10 YEARS AFTER THE CRISIS - MODELLING MEETS POLICY MAKING

Coping With Collapse

January 16, 2019

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French Development Agency

Outline

1 Introduction

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5 Modeling uncertainty

6 Climate prospective

7 Concluding remarks

Introduction

Publications

ELSEVIER

Ecological Economics

Volume 147, May 2018, Pages 383-398

Analysis

Coping With Collapse: A Stock-Flow Consistent Monetary Macrodynamics of Global Warming

Emmanuel Bovari [b, c], Gaël Giraud [a, b, c], Florent Mc Isaac [a, c]

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Coping With Collapse, Ecological Economics, Volume 147, 2018, Pages 383-398.

ELSEVIER

International Economics

Available online 19 February 2018

In Press, Corrected Proof

Debt and damages: What are the chances of staying under the 2°C warming threshold?

Emmanuel Bovari [a, c], Oskar Lecuyer [b], Florent Mc Isaac [b, c]

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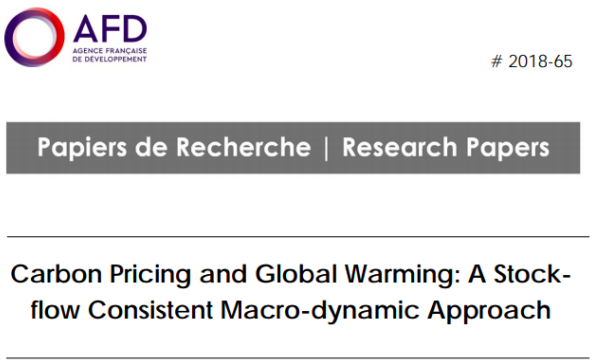
Debt and damages: What are the chances of staying under the 2C warming threshold? International Economics Volume 155, October 2018, Pages 92-108.



AFD AGENCE FRANÇAISE DE DÉVELOPPEMENT

2018-65

Papiers de Recherche | Research Papers

Carbon Pricing and Global Warming: A Stock-flow Consistent Macro-dynamic Approach

Carbon Pricing and Global Warming, AFD Research Papers, 2018

Introduction

Research questions

- Combine two sources of global instabilities, climate and finance, in a minimal dynamic framework to perform a prospective analysis.

  Can climate change drive the global economy in a deep recession?

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- Provide guidance for the implementation of public policy objectives in order to ensure economic stability and perform the energy shift.

  Is a price signal sufficient?

Introduction

Research questions

- Combine two sources of global instabilities, climate and finance, in a minimal dynamic framework to perform a prospective analysis.

  Can climate change drive the global economy in a deep recession?

- Provide guidance for the implementation of public policy objectives in order to ensure economic stability and perform the energy shift.

  Is a price signal sufficient?

- Cope with climate as well as economic uncertainties in order to have a deeper understanding of our chances to meet to Paris Agreement's objectives.

  What are our chances to stay below +2° C?

Introduction

Main findings

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Main findings

- In a business as usual scenario, climate change drives the global economy towards a situation of “economic collapse.”
- A price signal (carbon tax) provides indeed the right incentives to avoid most of climate damages.
- However, financial risks are not entirely precluded: in line with the Stern-Stiglitz report (2017), a green public intervention is required to tackle both instabilities.
- Our chances to achieve the Paris Agreement target stay, at most, below 25%.

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Related Literature

The Integrated Assessment Modeling (IAM) approach

A workhorse model: the Dynamic Integrated Climate Economy (DICE) model of Nordhaus in a seminal series of papers (1993, 2013, 2014, 2016)

- The Ramsey-Kass-Coopmans' approach as a core macroeconomic model
- A climate feedback loop with a damage function
- A carbon price instrument to shape the energy shift

Related Literature

The Integrated Assessment Modeling (IAM) approach

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Various extensions of the climate-economic interactions

- Endogenous technological progress (Moyer, 2014)
- Allocation of climate damages (Dietz and Stern, 2015)
- Finance and green policies (Dafermos, 2016)

This paper: assess financial instability (Keen, 1995 and Grasselli *et al.*, 2012)

Related Literature

The approaches of Goodwin (1967) and Keen (1995)

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  - Phenomenological approach relying on empirical data

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  - Phenomenological approach relying on empirical data
- Dynamic interaction of deep macroeconomic behaviors
  - Lotka-Volterra relationship linking the employment rate to the wage share
  - Short-term Phillips curve (Mankiw, 2010 or Krugman, 2014)
  - Investment as a function of profit share
  - Dynamics of corporates' private debt

