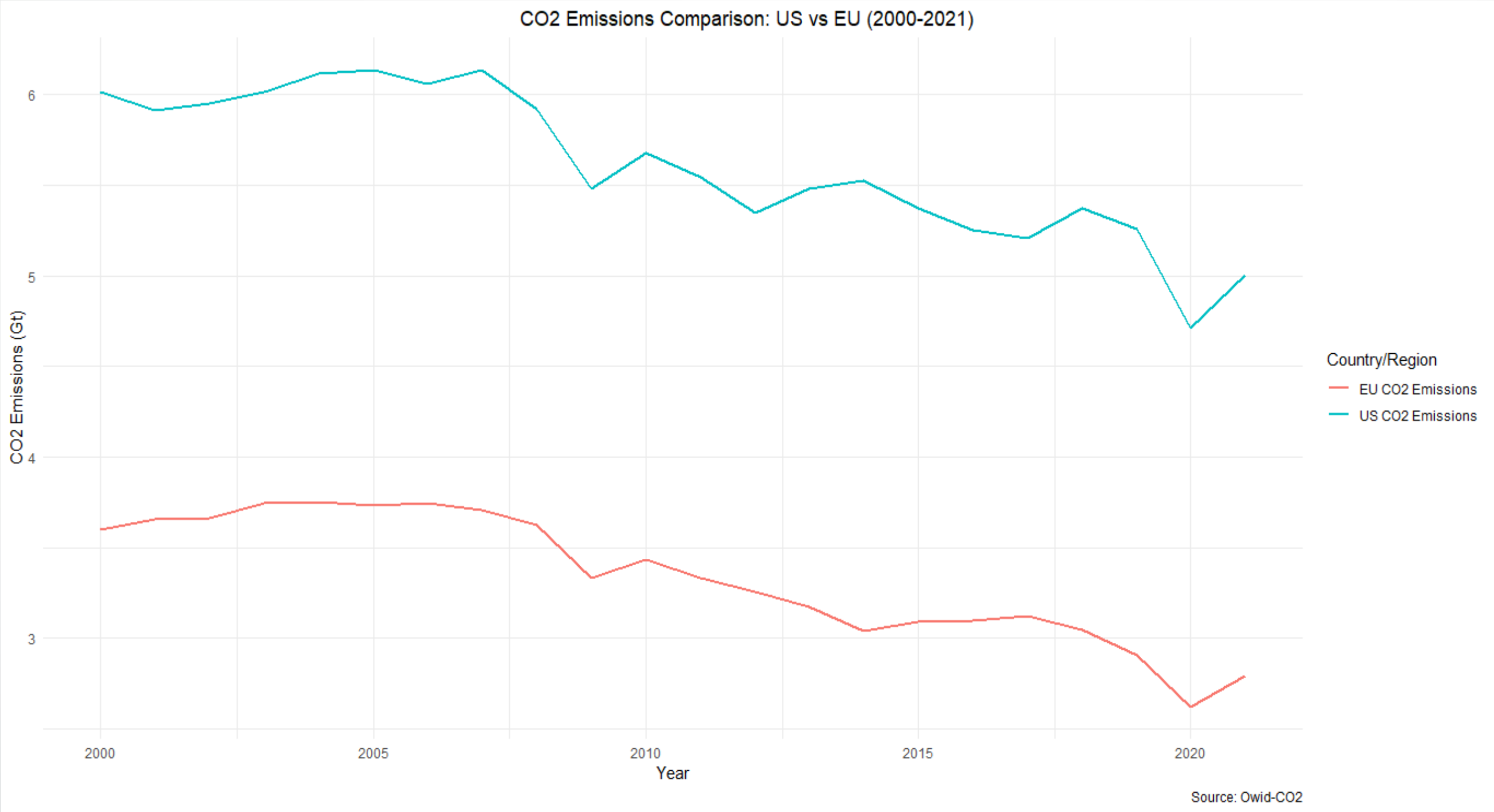


Lecture 4.2 Carbon Curve and Carbon Budget? ; Where are we now? At the upper constraint of 400 ppm Edenhofer et al. (2014), PIK research



Lecture 4.2 Facts: Current Situation – Is there some hope---a sufficient reversing of the carbon curve?

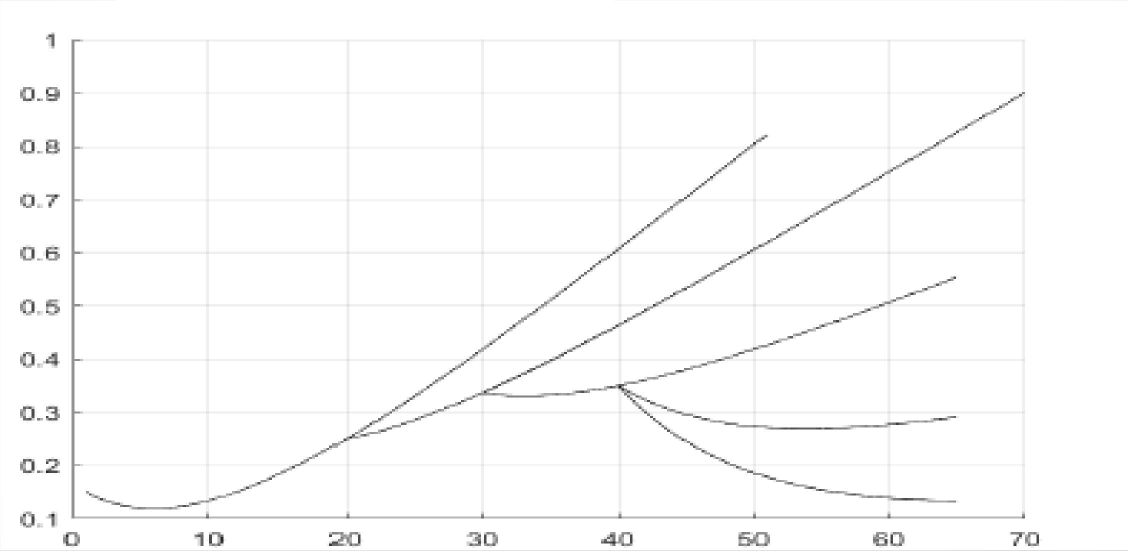
Requires lower and then zero growth rates of net emission



Lecture 4.2. Facts: Current situation -- How to reverse the carbon curve?
Lower growth rates and then net zero emission

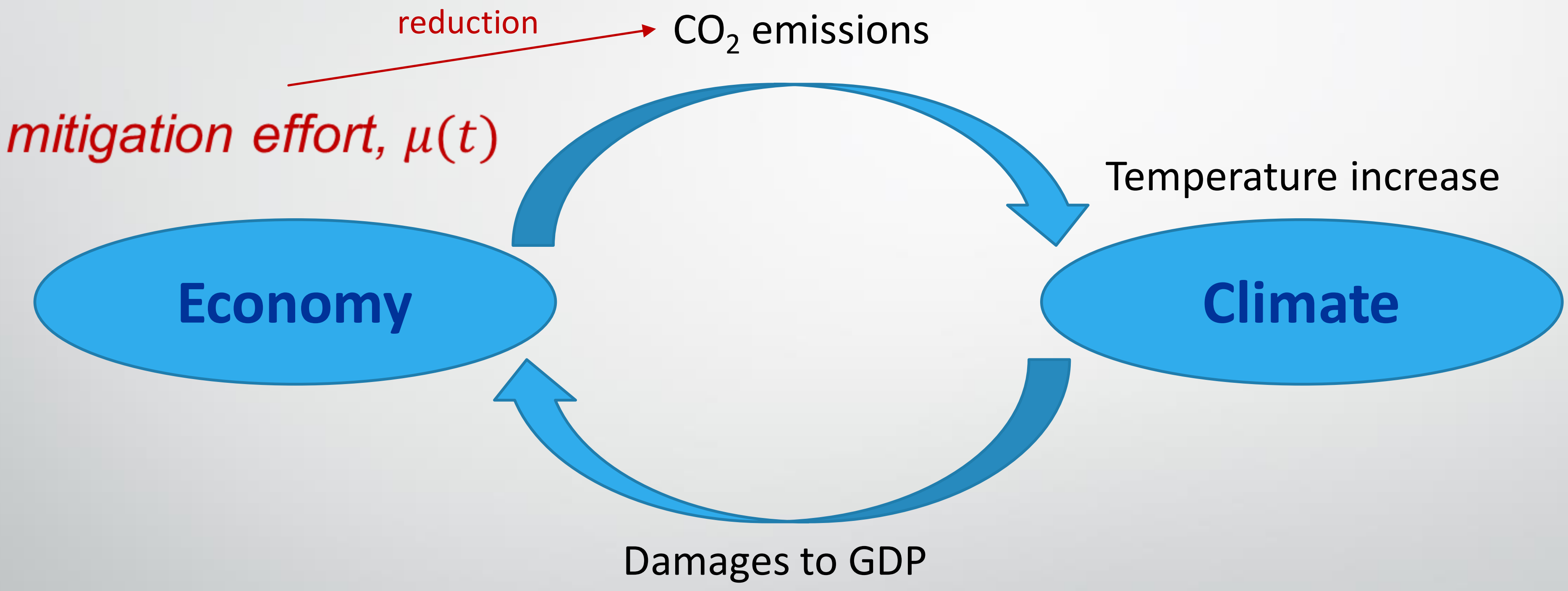
- Less output
- Standards, regulation
- Energy conversion
- Cap&trade E
- Carbon tax
- New energy technology
- Financial instruments

$$\dot{ce}(t) = -\alpha * ce(t) + log(e^{(g_{ce} t)})$$



Non-stationary carbon emission simulated; starting from the upper curve: $g_{ce} = 0.002$, $g_{ce} = 0.0015$, $g_{ce} = 0.001$, $g_{ce} = 0.0005$,and $g_{ce} = 0.0001$, only the lowest growth rate is not only flattening the curve but reversing it

