
A CRASH COURSE ON CLIMATE ECONOMICS:

FROM STRUCTURAL TRANSITIONS TO IMMEDIATE STABILIZATION

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INTRODUCTION

It's a crash and thus imperfect course on climate economics.

Schedule:

1. A Long Run View on Climate: The DICE Model (20 min)
2. A Short Term View: the New Keynesian Climate Model (20 min)
3. Simulating both short and long term dynamics of simple climate macroeconomic models (20min)

OUTLINE

1 Introduction

2 A Long Term View: The DICE Model

- Introduction
- The Model
- The socioeconomic block
- Economic decisions
- Simulating the model
- The Social Cost of Carbon

3 A short term view: the New Keynesian Climate Model

- Introduction
- The NKC model
- Estimation

4 The Anatomy of Green/Climateflation

PLAN

- 1 Introduction
- 2 A Long Term View: The DICE Model**
- 3 A short term view: the New Keynesian Climate Model
- 4 The Anatomy of Green/Climateflation

INTRODUCTION

- ▶ DICE (Dynamic Integrated Climate-Economy model) was developed by Nordhaus (1992) and went through several (minor) updates up to the latest 2023 snapshot;
- ▶ Simple but powerful model to provide fast estimates of the social cost of carbon and transition pathways for the world economy;
- ▶ It has become an intuitive benchmark.
- ▶ Back in the 90s, Bill Nordhaus's work on climate has never been published in top 5 journals (always rejected) but got published in Sciences, PNAS, etc.

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- ▶ The framework is old-fashion:
 - ▶ Solow growth model with climate externality;
 - ▶ Centralized equilibrium based on Ramsey allocations;
 - ▶ Purely deterministic setup;
- ▶ Physical capital, temperatures and carbon boxes are the main state variables that the planner uses to optimally maximize welfare.
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CARBON CYCLE

- ▶ Atmospheric loading of CO_2 is a system of differential equations:

$$M_t = \Phi_M M_{t-1} + \Xi_M E_t, \quad (1)$$

where $M_t = [M_t^{AT}, M_t^{UP}, M_t^{LO}]'$ comprises 3 layers of carbon: atmospheric, upper and lower ocean respectively.

- ▶ Matrices are determined by:

$$\Phi_M = \begin{bmatrix} 1 - \phi_{12} & \phi_{21} & 0 \\ \phi_{12} & 1 - \phi_{21} - \phi_{23} & \phi_{32} \\ 0 & \phi_{23} & 1 - \phi_{32} \end{bmatrix} \text{ and } \Xi_M = \begin{bmatrix} \xi_M \\ 0 \\ 0 \end{bmatrix}$$

- ▶ Carbon emissions go into the atmosphere, before being captured by oceans through a long lasting process.

TEMPERATURES

- ▶ Temperature anomalies $T_t = [T_t^{AT}, T_t^{OC}]$ of atmosphere and ocean respectively:

$$T_t = \Phi_T T_{t-1} + \Xi_T F_t, \quad (2)$$

- ▶ Matrices are given by:

$$\Phi_T = \begin{bmatrix} \varphi_{11} & \varphi_{12} \\ \varphi_{21} & \varphi_{22} \end{bmatrix} \text{ and } \Xi_T = \begin{bmatrix} \xi_T \\ 0 \end{bmatrix}$$

- ▶ Cooling effects of oceans through φ_{12} , ξ_T is the heating sensitivity to radiative forcing F_t .

RADIATIVE FORCING

- ▶ Greenhouse effect via radiative forcing (W/m^2):

$$F_t = \eta \log \left(M_t^{AT} / M_{1750} \right) / \log(2) + F_t^{EX} \quad (3)$$

- ▶ Here, η denote the forcing (Wm^{-2}) of equilibrium CO_2 doubling ($M_t^{AT} = 2M_{1750}$).
- ▶ F_t^{EX} is an exogenous process tracking the contribution of other sources of GHG (i.e. methane) on F_t

INPUT STRUCTURE

- ▶ World population (billion):

$$L_t = L_{t-1} (L_T/L_{t-1})^{\ell_g}, \quad (4)$$

$\ell_g \in [0, 1]$ convergence rate, $L_T \in [0, +\infty)$ long term population.

- ▶ Law of motion of capital:

$$K_t = (1 - \delta_K) K_{t-1} + I_t, \quad (5)$$

$\delta_K \in [0, 1]$ is the depreciation rate.

PRODUCTION OF GOODS AND EMISSIONS

- Production is Cobb-Douglas:

$$Y_t = A_t K_{t-1}^\gamma L_t^{1-\gamma} \quad (6)$$

where $\gamma \in [0, 1]$ is capital intensity, exogenous TFP A_t , physical capital K_{t-1} .

- Emissions (GtCO₂):

$$E_t = \sigma_t (1 - \mu_t) Y_t + E_t^{\text{land}} \quad (7)$$

where σ_t decoupling rate, μ_t is abatement share, E_t^{land} is exogenous process of carbon emission from change in land use (i.e. deforestation).

EQUILIBRIUM IN GOODS AND CLIMATE

- ▶ Resource constraint:

$$Y_t \left(1 - \theta_{1,t} \mu_t^{\theta_2}\right) \Omega(T_t) = C_t + I_t \quad (8)$$

LHS is output loss from abatement and damage, RHS is demand side.

- ▶ Damages are given by:

$$\Omega(T_t) = 1/(1 + aT_t^2) \quad (9)$$

This expression is subject to deep uncertainty, and should be taken as a normative measure of the social loss for the society of rising temperatures. Tipping points could be introduced [[Weitzman, 2012](#)].

EXOGENOUS TRENDS

Total factor productivity:

$$\Delta \log A_t = g_A - \delta_a \log (A_t/A_0)$$

Decoupling rate of carbon emission to GDP:

$$\Delta \log \sigma_t = g_\sigma - \delta_\sigma \log (\sigma_t/\sigma_0)$$

Cost of abating carbon emissions:

$$\theta_{1,t} = (1 - \delta_\theta) \theta_{1,t-1} \sigma_t / \sigma_{t-1}$$

Non-CO2 forcing law of motion:

$$F_t^{EX} = \min \left(F_{t-1}^{EX} + \Delta_F, F_{CAP} \right)$$

Land-use law of motion:

$$E_t^{\text{land}} = (1 - \delta_e) E_{t-1}^{\text{land}}$$

World population dynamic:

$$L_t = L_{t-1} (L_T/L_{t-1})^{\ell_g}$$

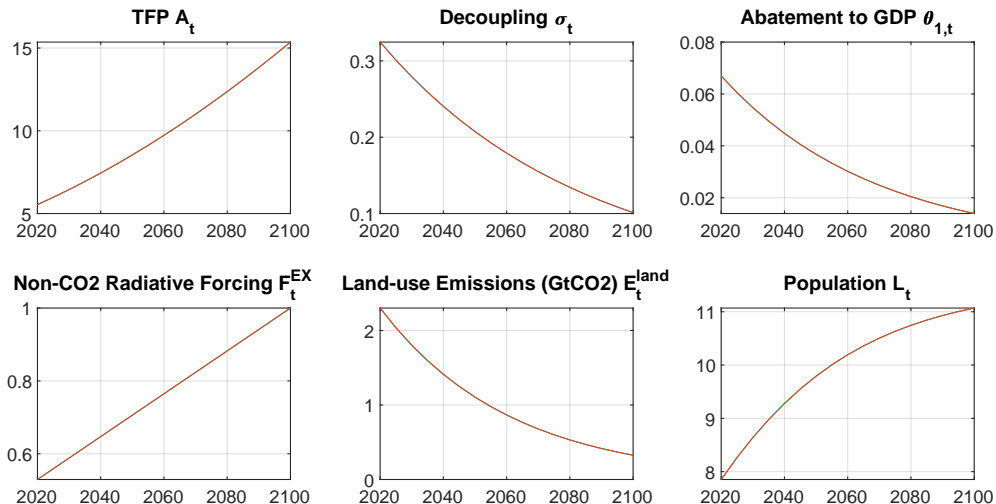


Figure. Exogenous variables

INTRODUCING A SAVING RATE

- ▶ How should we determine optimally C and I ?
- ▶ Could use decentralized decision problem, or use old-fashion centralized equation following Ramsey allocation;
- ▶ Introduce optimal saving rate S , consumption and investment becomes:

$$C_t = (1 - S_t) \times Y_t \left(1 - \theta_{1,t} \mu_t^{\theta_2}\right) \Omega(T_t) \quad (10)$$

$$I_t = S_t \times Y_t \left(1 - \theta_{1,t} \mu_t^{\theta_2}\right) \Omega(T_t) \quad (11)$$

→implicitly assuming that income spent between C_t and I_t .

- ▶ Economists typically assume that economic decisions are taken 'optimally' by solving an optimal control problem: e.g. maximizing welfare under budget constraint. Here optimal determination of S .

INTRODUCING A SAVING RATE

- ▶ The planner maximizes the social welfare:

$$\max_{\{S_t, \mu_t\}} \sum_{t=0}^{\infty} \beta^t L_t \left(c_t^{1-\alpha} - 1 \right) (1 - \alpha)^{-1} \quad (12)$$

where $c_t = C_t/L_t$ is the per capita consumption, utility function concave.

- ▶ How to solve the problem?
1. **Numerical solver:** use solver to find sequences $\{S_t, \mu_t\}_{t=0}^T$ that maximizes objective (12).
 2. **Ramsey solution:** maximize social welfare 12 based on N equations and $N + I$ control variables (I corresponding to the number of instruments).
 3. **Dynamic programming:** use Bellman equation and value function iterations or projections.

The Ramsey (1927) problem:

$$\begin{aligned}
 & \max_{\{c_t, Y_t, K_t, T_t, M_t, \mu_t, S_t\}} \sum_{t=0}^{\infty} \beta^t L_t \left(c_t^{1-\alpha} - 1 \right) (1 - \alpha)^{-1} \\
 & + \beta^t \lambda_{1,t} \left[(1 - S_t) Y_t \left(1 - \theta_{1,t} \mu_t^{\theta_2} \right) \Omega(T_t) - L_t c_t \right] \\
 & + \beta^t \lambda_{2,t} \left[K_t - (1 - \delta_K) K_{t-1} - S_t Y_t \left(1 - \theta_{1,t} \mu_t^{\theta_2} \right) \Omega(T_t) \right] \\
 & + \beta^t \lambda_{3,t} \left[Y_t - A_t K_{t-1}^{\gamma} L_t^{1-\gamma} \right] \\
 & + \beta^t \lambda_{4,t} \left[T_t - \Phi_T T_{t-1} - \Xi_T \left(\eta \log \left(M_t^{AT} / M_{1750} \right) / \log(2) + F_t^{EX} \right) \right] \\
 & + \beta^t \lambda_{5,t} \left[M_t - \Phi_M M_{t-1} - \Xi_M \left(\sigma_t (1 - \mu_t) Y_t + E_t^{\text{land}} \right) \right]
 \end{aligned}$$

Summary: optimal control problem with 7 control variables, 5 constraints \rightarrow 12 variables/equations.

(note that climate variables include more equations + Lagrangian multipliers)

Model summary:

- ▶ 6 exogenous variables $\{A_t, \sigma_t, \theta_{1,t}, F_t^{EX}, E_t^{\text{land}}, L_t\}$ and 6 exogenous processes;
- ▶ 5 core equations (from initial model) and 7 first order conditions (from Ramsey problem);
- ▶ There are 7 core endogenous variables $\{c_t, Y_t, K_t, T_t, M_t, \mu_t, S_t\}$ and 5 Lagrangian multipliers (from Ramsey) $\{\lambda_{1,t}, \dots, \lambda_{5,t}\}$;
- ▶ **In sum:** 18 equations and variables.
- ▶ **Next step:** get numerical simulations from the model.

NUMERIC SOLUTION

- ▶ The presence of state variables in constraints (1-5) implies that current decisions depend on future outcome; **example with capital**
- ▶ Stacking our equations into f:

$$\begin{bmatrix} (1 - S_t) Y_t \left(1 - \theta_{1,t} \mu_t^{\theta_2}\right) \Omega(T_t) - L_t c_t = 0 \\ K_t - (1 - \delta_K) K_{t-1} - S_t Y_t \left(1 - \theta_{1,t} \mu_t^{\theta_2}\right) \Omega(T_t) = 0 \\ Y_t - A_t K_{t-1}^\gamma L_t^{1-\gamma} = 0 \\ \dots \end{bmatrix} \rightarrow f(y_{t+1}, y_t, y_{t-1}) = 0$$

where $f(y_{t+1}, y_t, y_{t-1})$ is the state-space representation of our model featuring forward and backward looking variables.

- ▶ Here, $y_t = [K_t, S_t, \mu_t, \dots]$ is the vector of endogenous variables.

NUMERIC SOLUTION

A sketch of the numeric problem:

- ▶ Finite horizon problem for $t = 0, 2, \dots T + 1$;
- ▶ Terminal y_{T+1} and initial y_0 conditions are given \rightarrow need to numerically get $y_1, y_2, \dots y_T$;
- ▶ In absence of stochastic variables \rightarrow deterministic problem \rightarrow perfect foresight setup where any variable in y_{t+1} corresponds to the realized variable in $t + 1$;
- ▶ Forward-looking models admit infinity of stable solutions \rightarrow imposing a terminal condition is an instrument to obtain one unique solution (Boucekkine (1995));

NUMERIC SOLUTION

- Over the time horizon $t = 1, 2, \dots, T$, stacking $f(\cdot)$ over time:

$$F(Y) = \begin{bmatrix} f(y_2, y_1, y_0) \\ f(y_3, y_2, y_1) \\ \dots \\ f(y_T, y_{T-1}, y_{T-2}) \end{bmatrix}$$

with $Y = [y'_t, y'_{t+1}, \dots, y'_T]'$ and $F : \mathbb{R}^{NT} \rightarrow \mathbb{R}^{NT}$

- Y and $F(Y)$ are two vectors of size $NT \times 1$.

NUMERIC SOLUTION

- The goal is to numerically solve:

$$Y^* = \arg \min_{\{Y\}} |F(Y)|$$

- How? Newton–Raphson method very efficient as shown by [Laffargue \(1990\)](#), [Boucekkine \(1995\)](#) and [Juillard et al. \(1996\)](#). Basic idea:
 - Set an initial value $Y^{(0)}$.
 - n^{th} Newton iterations:

$$Y^{(n)} = Y^{(n-1)} - J_F \left(Y^{(n-1)} \right)^{-1} F(Y^{(n-1)})$$

where $J_F \left(Y^{(n-1)} \right)$ is Jacobian matrix of F of dimensions $NT \times NT$.