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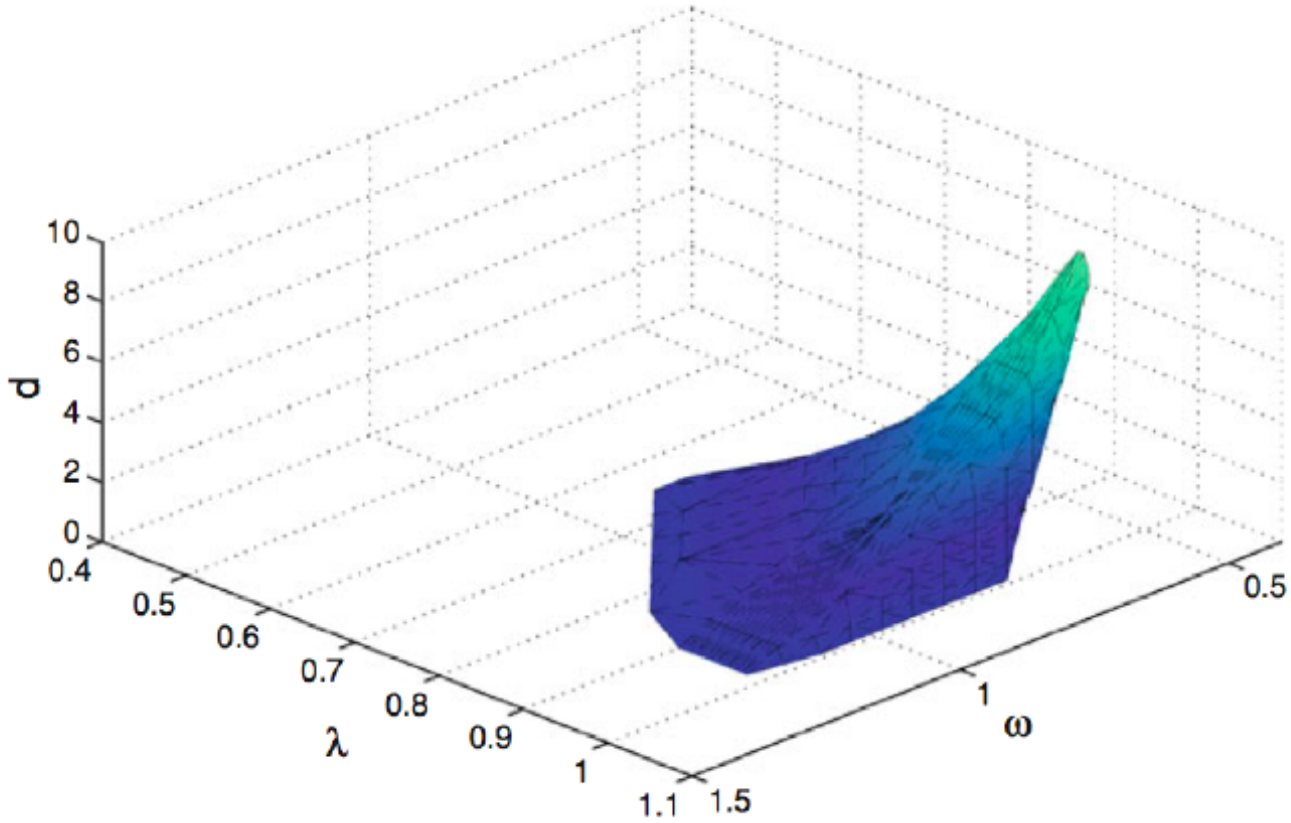
  - Investment as a function of profit share
  - Dynamics of corporates' private debt
- Multiplicity of long-term equilibria
  - A Solovian steady-state
  - A bad attractor leading to a breakdown in the long-run
  - Asymptotic local stability becomes key

Related Literature

Another view on public policy



λ: employment rate ; ω : wage bill/GDP ; d: debt/GDP
Source: Grasselli and Costa-Lima (2012)

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Modeling set-up

Key modeling highlights

Bridging climate and a global monetary economy

Modeling set-up

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Bridging climate and a global monetary economy

1. The macroeconomic core
   - Non-neutrality of money
   - Severe breakdowns do not appear as “black swan events”
   - Emissions, carbon price and abatement technology (Nordhaus, 2016)
   - Price dynamics under imperfect competition (Grasselli *et al.*, 2014)
   - Sigmoïd pattern of the global workforce (UN population scenarios, 2015)
   - Dividends payments

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Bridging climate and a global monetary economy

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   - Dividends payments

2. The DICE climate feedback loop of Nordhaus (2016) refined with
   - More convex damage functions (Weitzman, 2011)
   - Allocation of environmental damages between output and capital (Dietz *et al.*, 2015)

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Modeling set-up

Stock-flow consistency

	Households	Productive Sector		Banks	Sum
Balance Sheet					
Capital stock		pK			pK
Deposits	M^h	M^c		$-M$	
Loans		$-L_c$		L_c	
Equities	E	$-E^f$		$-E^b$	
Sum (net worth)	X^h	$X^f = 0$		$X^b = 0$	X
Transactions		current	capital		
Consumption	$-pC$	pC			
Investment		pI	$-pI$		
Acc. memo [GDP]		$[pY]$			
Wages	W	$-W$			
Capital depr.		$-(\delta + \mathbf{D}^{\mathrm{K}})pK$	$(\delta + \mathbf{D}^{\mathrm{K}})pK$		
Carbon taxes	pT_f	$-pT_f$			
Int. on loans		$-r_c L_c$		$r_c L_c$	
Bank's dividends	Π_b			$-\Pi_b$	
Productive sector's dividends	Π_d	$-\Pi_d$			
Int. on deposits	$r_M M^h$	$r_M M^c$		$-r_M M$	
Column sum (balance)	S^h	S^c	$-pI + (\delta + \mathbf{D}^{\mathrm{K}})pK$	S^b	
Flow of Funds					
Change in capital stock		$p\dot{K}$			$p\dot{K}$
Change in deposits	$\dot{M}^h$	$\dot{M}^c$		$-\dot{M}$	
Change in loans		$-\dot{L}_c$		$\dot{L}_c$	
Column sum (savings)	S^h	S^c		S^b	
Change in equities	$\dot{E}^f$	$-(S^c + p\dot{K})$			
Change in bank equity	$\dot{E}^b$			$-S^b$	
Change in net worth	$S^h + \dot{E}$	0		0	$p\dot{K} = p\dot{K}$

Modeling set-up – The macroeconomic core

Dynamics and behavioural relations

- Short term Phillips curve: $\frac{\dot{w}}{w} = \phi(\lambda)$
- Dynamic of prices (Grasselli *et al.*, 2014): $\frac{\dot{p}}{p} = \eta(m\omega - 1)$
- Investment behavior: $I = \kappa(\pi)pY$
- Dynamics of private debt: $\dot{D} = I - \Pi - \Pi_r$
- Taylor rule: $r = \max\{0, r^* + i + \phi(i - i^*)\}$
- Dynamics of capital: $\dot{K} = I - (\delta + \mathbf{D}^K)K$