Lecture 4. 3. Nordhaus DICE model (DICE- 2013R, or DICE 2016), also called Integrated Assessment Model (IAM), Nordhaus 2008, chs 4-6



Lecture 4.3. Nordhaus DICE Model; short description

Nordhaus 2008, chs 4-6, Long-run growth model (optimal version of Solow growth model)

Welfare $W = \sum_{t=0}^{T} (1+\rho)^{-s} U\big(c(t), L(t)\big)$ ➡ max

subject to

Economy

$$Q(t) = [1 - \Lambda(\mu(t))]\Omega(t)Y(t) = C(t) + I(t)$$
$$K(t+1) = I(t) + (1-\delta_K)K(t)$$
$$E_{Ind}(t) = \sigma(t)[1-\mu(t)]Y(t)$$
$$E(t) = E_{Ind}(t) + E_{Land}(t)$$
$$\Omega(t) = \frac{1}{1 + aT_{AT}^2(t)}$$

Climate

$$\begin{bmatrix} M_{AT}(t+1) \\ M_{UP}(t+1) \\ M_{LO}(t+1) \end{bmatrix} = \begin{bmatrix} \xi_1 \\ 0 \\ 0 \end{bmatrix} E(t) + \begin{bmatrix} \phi_{11} & \phi_{12} & 0 \\ \phi_{21} & \phi_{22} & \phi_{23} \\ 0 & \phi_{32} & \phi_{33} \end{bmatrix} \begin{bmatrix} M_{AT}(t) \\ M_{UP}(t) \\ M_{LO}(t) \end{bmatrix}$$

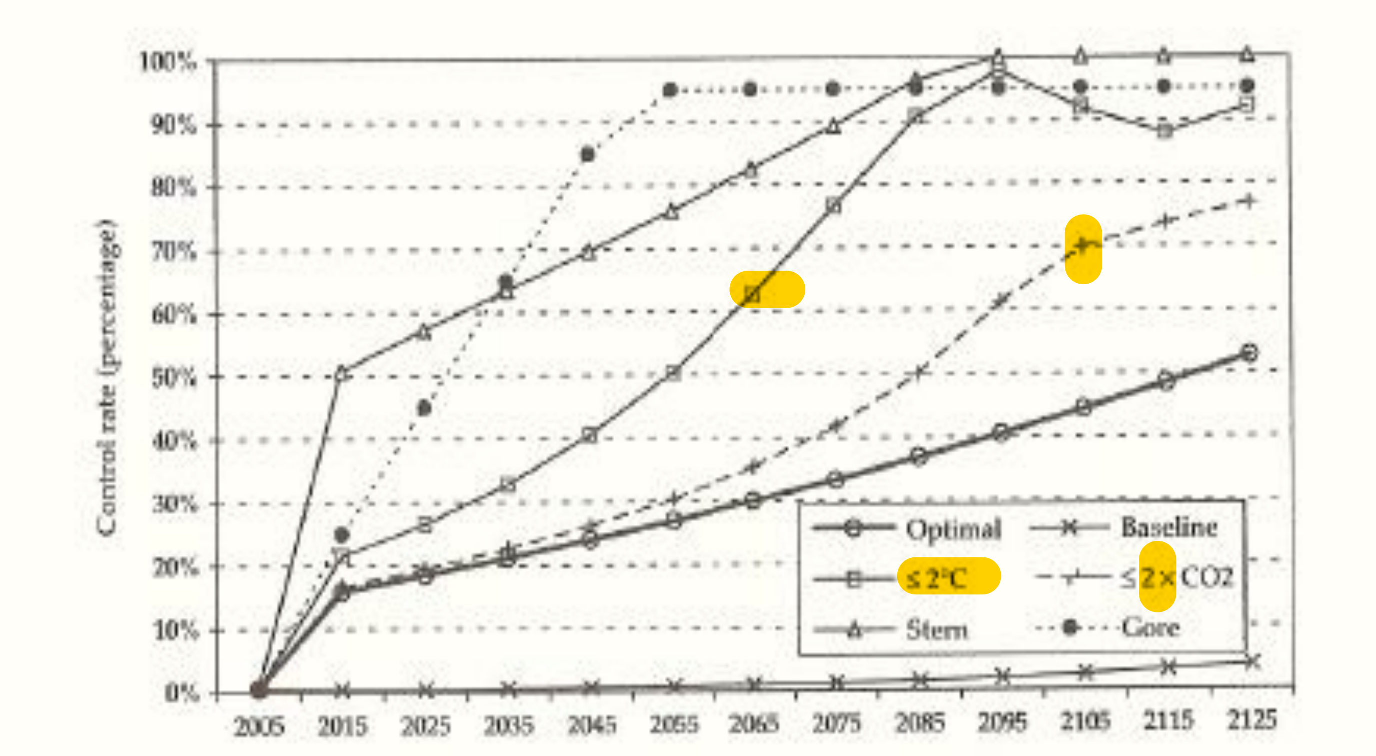
$$F(t) = \eta \log_2[M_{AT}(t)/M_{AT}(1750)] + F_{EX}(t)$$
$$\begin{bmatrix} T_{AT}(t+1) \\ T_{LO}(t+1) \end{bmatrix} = \begin{bmatrix} \xi_2 \\ 0 \end{bmatrix} F(t+1) + \begin{bmatrix} \zeta_{11} & \zeta_{12} \\ \zeta_{21} & \zeta_{22} \end{bmatrix} \begin{bmatrix} T_{AT}(t) \\ T_{LO}(t) \end{bmatrix}$$

6 dynamic equations

Decision variables: $C(t), \mu(t)$

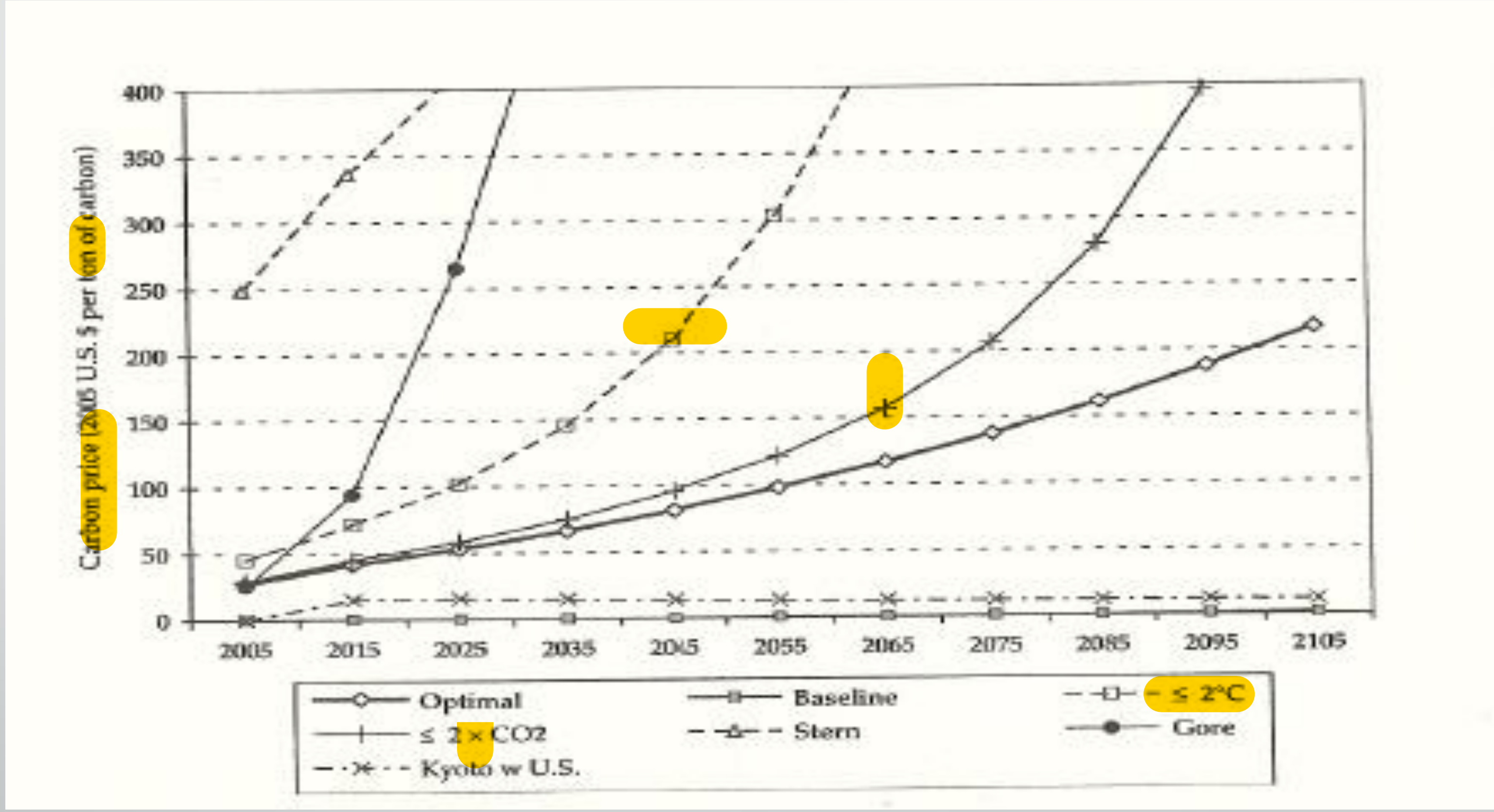
M – stock of carbon

Lecture 4.3. Nordhaus Dice Model; abatement policy (see Nordhaus, 2008, ch. 5)



Abatement efforts – Emission control rates for different scenarios

Lecture 4. 3. Nordhaus Dice Model; abatement policy (see Nordhaus, 2008, chs. 4-6)

