TISHMAN CENTER · SEPTEMBER 20, 2017

Willi Semmler Researches Climate Justice & Intergenerational Fairness

Willi Semmler, Arnhold Professor of International Cooperation and Development, spent his summer in Laxenburg and Vienna working in a new role as Senior Researcher at the International Institute for Applied Systems Analysis (IIASA) on climate change issues. The IIASA is an international scientific institute that conducts research into the critical

issues of global environmental, economic, technological, and social change that we face in the twenty-first century. Currently, the IIASA is the main research center investigating the urgent question of how to act in order to achieve the aspirational UN Sustainable Development Goals.

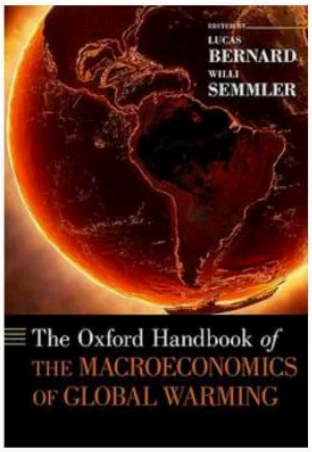
Professor Semmler's research this summer investigated green bonds, the transition to a low-carbon economy, and intergenerational fairness. He gave a talk sharing the research results. Scroll through the presentation to learn more:

Overlapping generations framework (Sachs, 2015)[1]

=> **Sachs contrasts**:
- Business-as-usual
- Mitigation effort by current generation, reimbursement through bond issuing
- Bond repayment through next generation

⇒ **Claim**: Intergenerational fiscal policy (bonds and taxes) is welfare improving for both generations

Caveats:
1. Phases are exogenous
2. Emission is exogenous
3. Taxes are exogenous



[1]Jeffrey D. Sachs Climate Change and Intergenerational Well-being // The Oxford Handbook of the Macroeconomics of Global Warming, 2015, pp. 248-260

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Continuous time framework (Flaherty et. al, 2016)[2]

- Three stages (phases):
  1. Business-as-usual scenario
  2. Green bonds issued compensating for climate change mitigation
  3. Bond debt repayment through taxation at later time period
- Each stage is solved separately with NMPC[3] until the solution is close to equilibrium

Caveats:
1. Separate phases
2. No dynamic decisions on tax rate
3. Little calibration of the model

[2]M. Flaherty, A. Gevorkyan, S. Radpour & W. Semmler Financing climate policies through climate bonds – A three stage model and empirics // Research in International Business and Finance, 2016

[3]L. Gruene, W. Semmler, M. Stieler Using nonlinear model predictive control for dynamic decision problems in economics // Journal of Economic Dynamics and Control, 60, 2015, pp. 112–133

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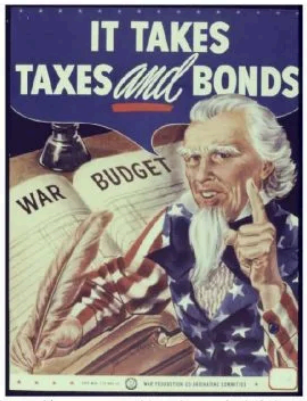
Use of DICE-2013R model with a mix of tax and bond financing

Why did we choose it?

- Core economic and climate variables
- Calibrated model
- Well-known tools to simulate (GAMS/CONOPT)

Objectives of using bonds:

- Politically feasible
- Speeding up the transition
- Intergenerational fairness
- Welfare improvement