- Stop the iterations if $|F(Y^{(n-1)})| < \varepsilon$.

- ▶ To simulate the model, we need to calibrate initial state variables (subset of y_0) to match values observed in 2015.
- ▶ Terminal conditions computed asymptotically $t \rightarrow +\infty$ by determining y_{T+1} that satisfies:

$$f(y_{T+1}, y_{T+1}, y_{T+1}) = 0$$

- ▶ In finite horizon problem, T must be large enough to verify condition:

$$|f(y_{T+1}, y_T, y_{T-1}) - f(y_{T+1}, y_{T+1}, y_{T+1})| < \varepsilon$$

- ▶ $\Delta t = 5$ years, $t = \{t_0, t_1, \dots, T\}$, with $t_0 = 2015$ and $T = 2600$;
- ▶ Consider two policies:
 1. The mitigation policy:

$$\begin{aligned} \max_{\{c_t, Y_t, K_t, T_t, M_t, \mu_t, S_t\}} \quad & \sum_{t=0}^{\infty} \beta^t L_t \left(c_t^{1-\alpha} - 1 \right) (1 - \alpha)^{-1} \\ \text{s.t.} \quad & (1) - (5) \end{aligned}$$

2. The *laissez-faire* / Business As Usual (BAU) policy:

$$\begin{aligned} \max_{\{c_t, Y_t, K_t, T_t, M_t, S_t\}} \quad & \sum_{t=0}^{\infty} \beta^t L_t \left(c_t^{1-\alpha} - 1 \right) (1 - \alpha)^{-1} \\ \text{s.t.} \quad & (1) - (5) \\ & \text{s.t. } \mu_t = 0.03 \end{aligned}$$

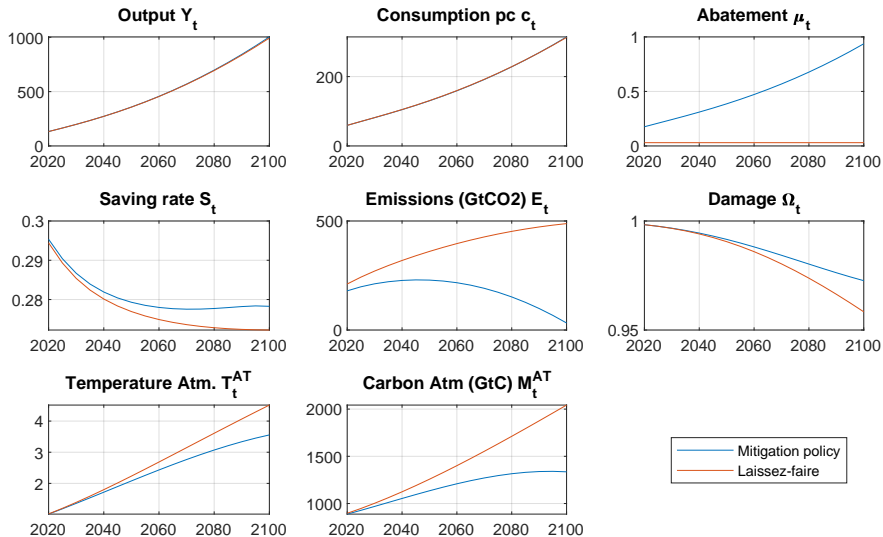


Figure. Simulations under two policy scenarios

Some striking but controversial results from DICE:

- ▶ “Optimal” to warm the planet up to 3.5°C ;
- ▶ Mitigation policy saves about 2% of climate damage;
- ▶ Net zero emission optimal by 2100, 50 years later than in Paris-Agreement;
- ▶ Main critic from DICE’s policy output: those results have scientifically grounded climate inaction in policy circles...

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SOCIAL COST OF CARBON

- ▶ Why is it optimal to warm so much the planet according to DICE?
- ▶ An optimal carbon tax = how much the society is willing to pay to reduce emissions (\$ per ton of carbon).
- ▶ This is usually referred to as the Social Cost of Carbon (SCC) in literature.
- ▶ SCC reflects the society's gains and losses from implementing the carbon tax.
- ▶ What is the model implied SCC?

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SOCIAL COST OF CARBON

- Get back to FOCs of the Ramsey-planner:

$$M_t^{AT} : \lambda_{5,t}^{AT} = \beta \Phi_M \lambda_{5,t+1}^{AT} + \lambda_{4,t}^{AT} F'(M_t)$$

$$T_t^{AT} : \lambda_{4,t}^{AT} = \beta \Phi_T \lambda_{4,t+1}^{AT} + \lambda_{2,t}^{AT} S_t Y_t \left(1 - \theta_{1,t} \mu_t^{\theta_2}\right) \Omega'(T_t)$$

$\lambda_{5,t}^{AT}$ ($\lambda_{4,t}^{AT}$) is the marginal loss from carbon (temperature) increase.

- SCC expresses the social loss into numeraire equivalents (here consumption):

$$SSC_t = -1000 \times \lambda_{5,t}^{AT} / \lambda_{1,t} \simeq -1000 \times (\partial W_t / \partial M_t) / (\partial W_t / \partial C_t)$$

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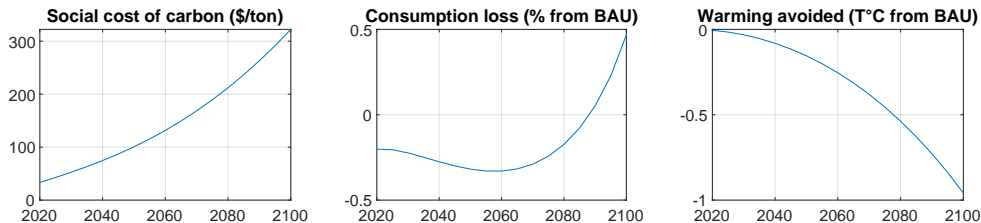


Figure. Social cost of carbon

- ▶ SCC reflect the planner's relative gains in terms of welfare from controlling M_t against its consumption losses C_t from such action;
- ▶ Optimal to cut consumption now by 0.5% in order to avoid 1°C of warming in 2100;
- ▶ As well off between scenarios by 2090 on current consumption grounds (but not in welfare terms).

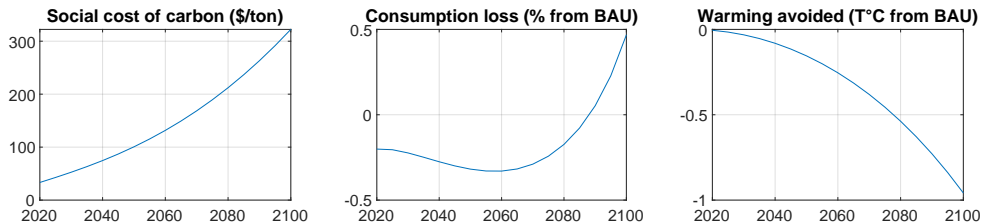


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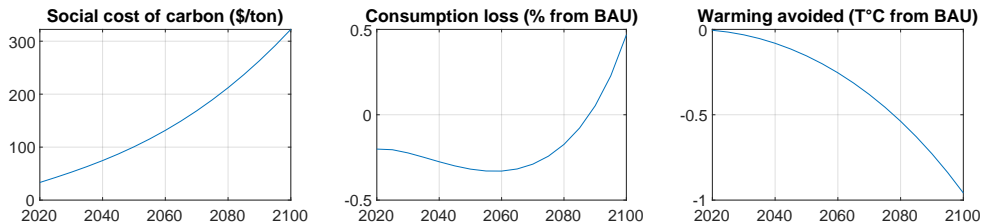


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- ▶ Climate change will shake the macroeconomic landscape in the next decades and the central bank will have to face 2 phenomena [Schnabel 2022]:
 - ▶ On the one hand, a warming planet causes damages that will make resources scarcer & prices higher → **climateflation**.
 - ▶ On the other hand, the fight against climate change through increasing carbon taxes will increase production costs → **greenflation**.
- ▶ How should the central bank conduct monetary policy in this new landscape?
- ▶ Answering this question requires a new class of IAM with New Keynesian ingredients to capture inflation dynamics.
- ▶ Current models used by IPCC neglect the nominal implications of climate policy/change.