Modeling set-up – The macroeconomic core

Introducing climate change and public policies

- Joint production process incorporating climate damages

$$\begin{aligned} Y^0 &= \min\{K/\nu; aL\} \\ Y &= (1 - \mathbf{D}^Y)(1 - A(p_{BS}))\, Y^0 \\ E_{ind} &= \sigma(1 - n(A))\, Y^0 \end{aligned}$$

- Public policies and aggregated profit

$$\Pi = pY - wL - rD - pT(p_C, E_{ind}) - (\delta + \mathbf{D}^K)pK,$$

- Endogenous choice of the emission reduction rate in the productive sector

$$n = \min\left\{\left(\frac{p_c}{p_{BS}}\right)^{\frac{1}{\theta-1}}; 1\right\}$$

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Modeling set-up – The climate module

Physical process overview

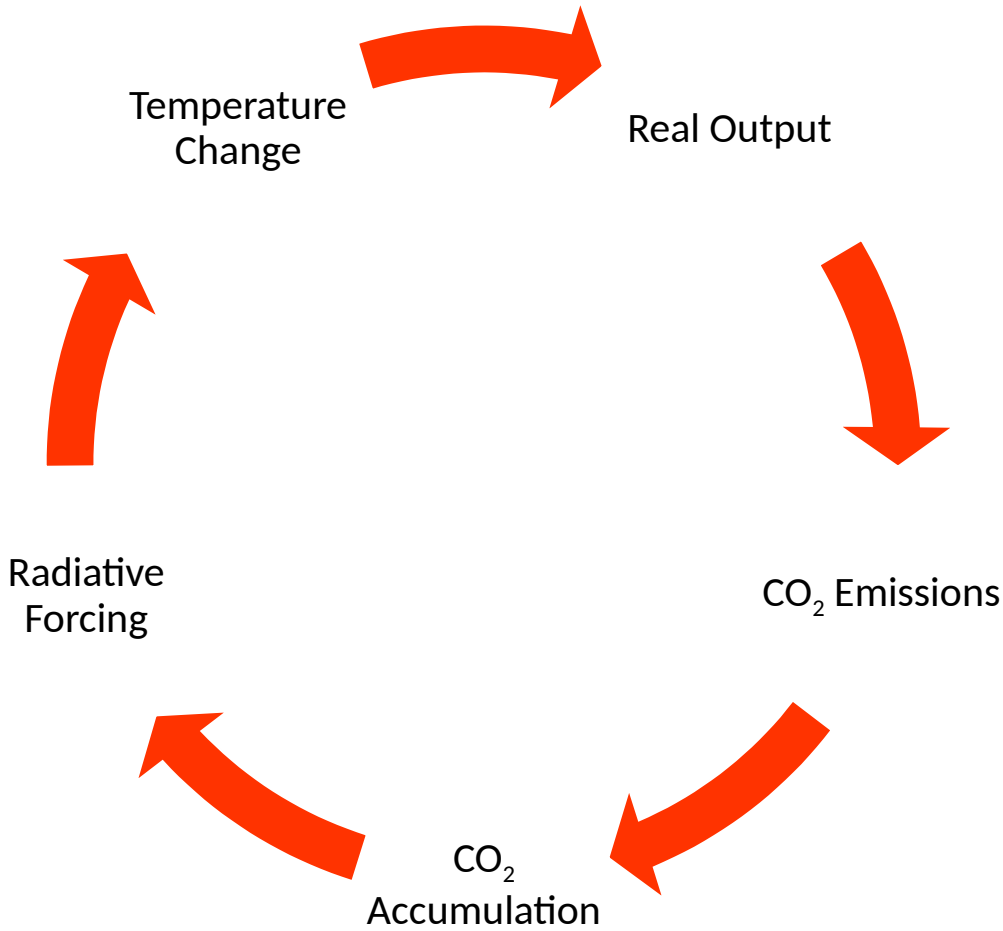

Figure: Climate-economy interactions diagram.