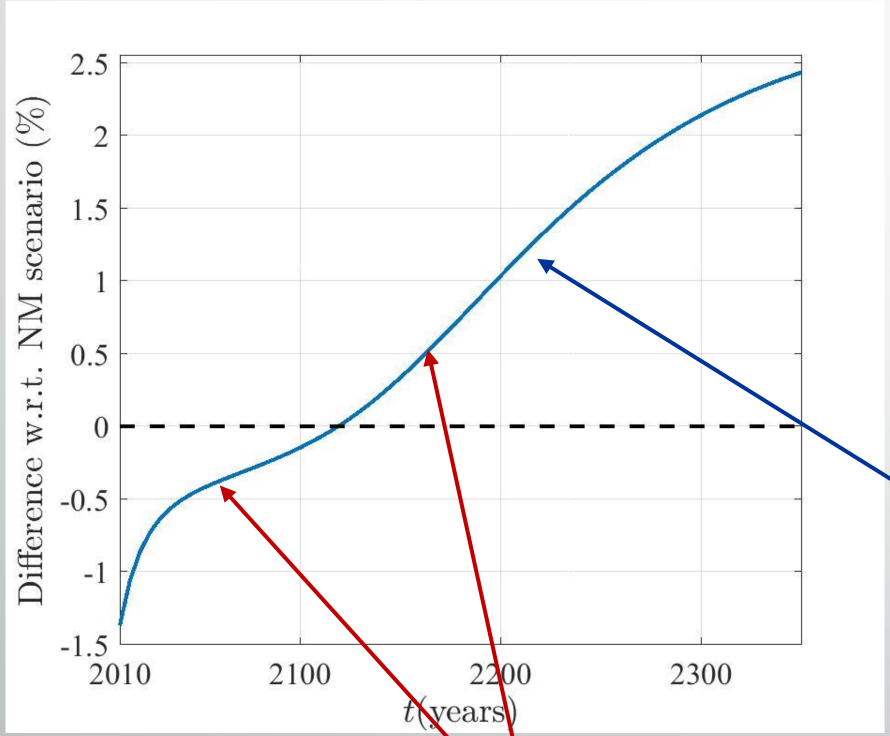


Carbon prices for the different scenarios

Lecture 4. 3. Nordhaus Dice Model – Intertemporal Fairness problem?

DICE scenarios $(C(t), \mu(t))$:

- No mitigation (NM)
- Optimal mitigation (OM)



Sequential social welfare function:

$$W(t) = \sum_{s=0}^{t}(1+\rho)^{-s}U\big(c(s), L(s)\big)$$

- ρ – discount rate
- $c(t)$ – consumption per capita
- $L(t)$ – labor
- $U\big(c(t), L(t)\big)$ – utility function

Plot of percentage change $[W^{OM}(t) - W^{NM}(t)]/W^{NM}(t)$

Intergenerational problem

Lecture 4.3. Nordhaus DICE model – Fairness Problem=> Intertemporal Fiscal Policy, Sachs (2015), Flaherty et al (2016), Orlov et al (2018)

- Current spending? =>Abatement of CO_2

In Nordhaus it comes from taxation, reducing current GDP or income

But it could come from credit flows:

- External debt: Borrowing from abroad/foreign investments
- Internal debt: households invest in government bonds (but will government debt be a problem?)

=> challenge of Ricardian equivalence theorem? But it is not valid: because of "productive investment" (avoidance of future damages)

Lecture 4.3. Nordhaus DICE model modified; Intertemporal

Borrowing and lending-- Issuing of bonds, see Sachs (2015) and Flaherty et al. (2016), Heine et al (2019), Semmler et al (2021) sect 4.

- Dynamics of bonds (=government budget constraint)

$$B(t+1) = (1 + r_B)B(t) - \left[\tau(t) - \Lambda\big(\mu(t)\big)\right]\Omega(t)Y(t)$$

tax rate

- Bonds are to be repaid

$$B(T) = 0$$

- Initial governmental debt is

$$B(0) = 0$$

Lecture 4. 4: Public sector and macroeconomic policies; Comprehensive dynamic macro models, as guidance for climate policies? (Book, ch.9), for finite horizon

- As compared to long-run growth-oriented models; IAM (DICE), DSGE, and others
- Our medium-run (large-scale) dynamic macro models with **macro policies** include:

-- source of CO2 emission

-- innovative technology

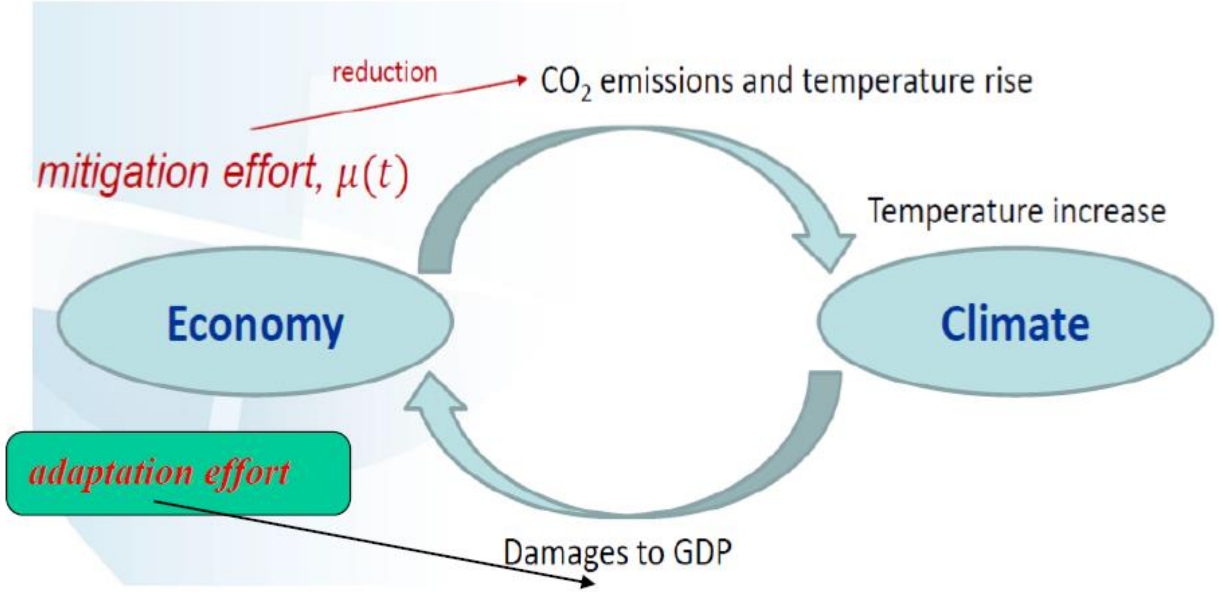
-- mitigation policies

-- adaptation policies

-- tipping points&regime changes

-- vulnerabilities, disasters and disruptions (traps)

Starting with a growth model, a high dim macro model with extensive public sector; IMF Working paper no **WP/19/145**, see also and Bonen et al. (2016), Maurer et al. (2016, 2018)



⇒ **Model should include:**

- **Capital accumulation** and growth
- **Causes:** Should include **fossil energy** extraction (coal, oil, gas), producing pollution and externalities, generating
- **Disaster** vulnerability, with **damage effects on production and households**
- **Mitigation** policy, i.e. generation of **renewable energy**
- **Adaptation** policies; (carbon tax and climate investments; climate infrastructure, adaptation to disaster risk)
- **Options** of other policy decisions

Lecture 4.4. Public Sector; Large scale dynamic macro models – IMF models;

Generic large scale macro dynamics, with regime changes, see our work for the IMF, and AIMS

State variables, IAM only K, T, M:

- K : private capital per capita,
- g : public capital per capita,
- b : country's level of debt,
- R : non-renewable resource ,
- M : GHG (Green House Gas) concentration in the atmosphere.

Control variables:

- C : per capita consumption,
- ep : government's net tax revenue,
- u : extraction rate from the non-renewable resource,

The stock of public capital g is allocated among three uses:

- ν_1 : standard infrastructure,
- ν_2 : climate change adaptation,
- ν_3 : climate change mitigation (IAM; μ),

$$\nu_1, \nu_2, \nu_3 \geq 0, \quad \nu_1 + \nu_2 + \nu_3 = 1.$$

$$W(T, X, U) = \int_0^T e^{-(\rho - n)t} \frac{\left(C \, (\alpha_2 ep)^{\eta} \left(M - \tilde{M} \right)^{-\epsilon} (\nu_2 g)^{\omega} \right)^{1-\sigma} - 1}{1 - \sigma} \, dt$$

s.t. $\quad Y(K, u) = A(A_K K + A_u u)^{\alpha} \quad$ and

$$\dot{K} = Y \cdot (\nu_1 g)^{\beta} - C - ep - (\delta_K + n)K - u\,\psi R^{-\zeta},$$

$$\dot{R} = -u,$$

$$\dot{M} = \gamma\, u - \mu(M - \kappa \tilde{M}) - \theta(\nu_3 \cdot g)^{\phi},$$

$$\dot{b} = (\bar{r} - n)b - (1 - \alpha_1 - \alpha_2 - \alpha_3) \cdot ep,$$

$$\dot{g} = \alpha_1 ep + i_F - (\delta_g + n)g.$$

Lecture 4.4. Public Sector; Large scale dynamic macro models, Macro policies

=> Models of the Climate-macro links with many components

=> Conclusion: Extensive policy tools available

Model type	Individual models	Model features: Extended welfare function	Mitigation policy	Adaptation policy	Renewable and nonrenewable energy sources	Nonlinearities and tipping points	Carbon tax	Green bonds	Multiphase
(1) DICE 2008	Nordhaus (2008)		✓				✓		
(2) Extended IAMs	Bonen et al. (2016)	✓	✓	✓	✓	✓			
	Semmler et al. (2018)	✓	✓	✓	✓	✓[a]			
	Atolia et al. (2018)	✓	✓	✓	✓[b]	✓			
(3) Macro policy augmented models	Kato et al. (2015)		✓[c]		✓		✓		
	Flaherty et al. (2016)		✓[c]					✓	✓
	Heine et al. (2019)		✓[c]				✓	✓	✓
	Orlov et al. (2018)		✓					✓	✓[d]
(4) Synthesis models	Semmler et al. (2019)	✓	✓	✓	✓	✓		✓	✓
	Mittnik et al. (2020)	✓	✓	✓	✓	✓[e]		✓	✓