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- ▶ This paper develops The New Keynesian Climate (NKC) model by:
 - ▶ extending with a **carbon accumulation** constraint and a **mitigation policy** from the Integrated Assessment Model (IAM) [Barrage and Nordhaus 2023];
 - ▶ estimating NKC for the world economy with techniques that take into account nonlinearities resulting from climate change;
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METHODOLOGICAL BREAKTHROUGH

- ▶ Standard view: stable propagation mechanism with fluctuations naturally decaying over time back to a steady state [Smets and Wouters 2007].
- ▶ Climate problem: Cumulative emissions permanently alter the propagation mechanism \rightarrow no steady state.
- ▶ Why? Cumulative carbon induces permanent shifts in productivity, structurally similar to an endogenous (de-)growth model.
- ▶ Climate damages $\Omega(M)$ in production ($Y = \Phi(M) \cdot L$) does not scale proportionally with economic growth, violating the homogeneity assumption required for Solow's detrending techniques.
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LITERATURE

Our paper is connected to three literatures:

- ▶ **Long-term climate analysis:** IAMs analyze the long-term effect of carbon accumulation [Nordhaus 1992; Dietz and Venmans 2019; Barrage and Nordhaus 2023; Folini et al. 2024] & IPCC models, but ignore fluctuations and/or price rigidity.
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THE NEW KEYNESIAN CLIMATE MODEL

Carbon accumulation and its damages:

$$\text{IS:} \quad \left(\frac{\tilde{y}_t x_t - \omega d}{1 - \omega} \right)^{-\sigma_c} = \beta \mathbb{E}_t \frac{\varepsilon_{b,t+1}}{\varepsilon_{b,t}} \frac{r_t}{\pi_{t+1}} \left((1 - \omega) \left(\frac{x_{t+1} \tilde{y}_{t+1} - \omega d}{1 - \omega} \right)^{-\sigma_c} + \omega d^{-\sigma_c} \right)$$

$$x_t = 1 - (1 - \vartheta) 0.5 \kappa (\pi_t - \pi_t^*)^2 - \vartheta (1 - \varepsilon_{p,t} m c_t)$$

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Anthropogenic carbon stock

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Deterministic
Decoupling trend

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Deterministic
Decoupling trend

Deterministic
TFP trend

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Anthropogenic carbon stock

Deterministic
TFP trend

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Deterministic
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Emission AR(1) shock

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THE NEW KEYNESIAN CLIMATE MODEL

Mitigation policies as function of exogenous carbon tax $\tilde{\tau}_t$:

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Mitigation
expenditures

$$x_t = 1 - (1 - \vartheta) 0.5 \kappa (\pi_t - \pi_t^*)^2 - \vartheta (1 - \varepsilon_{p,t} m c_t) - \theta_{1,t} \tilde{\tau}_t^{\theta_2 / (\theta_2 - 1)}$$

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Mitigation
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Mitigation
expenditures

$$x_t = 1 - (1 - \vartheta) 0.5 \kappa (\pi_t - \pi_t^*)^2 - \vartheta (1 - \varepsilon_{p,t} m c_t) - \theta_{1,t} \tilde{\tau}_t^{\theta_2 / (\theta_2 - 1)}$$

Carbon tax costs

$$\text{PC:} \quad (\pi_t - \pi_t^*) \pi_t = (1 - \vartheta) \beta \mathbb{E}_t g_{z,t} \tilde{y}_{t+1} / \tilde{y}_t (\pi_{t+1} - \pi_{t+1}^*) \pi_{t+1} + \zeta \kappa^{-1} \varepsilon_{p,t} m c_t + \kappa^{-1} (1 - \varsigma)$$

$$m c_t = \psi (x_t \tilde{y}_t - \omega d)^{\sigma_c} \tilde{y}_t^{(1 + \sigma_n) / \alpha - 1} \Phi(\tilde{m}_t)^{-(1 + \sigma_n) / \alpha} + \theta_{1,t} \tilde{\tau}_t \left(\theta_2 + (1 - \theta_2) \tilde{\tau}_t^{1 / (\theta_2 - 1)} \right)$$

$$\text{MP:} \quad r_t = r_{t-1}^\rho \left[r_r (\pi_t^* / \pi) (\pi_t / \pi_t^*)^{\phi_\pi} (\tilde{y}_t / \tilde{y}_t^n)^{\phi_y} \right]^{1 - \text{Abatement share}}$$

$$\text{CC:} \quad \tilde{m}_t = \tilde{m}_{t-1} + \xi_m \sigma_t z_t l_t \tilde{y}_t \varepsilon_{e,t} \left(1 - \tilde{\tau}_t^{1 / (\theta_2 - 1)} \right)$$

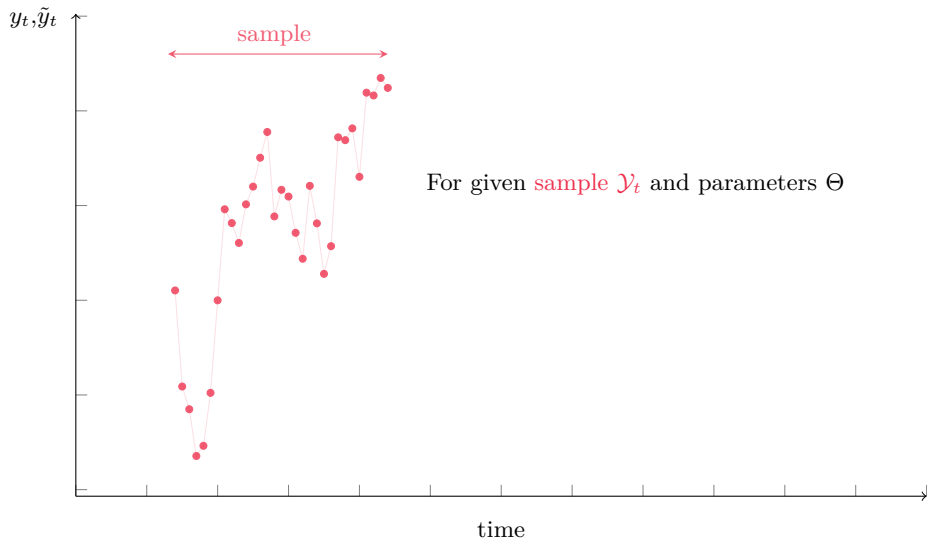
ESTIMATION

- ▶ Estimation on world data from 1985Q1 to 2023Q3 (sources: World Bank, OECD and OurWorldInData).
- ▶ There are four observable variables:

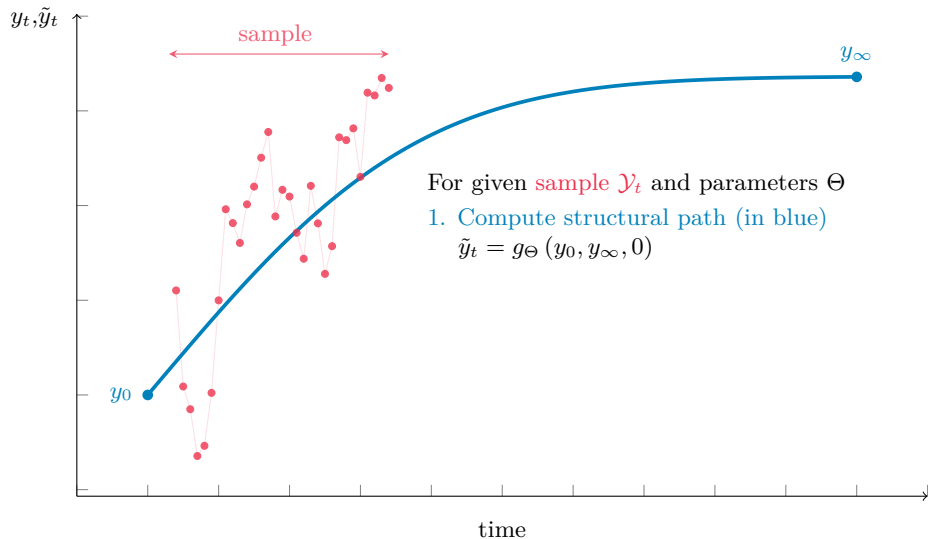
$$\begin{bmatrix} \text{Real output growth rate} \\ \text{Inflation rate} \\ \text{Short-term interest rate} \\ \text{CO}_2 \text{ emissions growth rate} \end{bmatrix} = 100 \times \begin{bmatrix} \Delta \log(y_t) \\ \pi_t - 1 \\ r_t - 1 \\ \Delta \log(e_t) \end{bmatrix}$$

- ▶ Solution & filtering methods from [Fair and Taylor \(1983\)](#): fully nonlinear, MIT shocks and no aggregate uncertainty.