Modeling set-up – The climate module

Climate damage as a percentage of real GDP

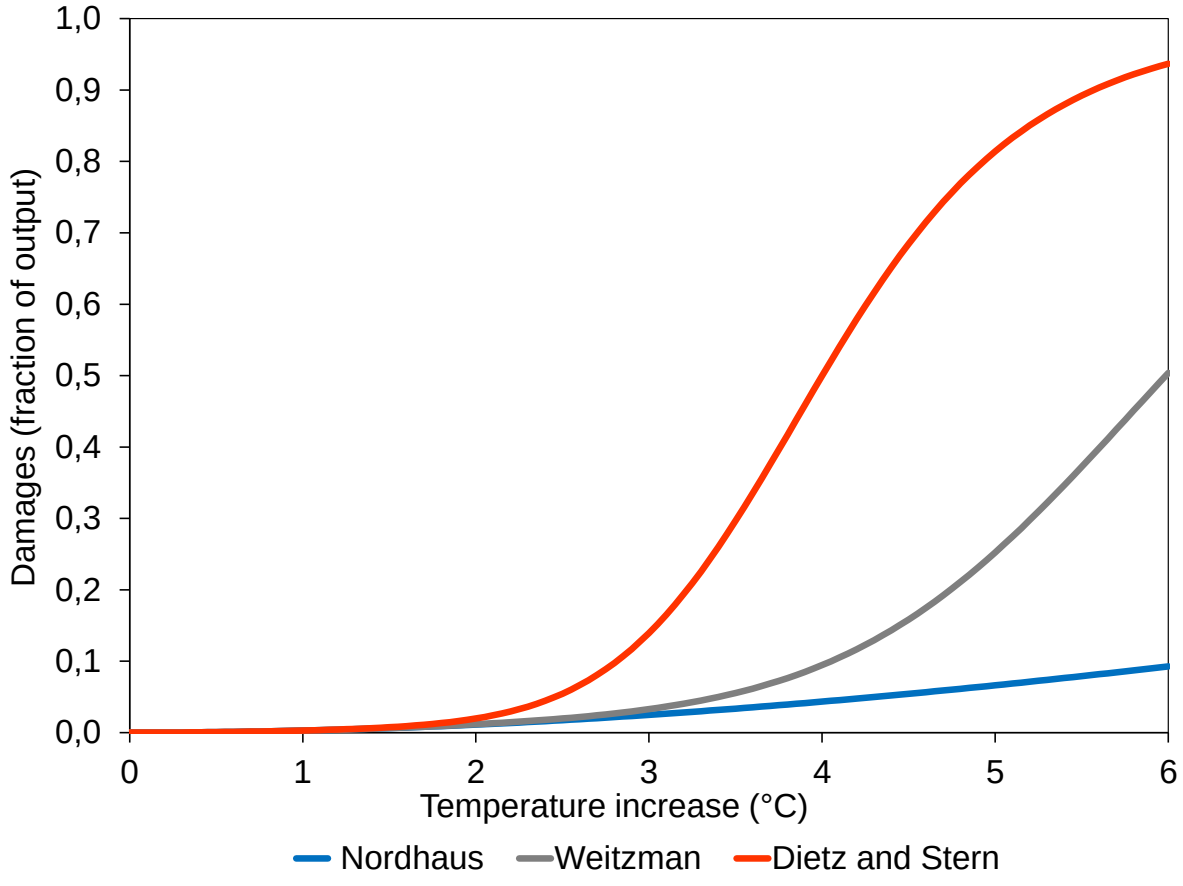

Figure: Shape of various damage functions

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Target achievements –

Which temperature targets can be reached?

- Nordhaus (2016) following a recalibration of the climate module of DICE:[1]

> *The study confirms past estimates of likely rapid climate change over the next century if there are not major climate-change policies. It suggests that it will be extremely difficult to achieve the 2° C target of international agreements even if ambitious policies are introduced in the near term. The required carbon price needed to achieve current targets has risen over time as policies have been delayed.*

- Illustration:

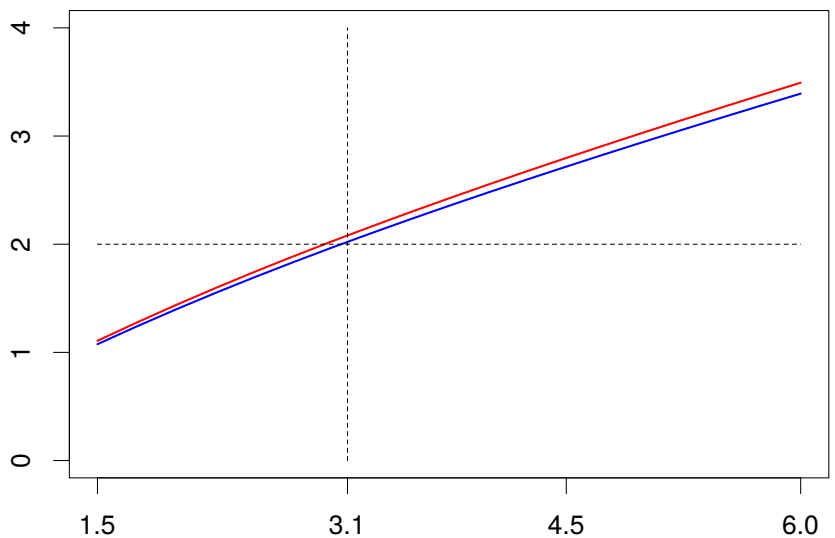

Figure: Temperature increase in 2100 as a function of the climate sensitivity whenever zero net emission is reached in 2016 (blue line) or 2018 (red line).

[1] http://cowles.yale.edu/sites/default/files/files/pub/d20/d2057.pdf

Target achievements –

Which shape for the carbon price?