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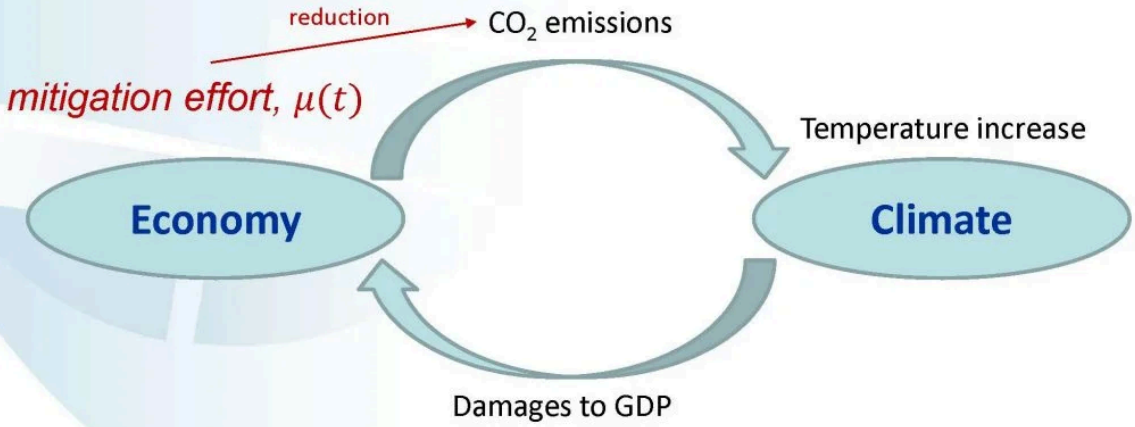
DICE-2013R model



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DICE-2013R short description

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

subject to

Economy

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

Climate

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

6 dynamic equations

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

Decision variables: $C(t), \mu(t)$ M – stock of carbon

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Two scenarios

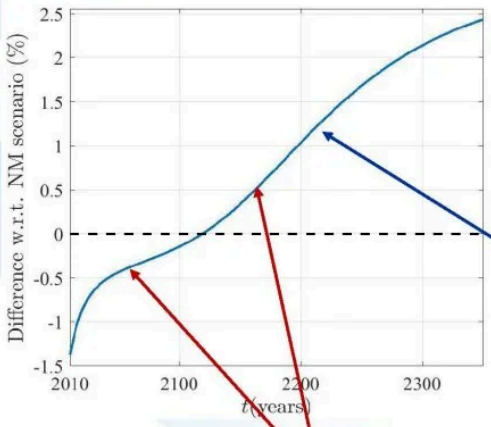
DICE scenarios $(C(t), \mu(t))$:

- 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

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Bonds in the DICE model

- **Dynamics of bonds**

$$Bonds_{t+1} = (1 + Rate) \cdot Bonds_t - (Taxation_t - Abatement_t)$$

- **Bonds have to be repaid**

$$Bonds_T = 0$$

new decision variable

- **Initial governmental debt is zero**

$$Bonds_0 = 0$$

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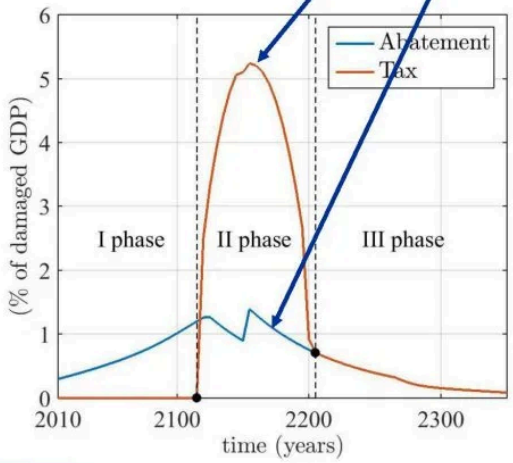
Optimal mitigation with bonds (OMB)

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

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



Sequence of three phases

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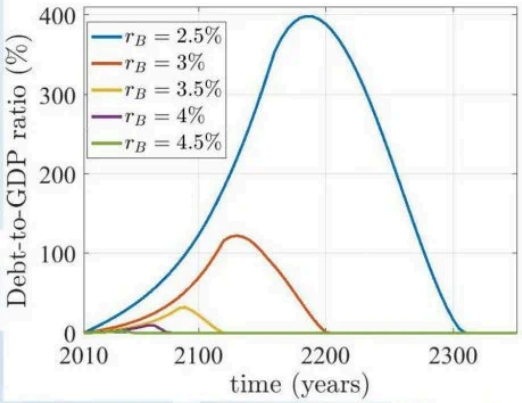
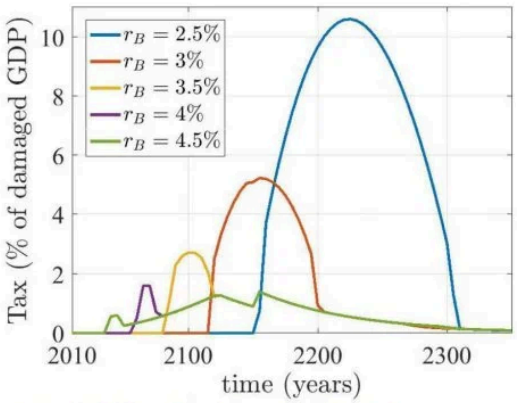
Optimal mitigation with bonds (OMB)