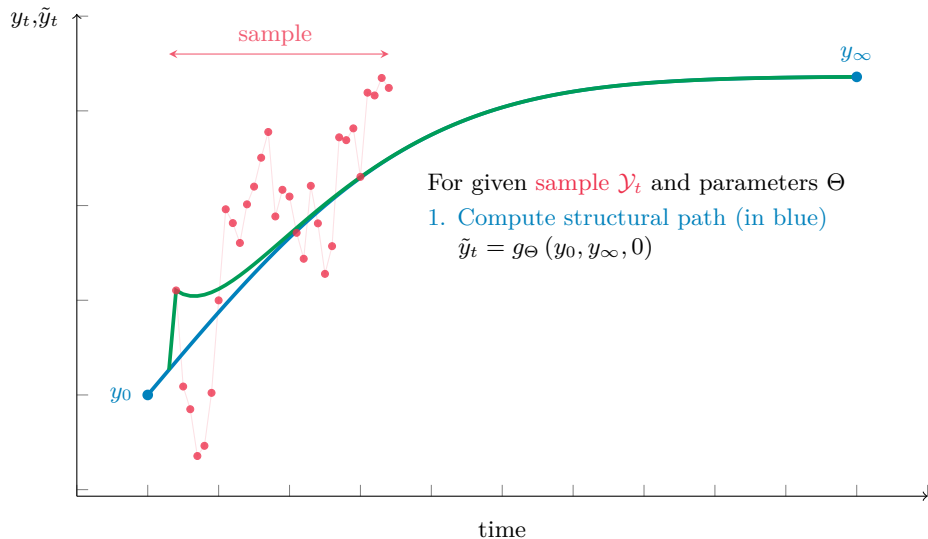
ESTIMATION



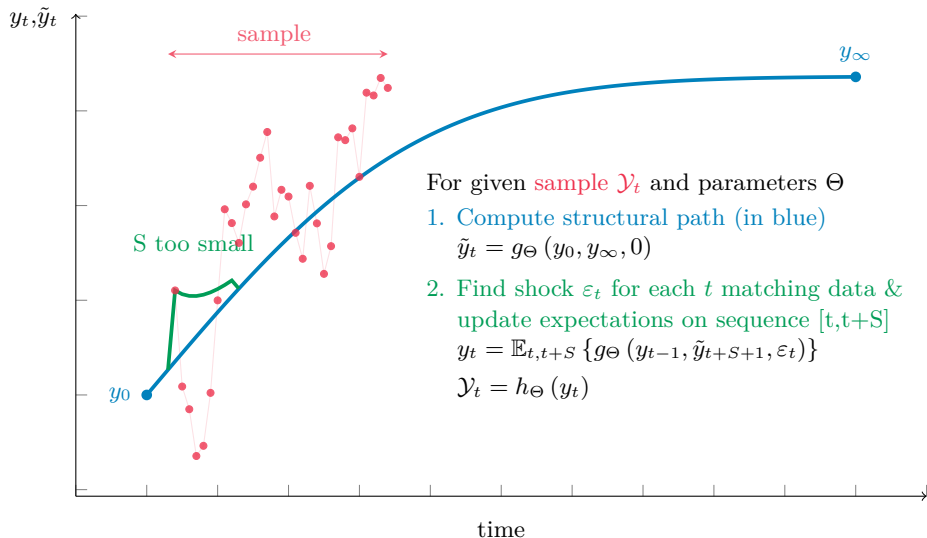
ESTIMATION



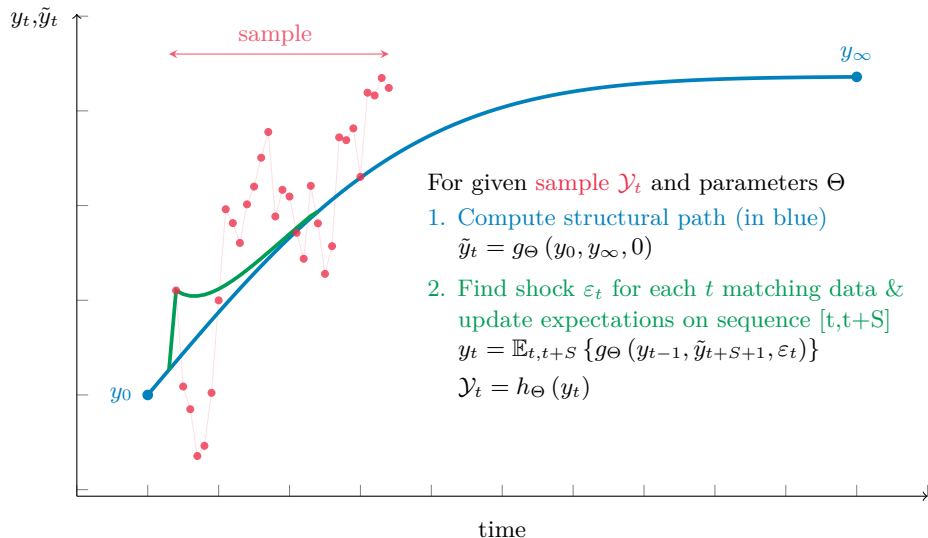
ESTIMATION



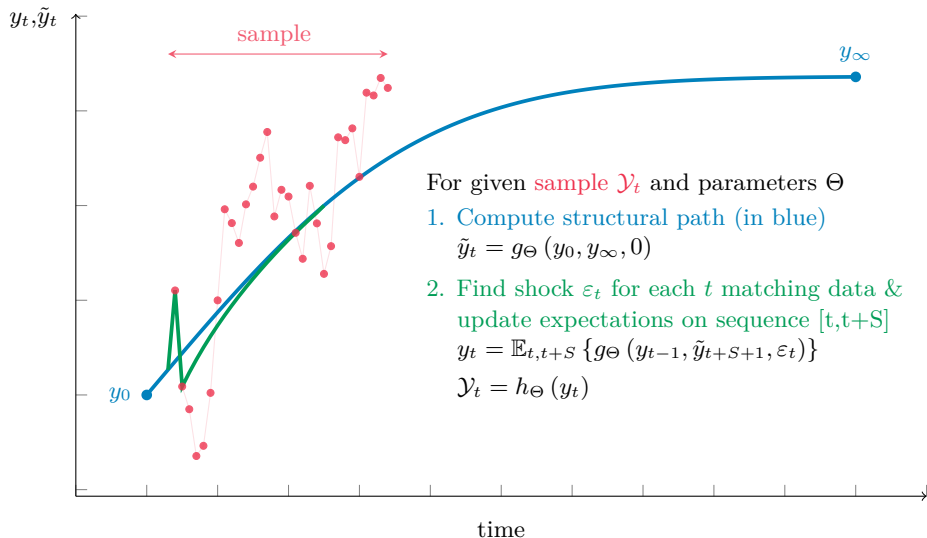
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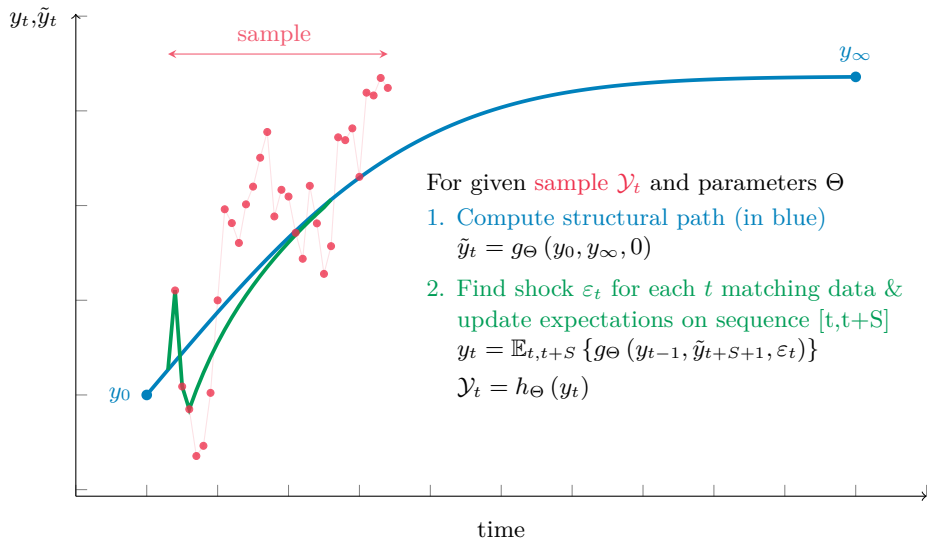
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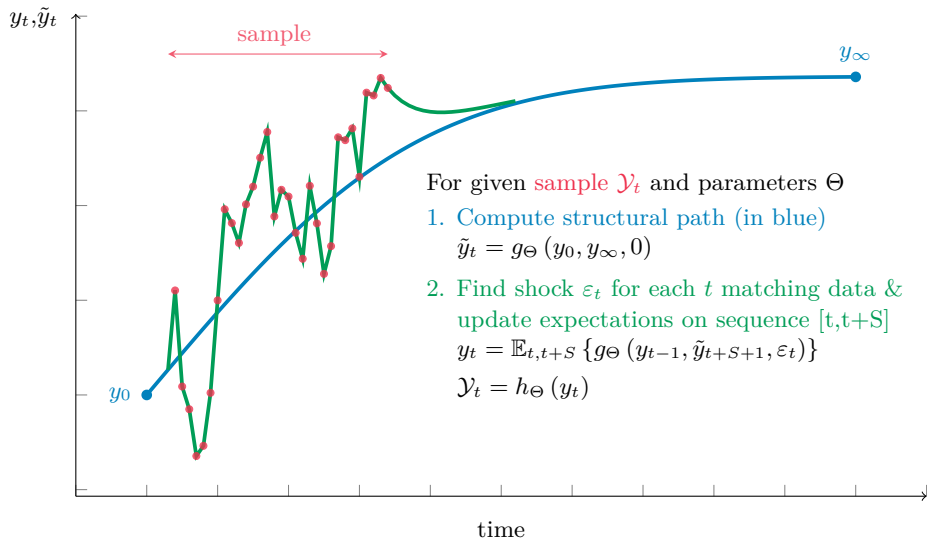
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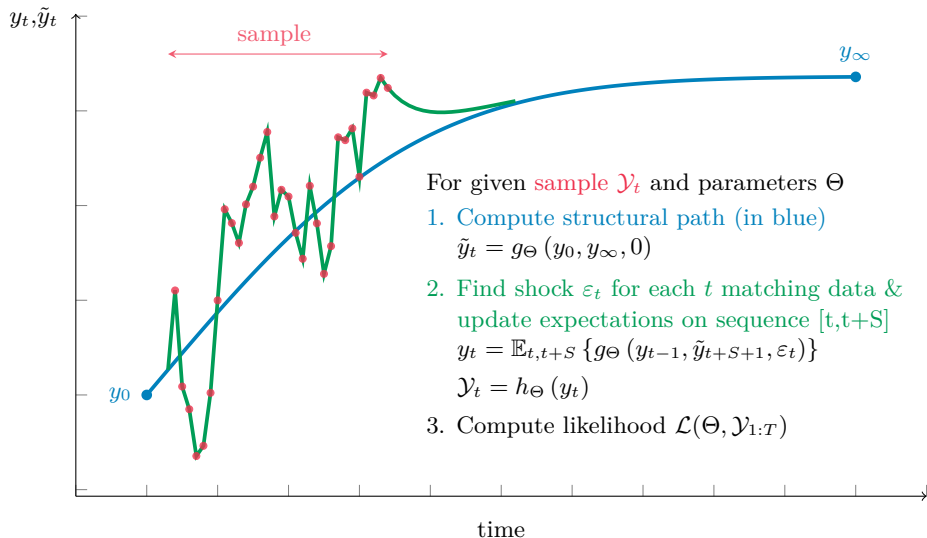
ESTIMATION