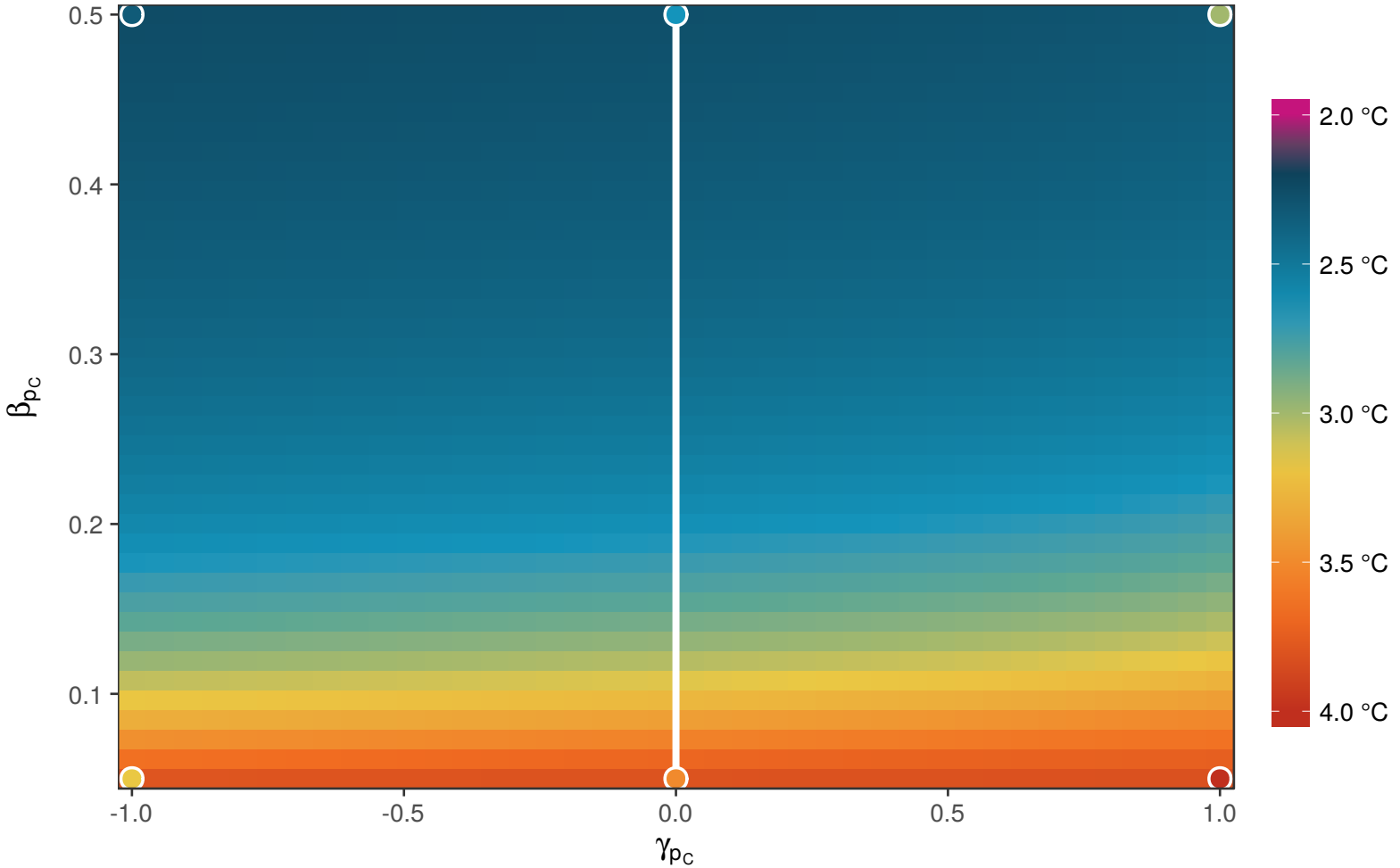

Figure: Heatmap in 2100 depending on the carbon price path in the Type 3 scenario (exponential case in the white line).

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Modeling uncertainty

Uncertainty parameters

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1. On the macroeconomic parameters
   - α, that drives the labor productivity growth, and consequently, the long-term growth.

2. On the climate module parameters
   - S, the climate sensitivity parameter.
   - C^{up}, the biosphere and upper ocean's ultimate load capacity of absorption CO_2.
   - In all our simulations, we test various damage functions between Nordhaus's and the Dietz and Stern's.