Sensitivity of interest rate to bonds



Sensitivity of interest rate to tax

- *The lower the interest rate (more bonds issued) the faster the emissions decrease*
- *The lower the interest rate (more bonds issued) the later bonds are repaid*

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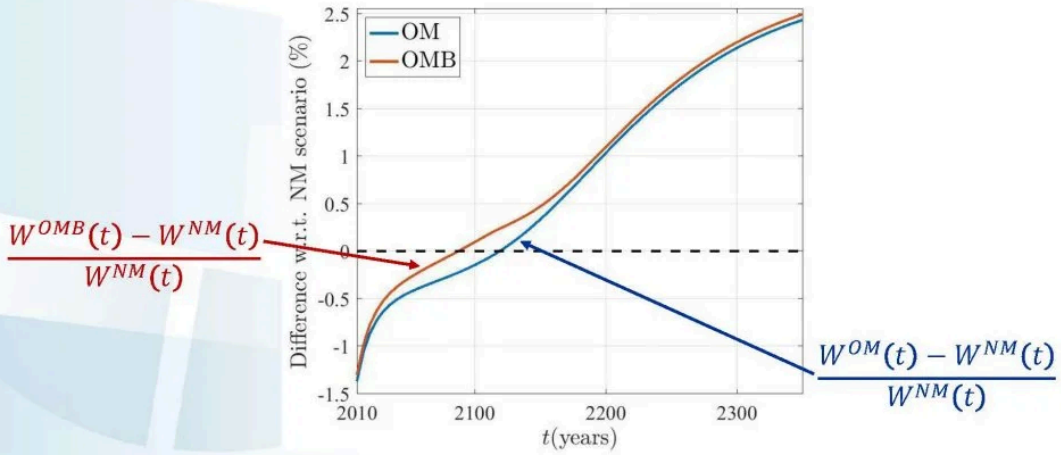
Optimal mitigation with bonds (OMB)



- Pareto improvement over OM scenario
- Still no Pareto improvement over NM scenario

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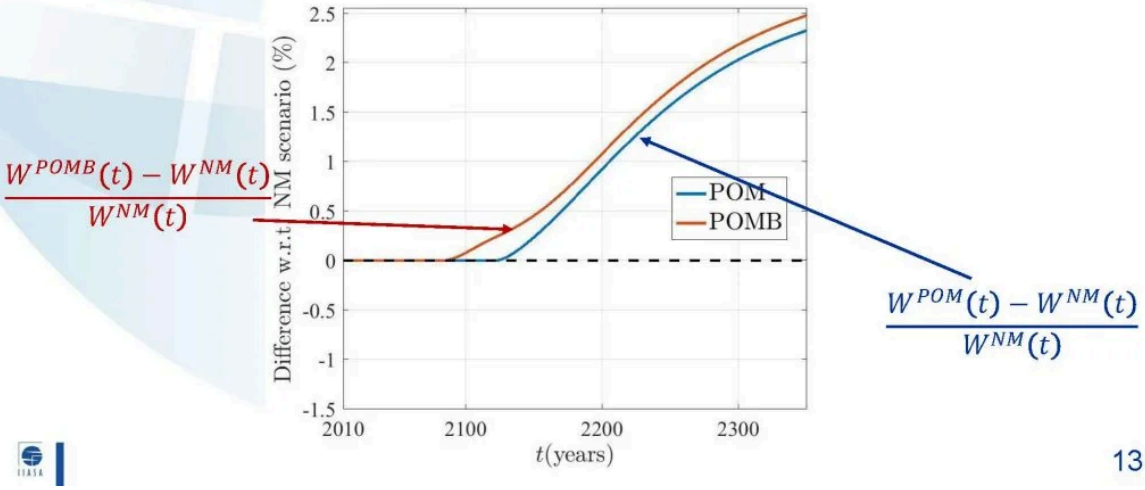
Pareto optimal scenarios