Lecture 4.5. Multisectoral decarbonization

Stefan Mittnik (Munich) and Willi Semmler (New School)

In: Oxford University Handbook, The Macroeconomics of Global Warming 2015; DIW Berlin, VJH 2023

=> **Broad sectors:** see OWID-CO2: electricity production, housing, transport, manufacturing; agriculture, see data at OWID, see also German Klimarat (2024)

=> **Multisectoral models of decarbonization**: based on Input-Output analysis (70 sectors)

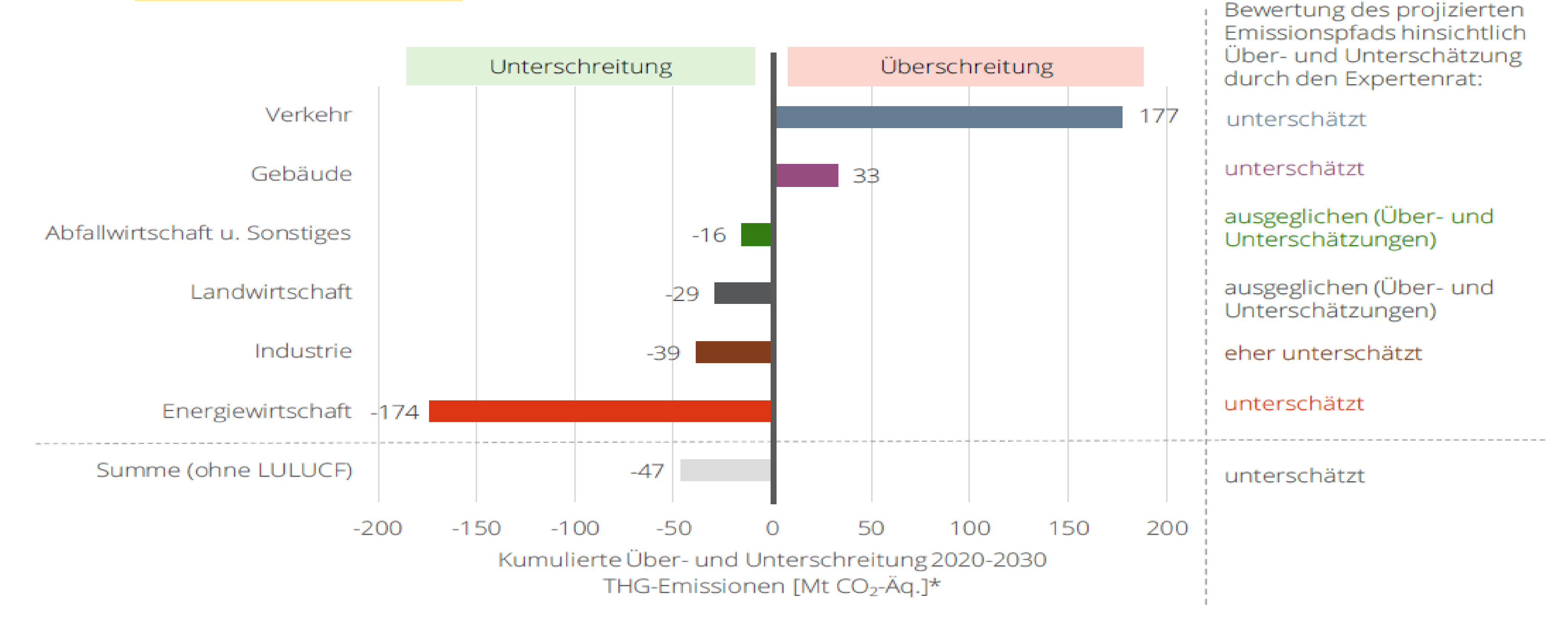
- Multisector macro model with preferences: input-output system with energy coefficients
- Data: German I-O tables (1995**),** 71 sectors with energy intensity**,** C02 intensity aggregated into 2 sectors (LCI, HCI), using EU Klemps data for output and employment of those sectors, for 8 countries
- Decarbonization Policies**:** Preferences for sectors (CES preference), Carbon Tax only, Carbon tax and wage subsidies, carbon tax and subsidy
- Method: Estimation of policy impacts with double-sided (composite) VAR
- Results**: Employment** and **output** dynamics for 8 countries

Lecture 4.5: Multisectoral decarbonization

Stefan Mittnik and Willi Semmler

In: Oxford University Handbook, The Macroeconomics of Global Warming 2015; DIW Berlin, VJH 2023, OWID

=> **Broad sectors that Governments have focused on:** see OWID-CO_2: **energy production, housing, transport, manufacturing; and agriculture,** see sectoral data at OWID, Klima Expertenrat (2024)



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- Decarbonization Policies: Preferences for sectors (CES preference), Carbon Tax only, Carbon tax and wage subsidies, carbon tax and subsidy
- Method: Estimation of policy impacts with double-sided (composite) VAR

Lecture 4.5. Multisectoral model (see Kaldor's 3 sector model)

$$U_t = \int_0^T e^{-\rho t} \frac{\left[H_t^{\beta} L_t^{\theta}\right]^{1-\sigma} - 1}{1-\sigma} dt,$$

$$\begin{aligned} \dot{K}_t + \delta K_t &= B_K N_t^K F(K_t, X_t) \\ &= B_K \left(1 - N_t^H - N_t^L\right) F(K_t, X_t) \\ &= B_K F(K_t, X_t) - P_H H_t - P_L L_t, \end{aligned}$$

- K: Capital stock
- H: Hi carbon intensity consumption goods
- L: Low carbon intensity consumption goods
- X: Technical progress
- The effects of all four policies can be explored in this model
- T: Model with finite time horizon

Lecture 4.5. Multisectoral model => Data Description

- We use German (energy) Input-Output Tables (1995) to disaggregate the economy into an H and an L sectors
- Calculation of direct and total CO_2 intensities for 71 sectors
- Median as cut-off value
- Approx. 90% of CO_2 in the production process HCIS is emitted in (HCSI:High Carbon Intensity Sectors)
- We use for the same sectors the Klemps data for employment and output for the same sectors

#	Sector	Dir.	Tot.	Sector	Sector
1	Supply of Electricity and Heat	5.652	6.145	H	H
2	Electricity and Gas	5.652	6.276	H	H
3	Other Air transport	0.867	1.309	H	H
4	Coke, refined petroleum and nuclear fuel	0.842	1.887	H	H
5	Basic metals	0.557	2.229	H	H
6	Fabricated metal	0.557	1.722	H	H
7	Foundry products	0.557	1.264	H	H
8	Glass and glass products	0.467	1.073	H	H
9	Other non-metallic minerals	0.467	1.082	H	H
10	Other mining and quarrying	0.340	0.915	H	H
...	(...)				
54	Electrical machinery and apparatus, nec	0.028	0.357	L	L
55	Medical, precision and optical instruments	0.025	0.272	L	L
56	Recreational, cultural and sporting activities	0.025	0.120	L	L
57	Other business activities	0.022	0.095	L	L
58	Computer and related activities	0.022	0.087	L	L
59	Post and telecommunications	0.021	0.127	L	L
60	Other service activities	0.019	0.137	L	L
61	Insurance and pension funding, except compulsory soc	0.017	0.113	L	L
62	Financial intermediation, except insurance and pensio	0.015	0.082	L	L
63	Leather, leather and footwear	0.013	0.410	L	L
64	Office, accounting and computing machinery	0.010	0.259	L	L
65	Wearing Apparel, Dressing And Dying Of Fur	0.010	0.426	L	H
66	Renting of machinery and equipment	0.009	0.031	L	L
67	Activities related to financial intermediation	0.009	0.082	L	L
68	Real estate activities	0.002	0.053	L	L
...	(...)				

Lecture 4.5. Multisectoral model=> Definitions of CO_2 Ratios

(Using I-O tables)

- Direct CO_2 (Output) Intensity [kt/mill. EUR]:

$$c^{*}_{\mathrm{dir}} \equiv X^{-1}c$$

- Total CO_2 Output Intensity [kt/mill. EUR]:

$$c^{*\mathrm{T}}_{\mathrm{tot}} = c^{*T}_{dir}\,(I-A)^{-1}$$

- Direct CO_2 (Labor) Intensity [kt/1000 workers]:

$$c^{*\mathrm{T}}_{\mathrm{e,\,dir}} = E^{-1}c$$

- Total CO_2 (Labor) Intensity [kt/1000 workers]

Lecture 4.5. Multisectoral model=> Decarbonization policies

- **Policies:**
- Preferences
- Carbon Tax only
- Carbon tax and wage subsidies
- Carbon tax and subsidy

- Germany, 1992 - 2005
- USA, 1970 - 2005
- Japan, 1973 - 2005
- United Kingdom, 1970 - 2005
- Sweden, 1970 -2005
- South Korea, 1970 – 2005
- Australia, 1989 – 2005
- Hungary, 1992 -2005