Modeling uncertainty

Shapes of the probability density functions

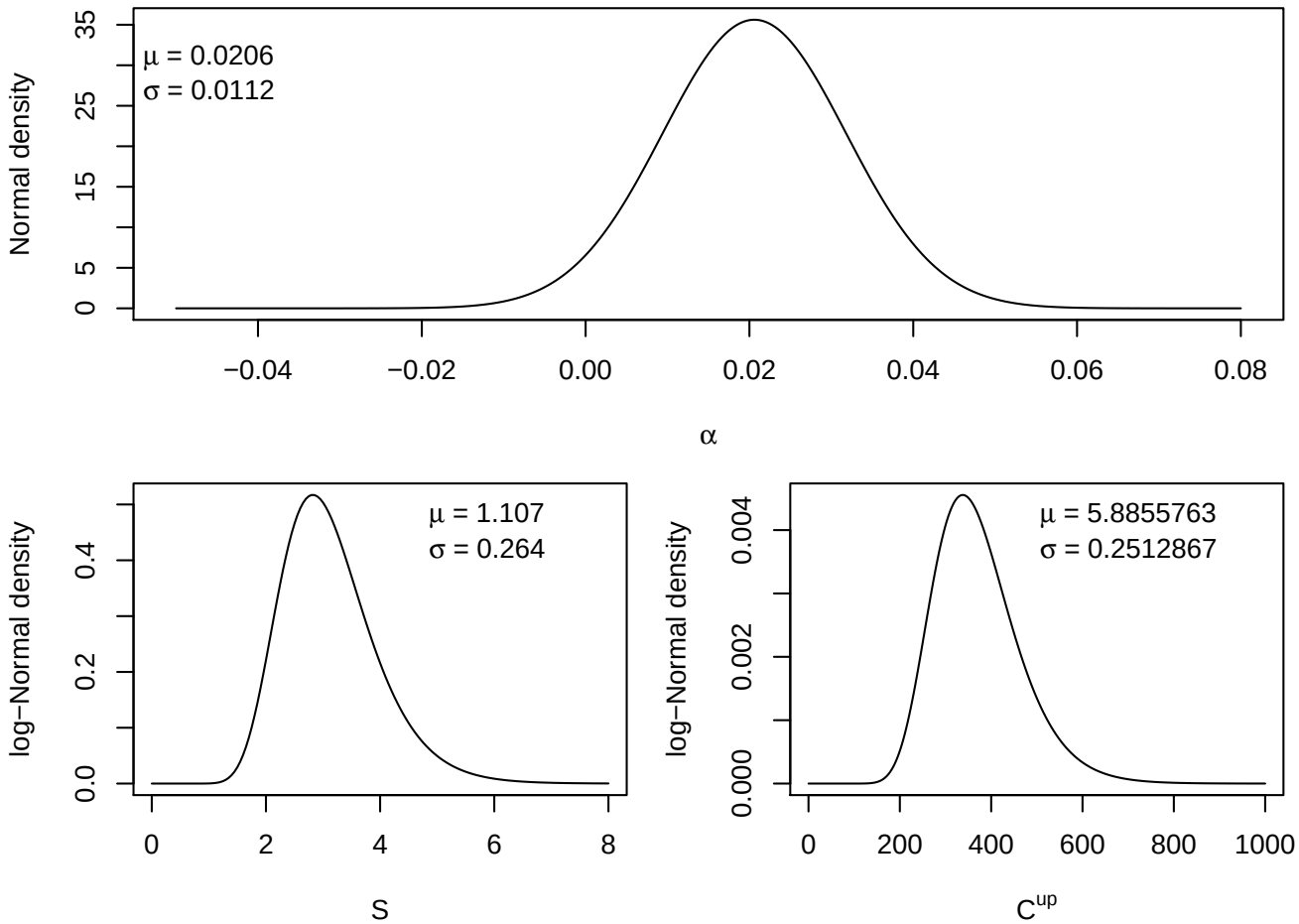

Figure: Probability density function of the parameters

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Climate prospective – Scope of analysis

Design of the prospective scenarios

- Calibration over a reconstructed world economy (approx. 85% of the "real" world) with a panel of 36 countries over the period 2000 – 2015 (dataset from World Bank, Penn University, the Bureau of Economic Analysis and the United Nations).
- Prospective analysis through 4 classes of scenarios:[2]

Scenario	**No climate**	**Baseline**	**Low policy**	**High policy**
Carbon tax (Weak p_C)	-	Yes	-	-
Carbon tax (High p_C)	-	-	Yes	Yes
Abat. subsidy (25%)	-	-	-	Yes
Damage Type	-	Stern	Stern	Stern

Table: Scenarios considered for the prospective analysis

[2]The scenarios listed in the presentation are drawn from a broader range assessed in this study.

Climate prospective – Scope of analysis

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Table: Scenarios considered for the prospective analysis

- Where the public policies are
  1. Weak p_C represents non-constraining carbon price starting at approx. 2 in 2016 and growing at a 2% rate per year
  2. High p_C represents a carbon price at 80 in 2020 and 100 in 2030
  3. A x% of abatement subsidy in equivalent to reducing abatements costs by x%

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Climate prospective – Scenario analysis

The no-climate scenario

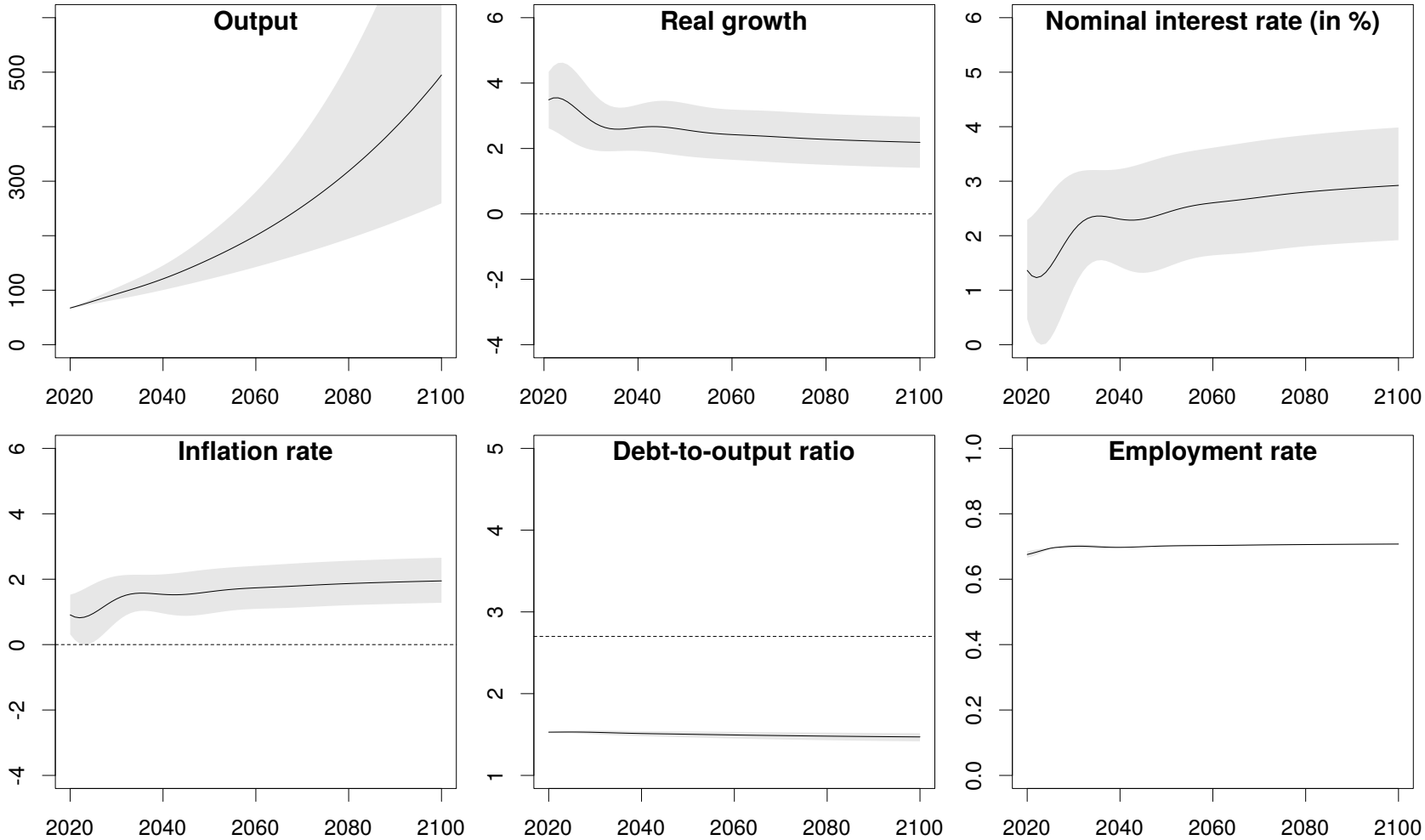

Figure: [0.25; 0.75] probability interval of the **No climate** scenario with a damage-to-capital ratio of 0% in black shades (medians in solid lines)