Constraints on consumption: $C(t) \geq C^{NM}(t),\ 0 \leq t \leq T$

Two more scenarios:

- Pareto optimal mitigation (POM) = OM + constraints on consumption
- Pareto optimal mitigation with bonds (POMB) = OMB + constraints on consumptior



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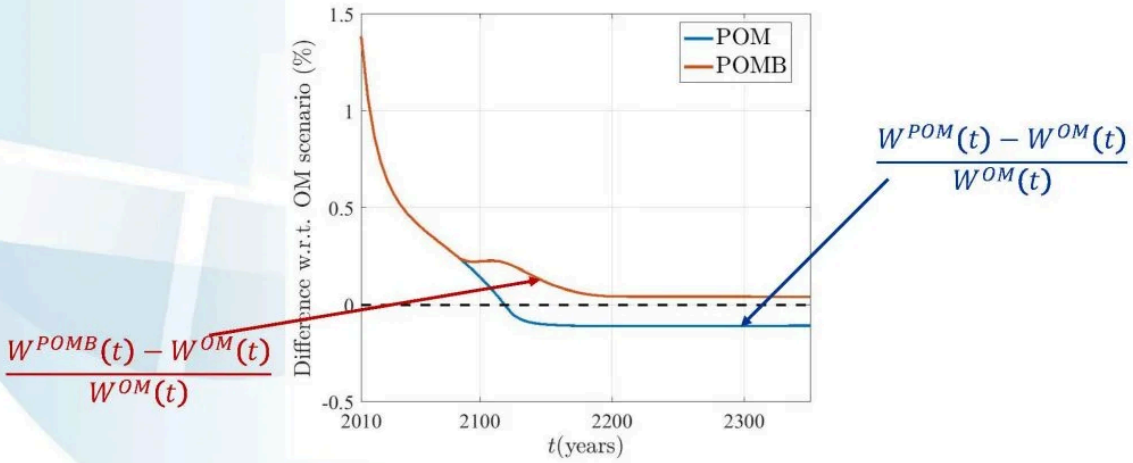
Pareto optimal scenarios

Constraints on consumption: $C(t) \geq C^{NM}(t),\ 0 \leq t \leq T$



- Pareto improvement of POMB over OM scenario and POM

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Summary

Does bond financing of climate policy and repayment later through taxation help?

- Politically more feasible than carbon tax alone
- Speeding up the transition
- Intergenerational fairness
- Welfare improvement
- Needs complementary policies (regulation, low carbon technology, infrastructure…, see our IMF work)

Thank you for your attention!

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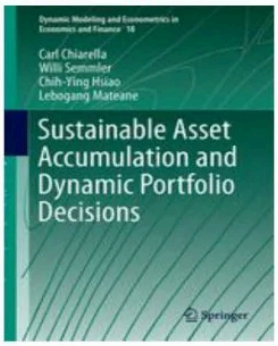
Appendix: Portfolio Approach

Instead of a 2-asset model (capital stock and bonds) we can have multiple assets



$$\max_{(C^*,\alpha)} \int_0^\infty e^{-\delta} U(C_t)dt$$

$$\text{s.t. } \dot{W}(t) = \alpha_t R_{e,t} W_t + (1-\alpha_t) R_{f,t} W_t - C_t$$

+ Wages- tau

$$\dot{x}(t) = 1$$

W_dot=K_dot + B_dot, or: K_dot=W_dot-B_dot (1)

$Q(t) = [1 - \Lambda(\mu(t))]\Omega(t)Y(t) = C(t) + I(t)$ *(2) ; whereby:* $\Lambda(\mu(t))\Omega(t)Y(t)$*=G-tau*

(3) B_dot=G-tau + $(1-\alpha_t) R_{f,t} W_t$

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