Lecture 4.5. Multisectoral model=> Double-sided (composite) VAR and IRs

The first-order VAR is of the form

$$y_t = c + Ay_{t-1} + \varepsilon_t,$$

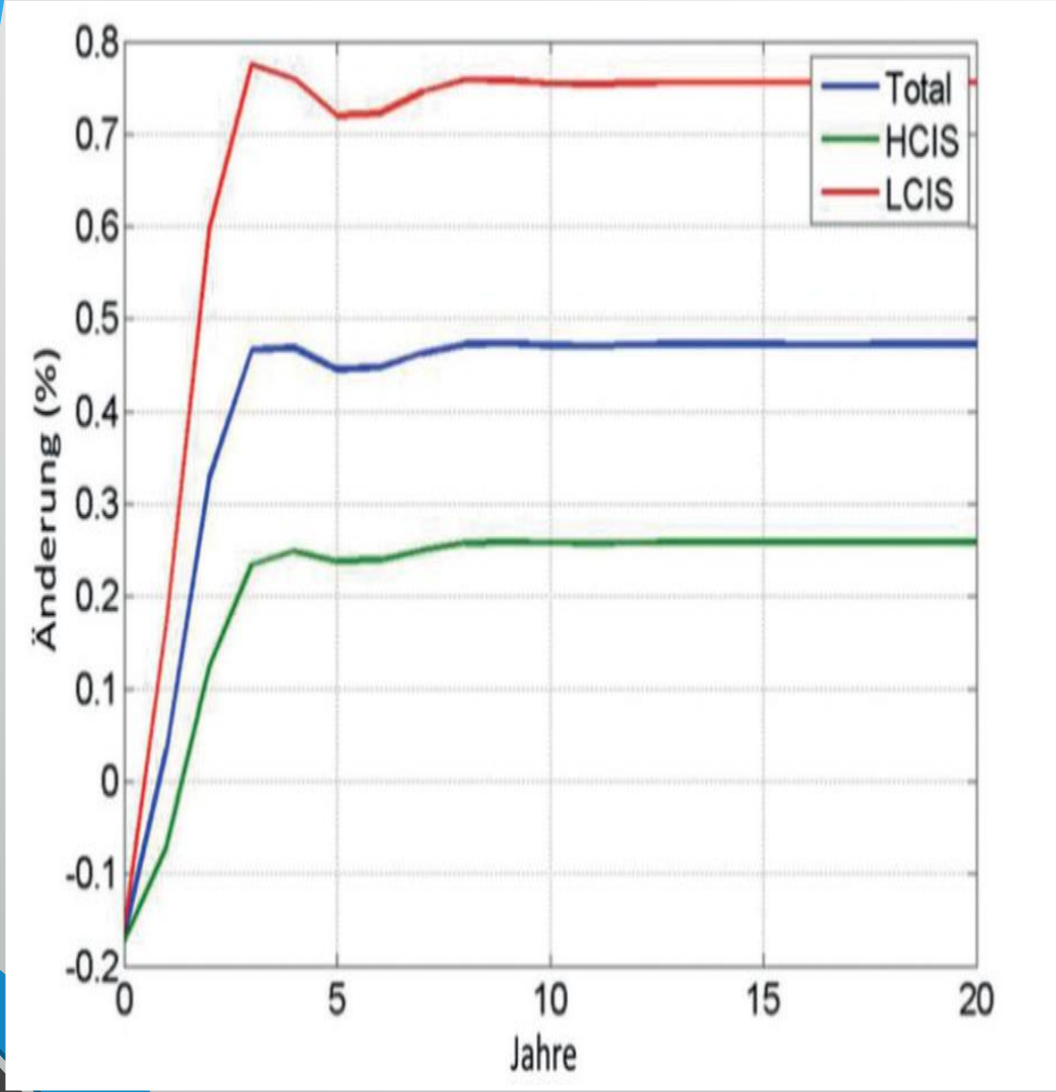
$$y_t = \begin{pmatrix} out_{hi,t} \\ out_{lo,t} \\ emp_{hi,t} \\ emp_{lo,t} \end{pmatrix}$$

Analysis consists of 4 steps:

1. For each country we estimate the joint dynamic process of output and employment both in HCIS and LCIS for each country.
2. Impulse response analysis (IRA): Investigate how the variables of the system respond to individual shocks.
3. Specify policy measures in terms of composite shocks.
4. Analyze responses to policy measures over time.

Lecture 4.5. Multisectoral model=> Results: After 10 years, for tax and **HCI** and subsidies for **LCI;** effects on sectoral **employment** and **outputs**

For US: **Employment** (left), Employment and Output (right)



Output and Employment Effects after 10 years

	EMPLOYMENT					*OUTPUT*		
	HCIS Relative Employm Effects	LCIS Relative Employm Effects	HCIS Absolute Employm Effects	LCIS Absolute Employm Effects	TOT Employm Growth Effects	HCIS Output Growth Effects	LCIS Output Growth Effects	TOT Output Growth Effects
Germany	0.51%	0.49%	108,984	90,806	199,790	-0.98%	0.74%	-0.02%
USA	0.27%	0.71%	233,624	475,082	708,707	-2.58%	-0.08%	-1.32%
Japan	0.27%	1.18%	98,106	344,981	443,087	0.81%	3.18%	2.02%
United Kingdom	0.15%	0.59%	22,570	86,385	108,955	-1.80%	0.19%	-0.81%
Sweden	-0.13%	0.00%	-3,331	-3	-3,334	-0.39%	0.94%	0.28%
South Korea	0.06%	0.82%	8,581	69,704	78,284	-1.18%	0.32%	-0.50%
France	0.37%	1.53%	51,249	177,598	228,847	-3.69%	-1.60%	-2.64%
Australia	-1.56%	-0.59%	-94,070	-17,832	-111,902	-2.69%	1.69%	-0.99%
Hungary	0.51%	1.22%	11,733	21,202	32,935	-0.79%	1.43%	0.32%

Lecture 4.5. Multisectoral models allow for the study of transition cost

- The approach needs compensatory and adjustment policies for structural change and reallocation of labor and capital (see our paper in Rodrick, ed., Industrial policies)
- Allows for studies of policies of greater (fossil fuel) energy independence: The use of IO tables can also be used for GDP growth loss estimation due to the Russian embargo of Germany computed: see Mittnik/Semmler in DIW, VJH 2022, German Energy crisis
- Sectoral guided studies with IO tables allow for study of sectoral (and general) inflation rates, see Del Negro et al (2024), Chen and Semmler (2024)
- Disadvantage: Sectors are not actors. Actors are companies, households and their preferences, policymakers. So public policies such as regulations, standards, taxes, and subsidies are needed to provide incentives

Lecture 4.6. Central Banks, climate risks and monetary policy, see Braga, Semmler (2024), SSRN

We presume in a finite horizon decision model a quadratic objective function given by eq. (2).

$$Min_{i(.)} \int_0^T e^{-\rho t}[w_\pi(\pi(t)-\pi_s)^2 + w_y(y(t)-y_s)^2 + w_l(l(t)-l_s)^2 + w_i i(t)^2]dt \tag{2}$$

The CB exogenously sets the policy targets given by π_s, y_s, and l_s. Eq. (2) assigns a quadratic penalty to the deviation of each variable from their target value, and defines weights for each target. The weights are given by w_π, w_y, w_l, and w_i.[12] Furthermore, the objective functional faces constraints given by the macro behavior of each variable. The state variables are represented by the following dynamic state equations:

$$\dot{\pi}(t) = -\alpha_1\pi(t) + \alpha_2 y(t), \quad with \quad \pi(0) = \pi_0 \tag{3}$$

$$\dot{y}(t) = -\beta_1 y(t) - \beta_2(i(t) + \sigma(y(t)) - \pi(t) - r) \quad with \quad y(0) = y_0 \tag{4}$$

$$\dot{l}(t) = \gamma_1 l(t) + \gamma_2(y(t)) - \gamma_3(i(t) + \sigma(y(t))) - \gamma_4\pi(t), \quad with \quad l(0) = l_0 \tag{5}$$

$$\dot{m}(t) = -\sigma_1(m(t) - m_s) + \frac{\sigma_2(y(t) + d(t))}{g_r(s)(\sigma_3 l(t) + \sigma_4 d(t)) + \sigma_5}, \quad with \quad m(0) = m_0 \tag{6}$$