Climate prospective – Scenario analysis

Policy scenarios – Trajectories and narratives

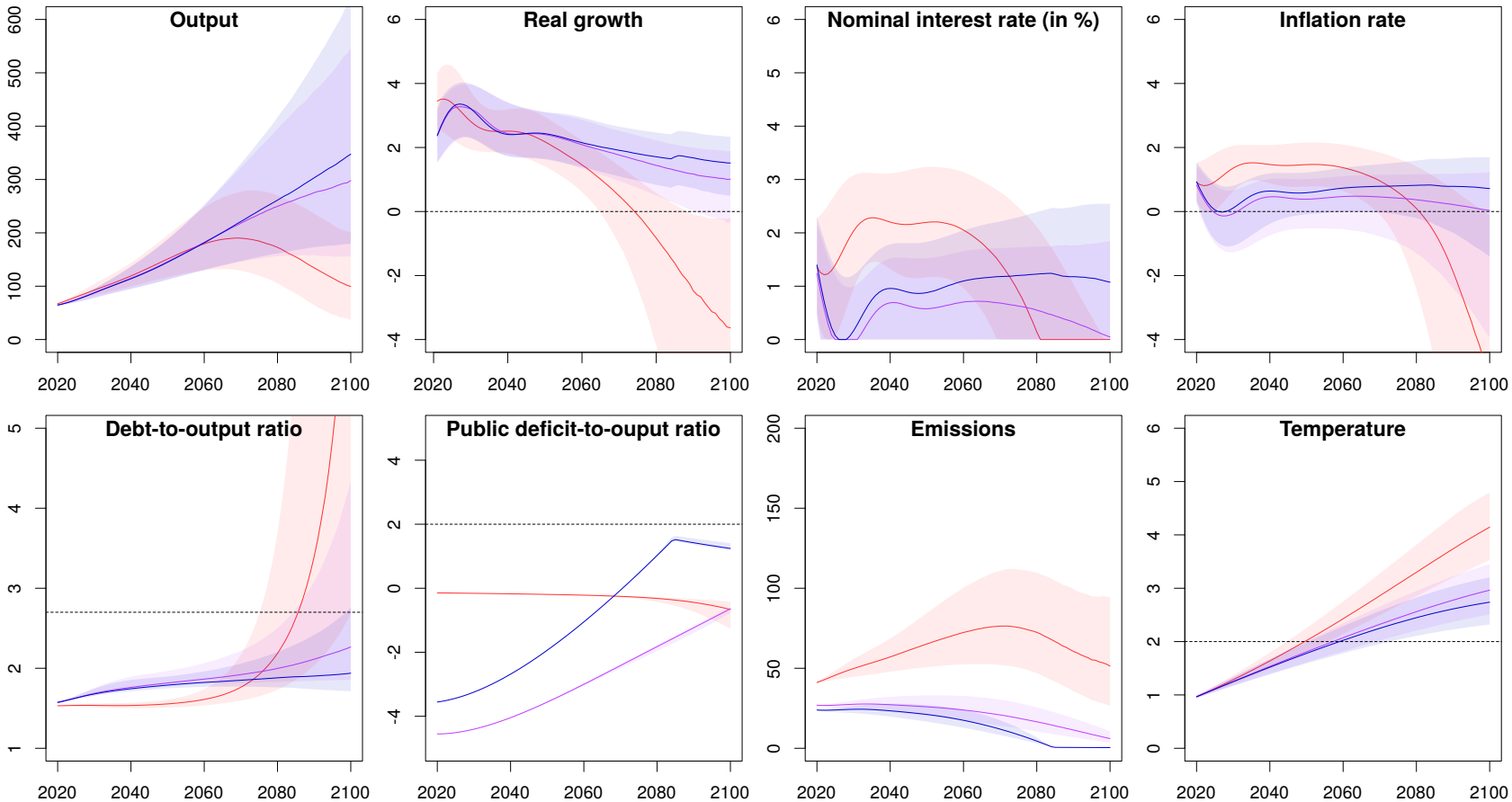

Figure: [0.25; 0.75] probability interval of the **Baseline**, **Low policy** and **High policy** scenarios with a damage-to-capital ratio of 0% in red, purple and blue shades (medians in solid lines)