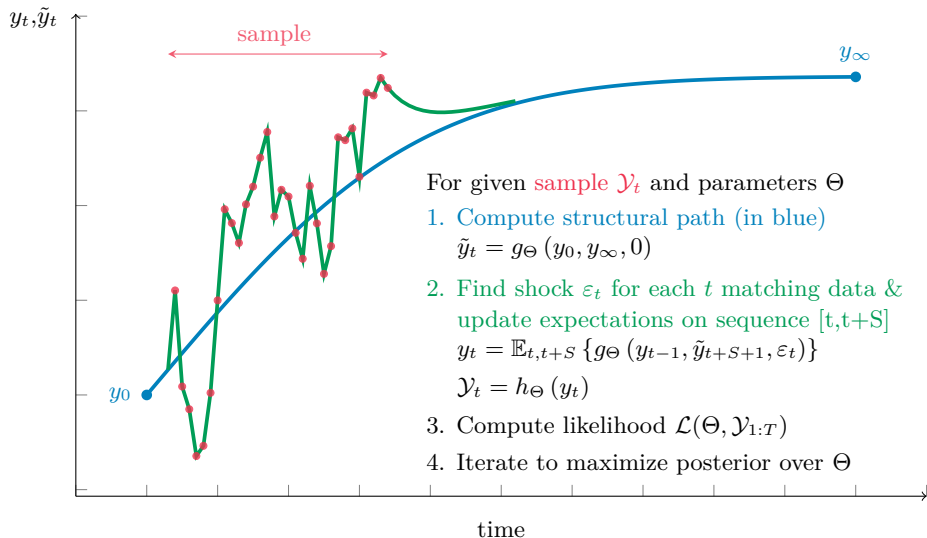
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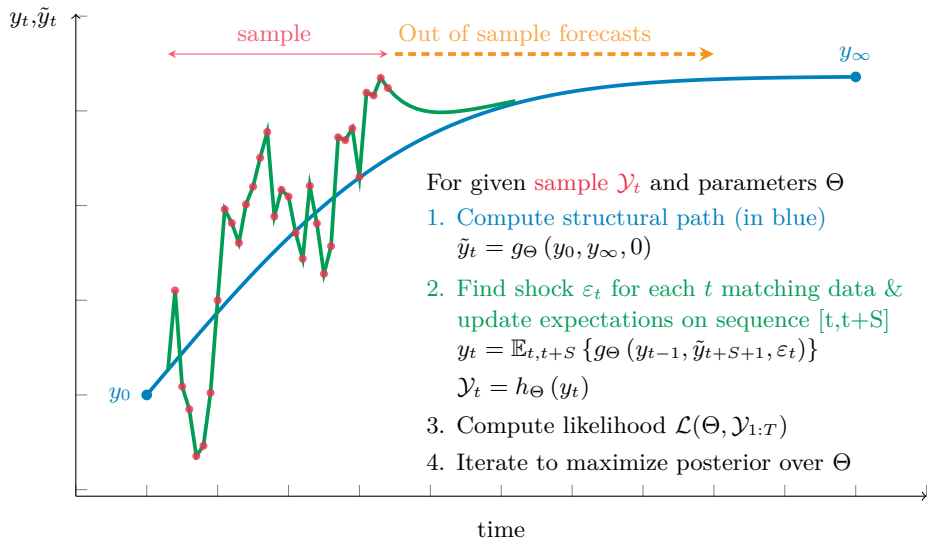
ESTIMATION



ESTIMATION



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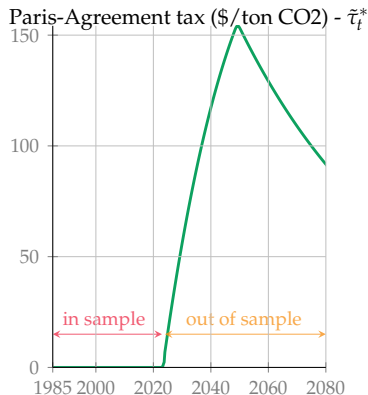


ESTIMATION

- ▶ Large uncertainty about future carbon tax: implications for estimation in particular at the end of the sample
- ▶ Let $\tilde{\tau}_t^*$ denote the Paris-Agreement tax, with linear decrease in carbon emissions up to 2050
- ▶ We let the data inform about the market-based expectations on future carbon mitigation policies:

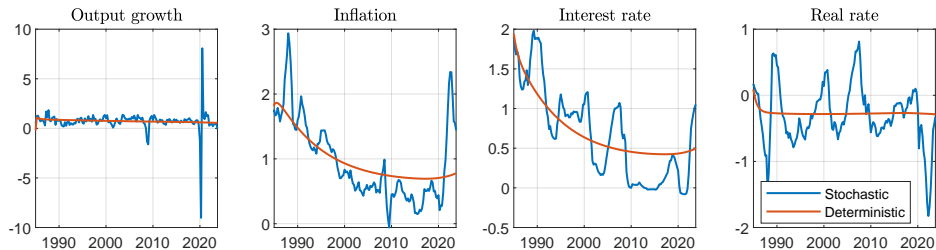
$$\mathbb{E}_t\{\tilde{\tau}_t\} = \varphi \tilde{\tau}_t^*$$

where $\varphi \in [0, 1]$ is the fraction of believers (or expected intensity) of Paris-Agreement policy.



STOCHASTIC AND DETERMINISTIC PATHS

Figure 1: Implied deterministic and stochastic paths



PLAN

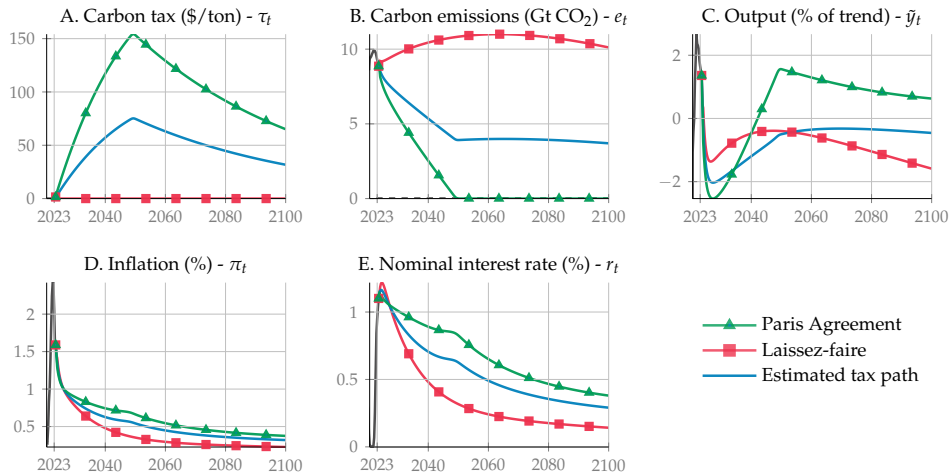
- 1 Introduction
- 2 A Long Term View: The DICE Model
- 3 A short term view: the New Keynesian Climate Model
- 4 The Anatomy of Green/Climateflation

THE ANATOMY OF GREEN/CLIMATEFLATION

- ▶ What is the future macroeconomic landscape by the end of the century?
- ▶ We consider three alternative scenarios based on the realization of the carbon tax $\varphi\tilde{\tau}_t^*$:
 - ▶ Paris-Agreement with $\varphi = 1$
 - ▶ Estimated carbon path with $\varphi = 0.53$
 - ▶ Laissez-faire with $\varphi = 0$

THREE TRANSITIONS

Figure 2: Model-implied projections based on alternative control rates of emissions



DISSECTING THE PC CURVE

- ▶ Stabilization objective of a central bank: important to understand how climate affects inflation.
- ▶ One can split the marginal cost into three term:

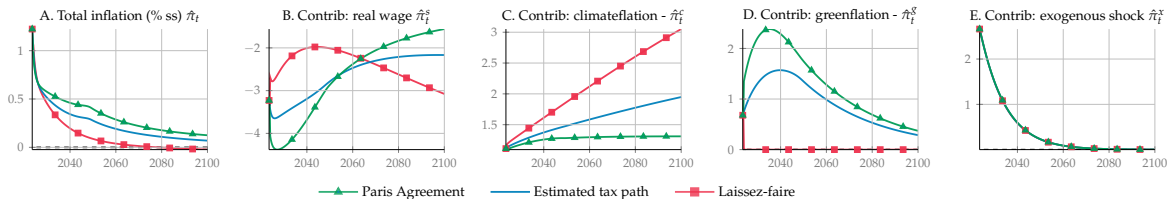
$$mc_t = \underbrace{\tilde{w}_t}_{\text{real wage}} / \underbrace{\Phi(m_t)}_{\text{climateflation}} + \underbrace{\theta_{1,t}\mu_t^{\theta_2} + \tau_{e,t}\sigma_t(1-\mu_t)\varepsilon_{e,t}}_{\text{greenflation}}, \quad (13)$$

which allows to break down inflation into 4 different forces:

$$\hat{\pi}_t \simeq \underbrace{\hat{\pi}_t^s}_{\text{wage term}} + \underbrace{\hat{\pi}_t^c}_{\text{climateflation}} + \underbrace{\hat{\pi}_t^g}_{\text{greenflation}} + \underbrace{\hat{\pi}_t^x}_{\text{exogenous shocks}} \quad (14)$$

with $\hat{\pi}_t = \pi_t - \pi_t^*$

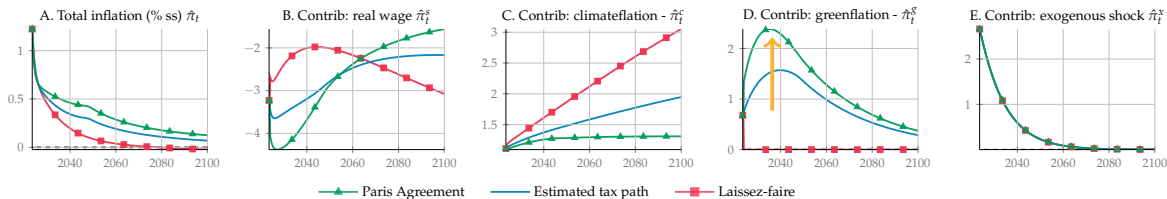
DISSECTING THE PC CURVE



► Under Paris Agreement:

- The immediate increase in carbon tax fuels inflation
- General equilibrium effect: increasing abatement expenditures reduces both consumption and in turn the wealth effect on the labor supply
- Net zero stabilizes damages, and hence climateflation

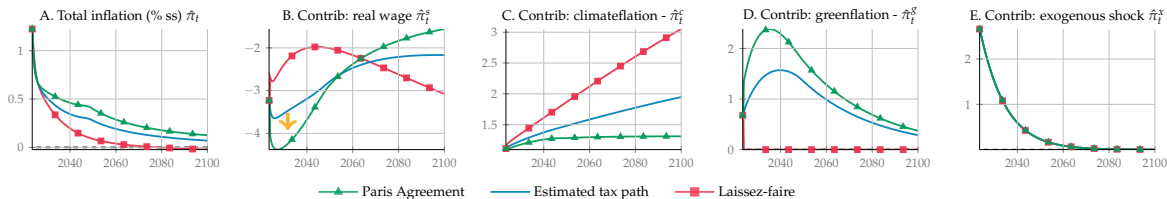
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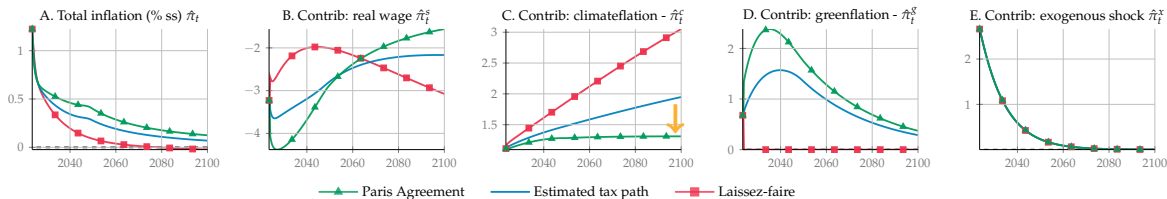
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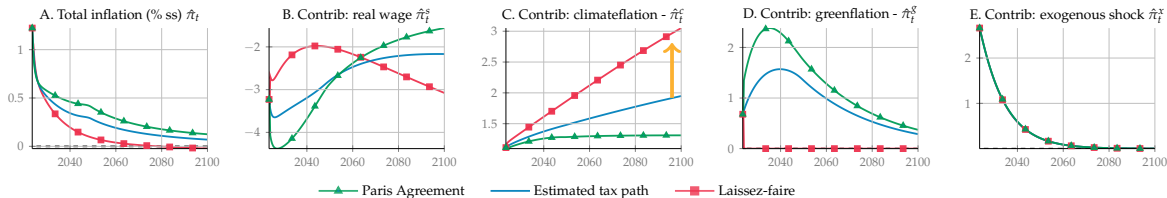
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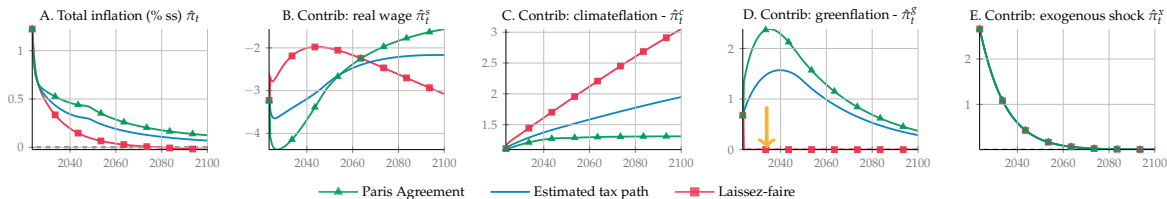
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► Under **Laissez-faire**:

- The rising damage makes resources scarcer: ever growing inflation as long as planet warms
- Disengagement from carbon policy makes carbon price to be zero
- General equilibrium effect: real wages fall as climate decreases productivity

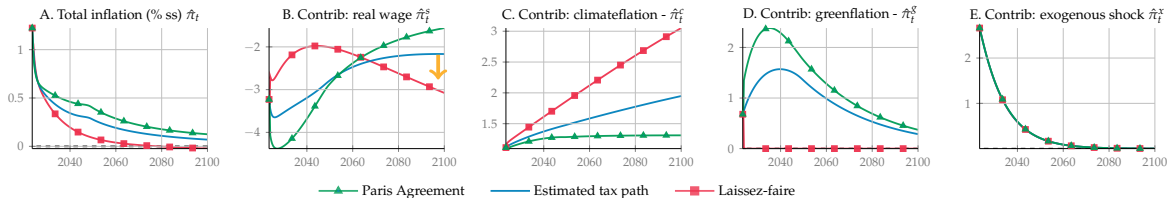
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DISSECTING THE PC CURVE



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WHAT DRIVES GREENFLATION?

Positive greenflation robust to alternative assumptions:

- ▶ Does capital in production increase inflation?
 - ▶ Yes! By dampening the cooling effects from real wage cuts.
- ▶ Do social transferts matter for greenflation?
 - ▶ Yes! Progressive redistribution softens the consumption decline, mitigating the recession.
- ▶ Do sticky wages increase inflation?
 - ▶ Yes! By reducing the decreases in real wages.
- ▶ Does implementing the optimal transition increase inflation?
 - ▶ Yes (in the short term)! SCC increases faster initially, boosting greenflation.

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Thank you for your attention

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