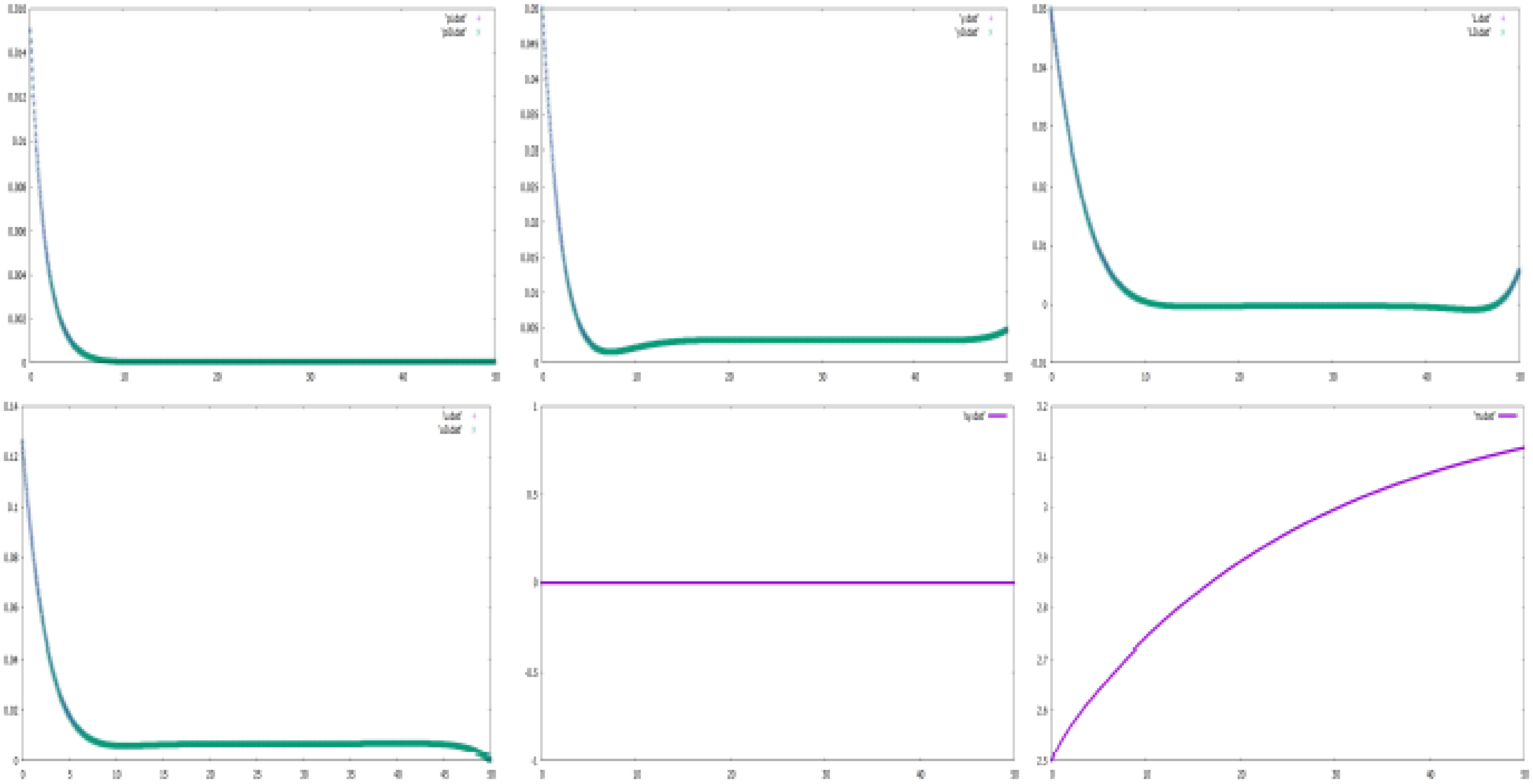


Figure 3: Model Simulation 1: Above: Inflation rate, positive output gap and credit flow; Below: interest rate (u), risk premium (sy), and emission (m) (when $g_r(s) = 0$or 1); emission control implicitly through $g_r(s)$ with time depending switches, as soon as interest rate moves down to 2%

Lecture 4.6. Central Banks, climate risks, and monetary policy, contractions

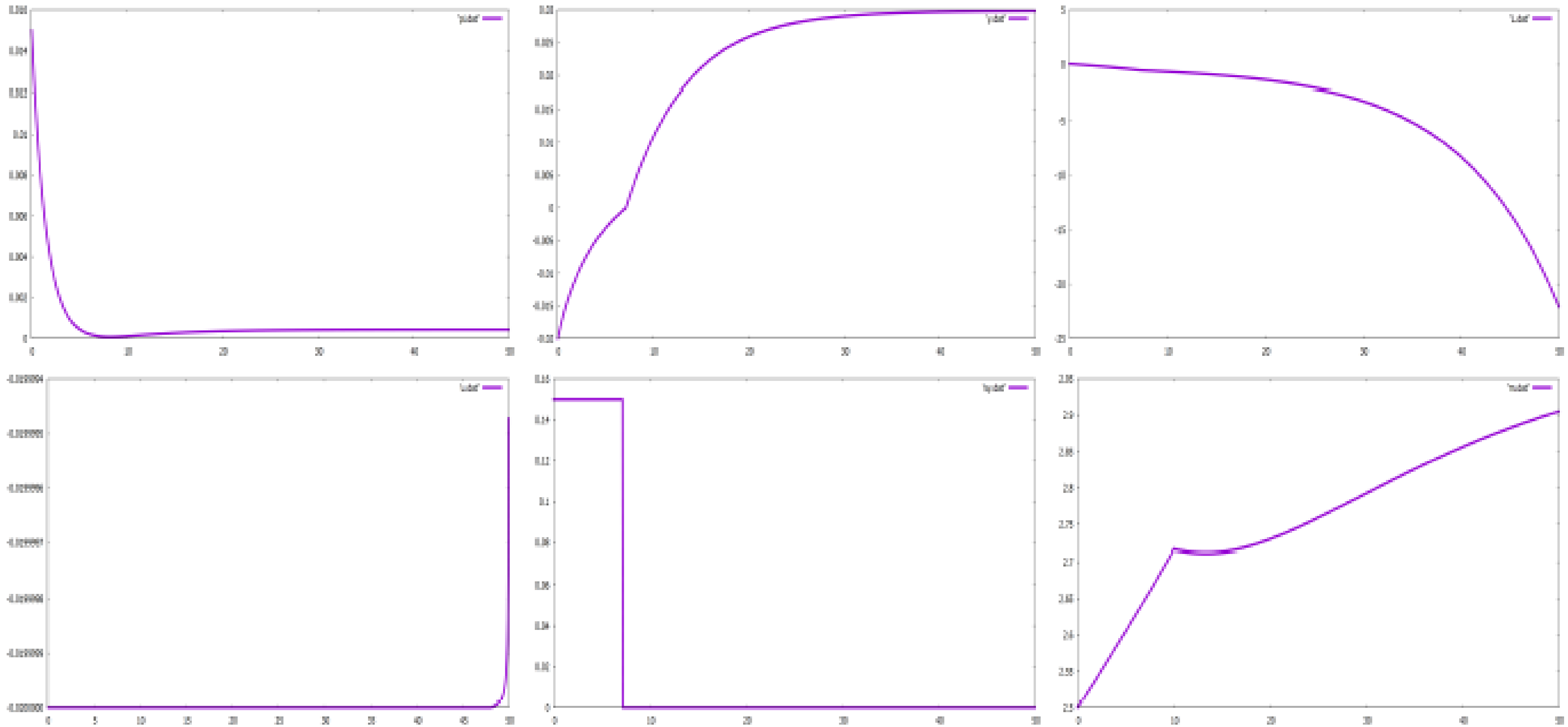


Figure 4: Simulation 2: Above: Inflation rate, negative output gap, and credit flow; Below: interest rate, risk premium and emission (when $g_r(s) = 0$ up to period 10 then $g_r(s) = 1$); time depending regime change, risk premium stays high as long as the output gap is negative; emission curve first increasing then flattening when credit flow for decarbonization is phased in.

Lecture 4.6. Central Banks, climate risks, and monetary policies

with decision and transmission delays (see Aghion et al. on cost of delays)

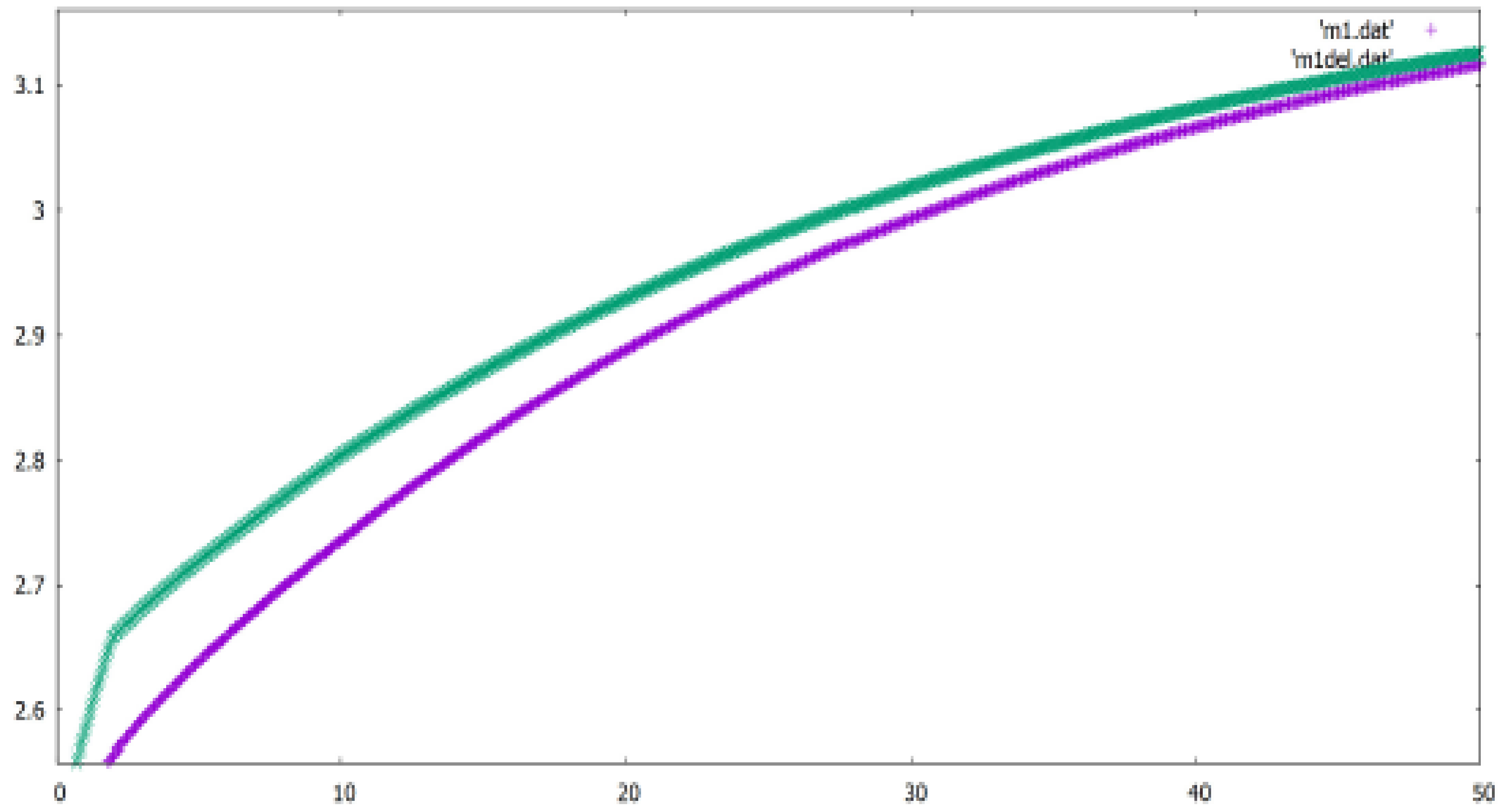


Figure 5: Upper graph: Model solution with delay, Lower graph: no delay; both graphs with regime switching $g_r(s)$ of credit flows