Climate prospective – Scenario analysis

Policy scenarios – Staying under the temperature and debt thresholds

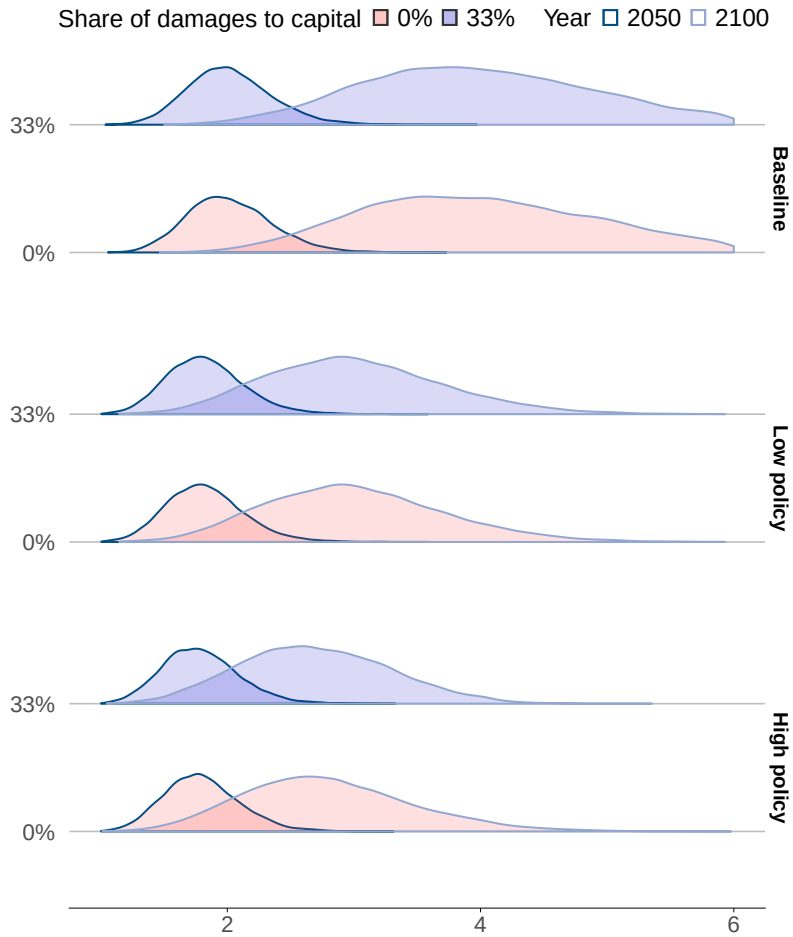

Figure: Probability density function of the temperature anomaly ratio in 2050 (dark blue) and 2100 (light blue).

Climate prospective – Scenario analysis

Policy scenarios – Basin of attraction

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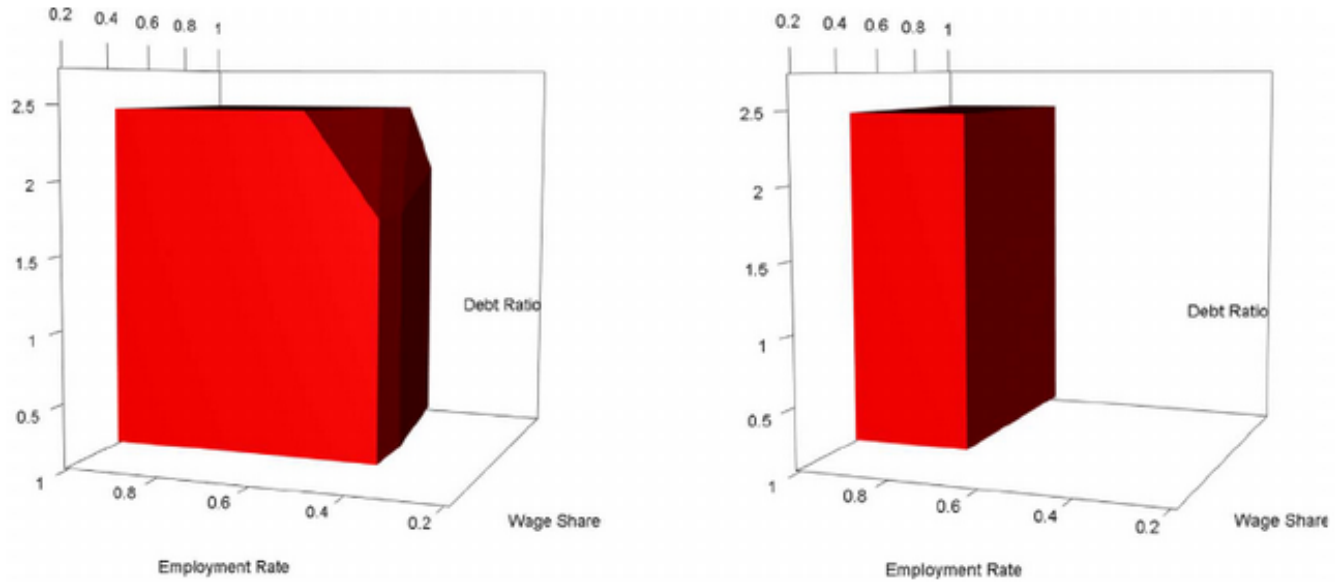

Fig. 3. "Good" basins of attraction in the *No feedback loop scenario* (left) and in the *Low damage scenario* (right).

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Main results

- We have developed of a stock-flow consistent monetary integrated assessment model calibrated at the world level

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Main results

- We have developed of a stock-flow consistent monetary integrated assessment model calibrated at the world level
- Inaction would most likely lead to a global collapse of the economic system
- Limited action (carbon price only) allows to avoid most climate damages but remains insufficient to preclude financial instability
- Wider public involvement (carbon price and subsidies) is more likely to meet both objectives, in line with the recommendations of the Stern-Stiglitz report (2017)

Concluding remarks

Some possible ways forward

- Develop more robust multivariate estimation and calibration methods (Thornton and Chambers 2014, Grasselli and Maheshwari 2018, Mc Isaac 2018).

Concluding remarks

Some possible ways forward

- Develop more robust multivariate estimation and calibration methods (Thornton and Chambers 2014, Grasselli and Maheshwari 2018, Mc Isaac 2018).

- Estimate behavioral functions by taking into consideration dataset with various frequencies–Financial vs. Economics (Thornton and Chambers 2017).

Thanks for your attention

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Shiny application of the model online