Business cycle analysis: Making variables stationary through filtering, detrending, or regime switching (Hamilton, 1989)

Cointegration:

VECM with mixed variables (stationary, and nonstationary variables)

Modeled for transitory and permanent effects, Gonzalo and Ng (2001);

Solution numerics in Boswijk and Doomik, (2004),

Applied in Chen et al. (2022)

$$\begin{bmatrix} \Delta Y_{1,t} \\ \Delta Y_{2,t} \end{bmatrix} = \alpha \begin{bmatrix} \beta'_{11} & \beta'_{12} \\ \beta'_{21} & \beta'_{22} \end{bmatrix} \begin{bmatrix} Y_{1,t-1} \\ Y_{2,t-1} \end{bmatrix} + \sum_{j=1}^{L-1} \phi_j \Delta Y_{t-j} + u_t.$$

$$\mathcal{H}_m : \beta'_{12} = 0 \text{ and } \beta'_{21} = 0.$$

Lecture 4.6. Central Banks, climate risks, and monetary policies; multiple objectives and Pareto Front (if defined as a CB's mandate)

$$Min_{i(.)} \int_0^T e^{-\rho t}[w\{(\pi(t)-\pi_s)^2 + (y(t)-y_s)^2 + (l(t)-l_s)^2\} + (1-w)\{(m(t)-m_s)^2 + i(t)^2\}]dt$$

- Recursive integration with weights 0<w<1;
- Plotted as Pareto front (Fmaster)
- Linear scalarization for multiple objective control with
- Fmaster: √(int1^2 + int2^2)
- See Kaya and Maurer (2023)

$$int1 = \int_0^T e^{-\rho t}[\{(\pi(t)-\pi_s)^2 + (y(t)-y_s)^2 + (l(t)-l_s)^2\}]dt$$

$$int2 = \int_0^T e^{-\rho t}[\{(m(t)-m_s)^2 + i(t)^2\}]dt$$

Lecture 4.6. Central Banks, climate risks, and monetary policies; **multiple objectives** and **Pareto Front** (if defined as a CB's mandate)

Fmaster function

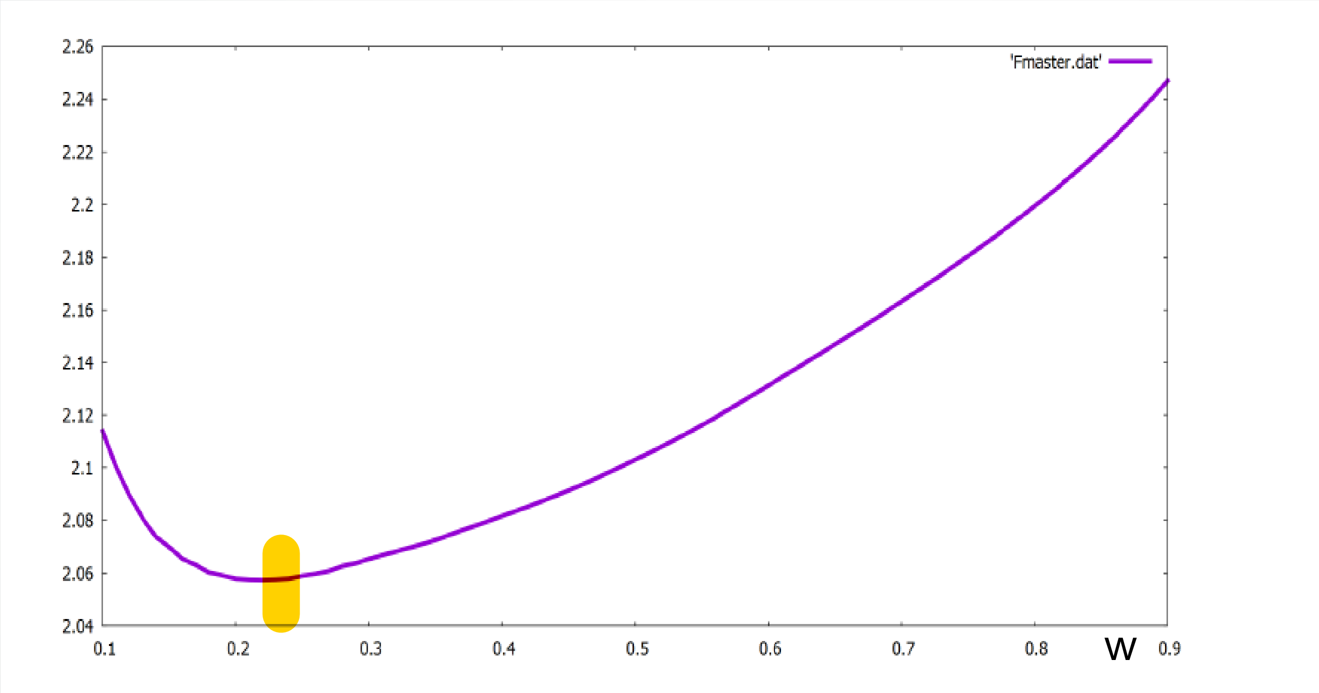
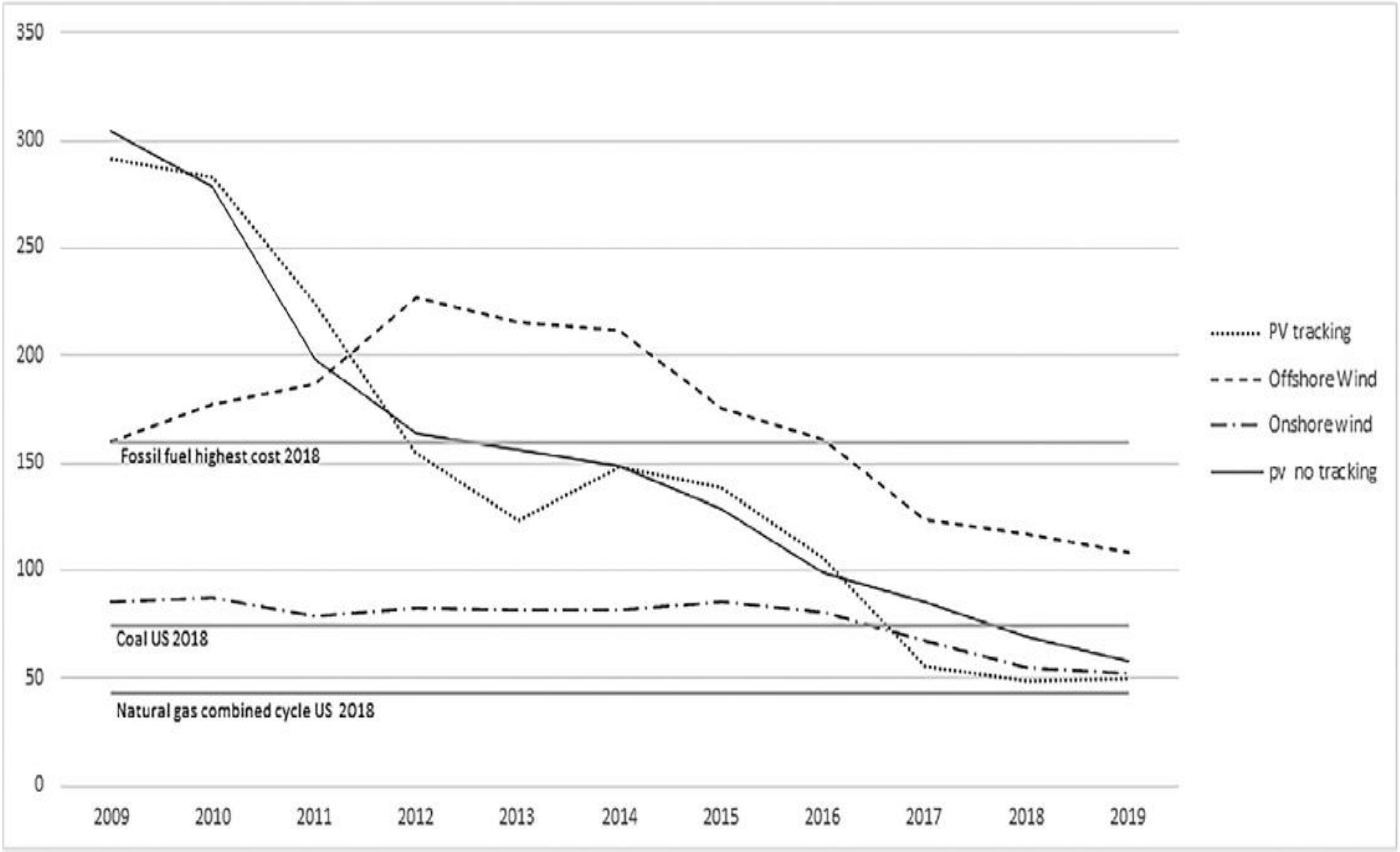


Figure 8: Fmaster function for the Pareto front, with initial conditions and parameters: $m_0 = 2.5$ and $m_s = 3.0$ for eqs. (19)-(21) and $\pi_o = 0.015$, $y_o = 0.05$, $l_o = 0.1$; m_0 corresponds to the current situation and m_s to the requirement to keep the carbon emission below the constraints of the carbon budget

Some positive outlook: Overall energy cost trends -- but still extensive policy games



Summary: Public Sector; Two issues-- Sovereign Debt and Inflation as Obstacles? Are there escape routes?

=> There could be a "good" and "bad" sovereign debt dynamics (Blanchard, 1987, 2019), and there are escape routes from "bad" ones : there are Escape routes from sovereign debt risk; Softening of Bad Debt dynamics (Blanchard 2029, Semmler and Proano, 2018); there are also studies to deal with fossilflation and greenflation rate:

1. Climate risks and **Fiscal** escape routes (Semmler and Proano, 2018)

- Primary balance (surplus), T>G , but: perils of contractionary budget consolidation
- Delay of interest and principal repayments
- Changing the maturity structure of debt (from short to long)
- Debt reduction/forgiveness and debt guarantees, higher inflation rates (Goodhart 2020)

2. Climate risks and **Financial** escape routes

- Issuing of convertible debt
- Windfall profit tax (on winners of the rise of fossil fuel prices)
- Tax on carbon-intensive wealth (Bastos and Semmler, 2023)
- Inflation-adjusted green bonds (Tahri 2023)

3 . Climate risks, Central Banks and Monetary policy (Faulwasseret al 2020, Braga et al 2024))

- Decrease of interest rate, UMP, QE, and macroprudential policies
- Climate mandate of CBs?

Conclusions

- Flattening and reversing of the carbon curve by policies-- is **not sufficiently** achieved
- Faster reversing of the carbon curve is needed – better **burden sharing** (within and across countries) and fair transitions are needed
- For mitigation **multiple policies** are required to facilitate transition-- market-oriented policies, innovative technology, green finance, sectorial policies, and macroeconomic policies (fiscal, monetary), are needed to flatten (or reverse) the carbon curve
- For adaptation -- **Multiple vulnerabilities** are interacting, producing not only more frequent but more severe extreme events; a better preparation for future extreme events is needed
- Great future perils are arising from **tipping points** -- They result from complex dynamics, which need to be studied more (regime shift models and more data-intensive research)
- Conflicting policy goals and **multiple worries**? between **growth** and **climate protection**? Between (sovereign) **debt** and **climate finance**? There are multiple **macroeconomic** worries and multiple goals (such as unemployment, inflation, financial stability, climate risk, fair transitions… more research is needed
- Empirical Challenges: 1) Decarbonization through carbon pricing and market prices, or renewable technologies (Acemoglu/Aghion)? (see empirical work by Roy et al. (2024), 2) Energy dependence and energy shocks, DIW, 3) Fossilflation and Greenflation? See empirical work by Chen and Semmler (2024), 4) Climate disaster risks, Extreme weather events, and disruptions (Mittnik, Haider, and Semmler, 2020), 5) Sectoral decarbonization

General Literature

- Nordhaus, DICE model solution package, Yale website
- Nordhaus, The Question of Balance (2007), Climate Casino (2013), IAM (DICE)
- Greiner and Semmler: Global Environment, Natural Resources and Growth, OUP (2008)
- Bernard and Semmler (eds): OUP Handbook, The Macroeconomics of Global Warming (2015)
- Gruene, Greiner, and Semmler, Economic Growth and the Transition from Non-renewable to Renewable Energy (2013)
- Bonen, Loungani, Semmler, and Koch, Investigating to Mitigate and to Adapt, IMF paper, 2016
- Atalio, Loungani, Maurer, and Semmler (2022), AIMS paper, previously IMF paper,
- Semmler, Maurer, and Bonen, Mitigation and Adaptation Policy, BoE paper (2015)
- Flaherty et al: Climate Financing through Climate Bonds, (2016), RIBF
- Kato, Mittnik, and Semmler, Output and Employment Effects of Climate Policies, ILO study and OUP Handbook, (2014);
- Semmler et al. WB Paper on: Fiscal Policy for a Low Carbon Economy (2021)
- Braga, Semmler, De-risking....JEDC paper (2022);
- Semmler, Lessmann, Tahri, and Braga, Green transition, investment horizon, and dynamic portfolio Decisions, Annals of Operations Research, 2022
- Semmler, Di Bartolomeo, and Fard, Game-theoretical papers on limit pricing (SCED, 2022)
- Mittnik and Semmler, Sectoral decarbonization
- Mittnik, Semmler, and Haider, (2020) Climate disaster risks—empirics and multi-phase dynamic model.
- Econometrics 8(3):1–27

Lichtenberger et al..(2022), Climate Finance, in „Econometrics" ; Bastos and Semmler (2023)

Computational and econometric works

Important recent methods for more advanced students:

Computational methods:

L. Gruene, M. Stieler, and W. Semmler (2015): "Using **NMPC** for Solving Dynamic Decision Problems in Economics, NSSR, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2242339, published in JEDC, 60: 112-133,

H. Maurer and W. Semmler (2015): Expediting the Transition from Non-Renewable to Renewable Energy", Discrete and Continuous Dynamic Systems, vol 35, no 9, September, 2015. using AMPL

Atalio M., P. Loungani, H. Maurer and W. Semmler "Optimal Control of a Global Model of Climate Change with Adaptation and Mitigation" (2022), Journal of the American Institute of Mathematical Sciences (AIMS), Doi: 10.3934/mcrf.2022009. This paper is using the computational methods AMPL, software packages for NMPC and AMPL exist.

E. Saltari and G., Di Bartolomeo,, and W. Semmler (2021). "A Nash Equilibrium for Differential Games with Moving-Horizon Strategies." (with 2021. Computational Economics. https://doi.org/10.1007/s10614-021-10177-8. with NMPC

L. Gruene, M. Kato and W. Semmler (2005), "Solving Ecological Management Problems Using Dynamic Programming", Journal of Economic Behavior and Organization, vol. 57, no. 4: 430-448, 2005.

L. Gruene and W. Semmler (2004): "Using Dynamic Programming with Adaptive Grid Scheme for Optimal Control Problems in Economics", Journal of Economic Dynamics and Control, vol. 28:2427-2456, 2004, with Dyn Program

Data and econometric work:

Data: on CO2 emission and economics, for countries regions and sectors: Owid-CO2; on renewable energy: International Energy Agency, ECB data, Fed St. Louis.

P. Chen, H. Maurer, and W. Semmler (2022) "Delayed Monetary Policy Effects in a Multi-Regime Cointegrated VAR (MRCIVAR)", in: Econometrics and Statistics, available online: https://doi.org/10.1016/j.ecosta.2022.03.004,

A. Lichtenberger, J. P. Braga, and W. Semmler, (2022) "Green Bonds for the Transition to a Low-Carbon Economy" (with, 2022, Published in Econometrics, DOI:10.3390/econometrics10010011Corpus ID: 247342223

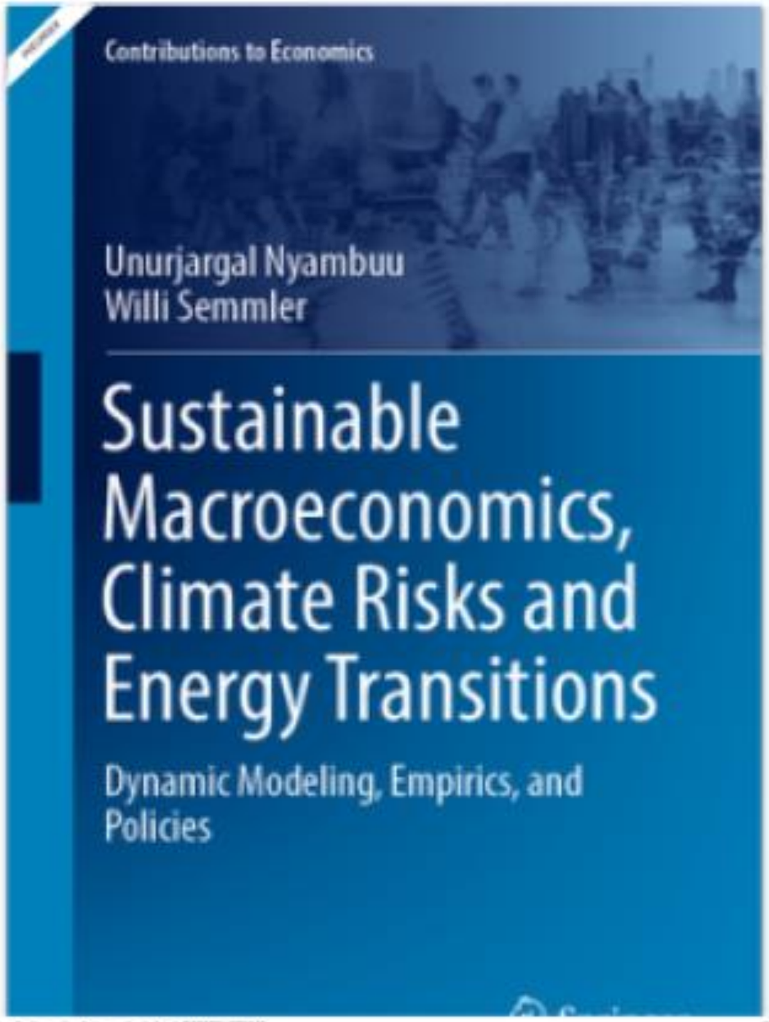
Braga, J., Chen, P., and Semmler, W. (2024), Central Banks, Climate Risks, and Energy Transition – A Dynamic Macro Model and Econometric Evidence, Extended Version, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4794049

Roy, A., P. Chen and W. Semmler (2024) Carbon Tax versus Renewable Energy Innovation — Dynamic Modeling and a Regime Switching CO-Integration VAR SSRN, forthcoming.

THANK YOU

Book:

- What kind of macroeconomics is needed for the climate challenges?
- Textbook for macro courses, researchers, and policymakers



=> Recent Book, Springer Publishing House, July 2023