Believe me when I say green!

Heterogeneous expectations and climate policy uncertainty

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Motivation

- Urgent to mitigate climate change
  - $\rightarrow$ Decarbonisation
- Markets won't go low-carbon by themselves
  - $\rightarrow$ Policies needed to modify relative prices
  - Long-lived capital assets $\rightarrow$ Future policies matter!
- Expectations on future policies
  - Policy-makers announced objectives (e.g. net-zero by 2050)
  - Degree of trust in policy-maker's commitment

Policy-makers come and go

Tony Abbott (2014)

"..the repeal of the carbon tax means a $550 a year benefit for the average family"

"On energy, I will cancel job-killing restrictions on the production of American energy - including shale energy and clean coal - creating many millions of high-paying jobs"

Donald Trump (2016)

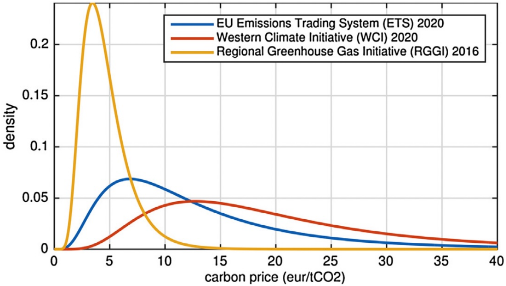
Transition-related disruptions

- Transition-related costs (unemployment, stranding, financial volatility)
- $\rightarrow$ Diversion from plans

Gilets Jaunes movement (2018)

Heterogenous climate policy sentiments

- Context of uncertainty and volatility
  - → Heterogeneity of expectations, opinions, beliefs ('sentiments')
- Evidence of heterogeneous expectations in climate policy
  - See Refinitiv Carbon Market Survey



Log normal distributions of carbon prices fitted to Refinitiv 2015 survey results. Source: Nemet et al. (2017)

Research aims

Sentiments and transition

How is the low-carbon transition affected by heterogeneity/volatility of climate-related sentiments?

Policy commitment

How do climate-related sentiments (and transition) react to policy uncertainty?

Effective climate policies

How should the policy-maker behave when announcing and implementing climate policies?

+ Methodological aim

Forward-looking expectations in non-optimisation transition models

Our contribution

- Firms allocate investment across two technologies based on expected costs
    - Low- and high-carbon capital stocks
    - Costs expectations affected by tax expectations
- Heterogeneous policy expectations
    - Two types of tax-related beliefs: sceptics and believers
    - Firms can switch belief depending on past accuracy
- Trade-offs in policy decisions
    - Policy-maker wants to stick to plan but is also afraid of transition costs
- $\rightarrow$ Dynamic feedback loop between beliefs, investments and policy decisions

Links to literature

- Rapid and orderly transition to carbon-free economy
  - Economic effects of climate policy uncertainty: van der Ploeg & Rezai (2020); Fried et al (2021)
  - Climate sentiments: Engle et al. (2020); Noailly et al. (2022); Basaglia et al. (2022)
  - Credible commitment: Helm et al. (2003); Nemet et al. (2017)
  - Transition risks: Semieniuk et al. (2021)
- Modelling framework
  - Rooted in discrete choice theory (McFadden 1973)
  - Heterogeneous expectations lit on finance & monetary policy: Brock&Hommes 1997, 1998; De Grauwe and Macchiarelli 2015; Hommes & Lustenhouwer 2019; Assenza et al. 2021)
  - Technological diffusion lit: Mercure et al 2014; Mercure 2015

Overview of results

- A low-carbon steady state exists if the tax target and the policy-maker's commitment to climate policy are sufficiently high
- Ambitious tax targets coupled with low commitment lead to the emergence of multiple steady states, including a high-carbon one
- Firms' beliefs about climate policy might delay transition, even in the presence of full policy commitment
- Delaying climate policy increases the transition risks involved to the point that the transition might fail
- Under weak commitment, polarised beliefs lead to a faster transition

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Climate policy

- At the beginning of the simulation run, the policy-maker announces a schedule of future tax targets $\bar{\tau}_t \ \forall t$
  - Long-term decarbonisation objectives (EU: net-zero by 2050)
  - $\rightarrow$ Implied optimal carbon tax (IAMs: ENGAGE scenarios)
- We assume an exponential tax announcement

$$\bar{\tau}_t = \bar{\tau}_0 (1 + \bar{g}_\tau)^t$$

where $\bar{\tau}_0$ is initial tax rate and $\bar{g}_\tau$ is the announced growth rate of τ

Firms' beliefs

- Firms have heterogeneous beliefs about credibility of policy commitment. We assume two belief categories $j = b, s$
  - Believers (b) trust policy-makers announcements more
  - Sceptics (s) trust policy-makers announcements less
- At every time $t + r$, expected tax rate is:

$$E_{j,t}(g\tau) = \epsilon_j \bar{g}_\tau$$

with $\epsilon_j \in [0, 1]$ indicating the degree of trust in the announced policy, and $\epsilon_b > \epsilon_s$

How do firms choose their beliefs?

- The share of firms adopting each belief type $n_j \in [0, 1]$ is then determined by

$$n_{j,t} = \frac{\exp(-\beta U_{j,t-1})}{\sum_j \exp(-\beta U_{j,t-1})}$$

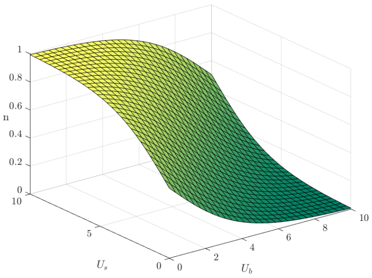
with β is the belief intensity of choice

- Firms evaluate the accuracy of their past beliefs via a fitness function U (Brock and Hommes, 1997, 1998):

$$U_{j,t} = \eta(E_{j,t-1}(\tau_t) - \tau_t)^2 + (1 - \eta)U_{j,t-1}$$

where $\eta \in [0, 1]$ is a memory (or belief inertia) parameter

The role of belief intensity choice β



(a) $\beta = 0.5$ (b) $\beta = 3$

Share of believers n_b as a function of fitness measures U_b and U_s

- $\beta \rightarrow 0$: random choice ($n_j = 0.5$)
- $\beta \rightarrow \infty$: all agents switch at the margin (n_j either 0 or 1)

Cost expectations

- Depending on their belief, firms evaluate the net present value Θ_i of expected costs of producing with technologies h and l:

$$E_{j,t}(\Theta_{i,t}) = \sum_{r=t+1}^{R} \rho^r \theta_{i,r}(1 + E_{j,t}(\tau_{i,r}))$$

where

- ρ: discount rate
- R: planning horizon
- θ i-specific production costs
- τ: tax rate on high-carbon production costs θ_h

Capital investments

- Based on their expected costs, the j-specific share of low-carbon investment $\chi_{j,t} \in [0, 1]$ is

$$\chi_{j,t} = \frac{\exp(-\gamma E_{j,t}(\Theta_{l,t}))}{\sum_i \exp(-\gamma E_{j,t}(\Theta_{i,t}))}$$

where γ is the investment intensity of choice; $E_j(\Theta_i)$ the expectation of population j on technology i production costs

Aggregate investment and capital allocation

- The low-carbon investment share for the overall economy is

$$\chi_t = n_{b,t}\chi_{b,t} + n_{s,t}\chi_{s,t}$$

- We define the low-carbon share of capital

$$\kappa_t \equiv \frac{K_{l,t}}{\sum_i K_{i,t}}$$

Transition risks and policy commitment

- Transition risk index π function of low-carbon capital share κ and planned tax rate $\bar{\tau}_t$:

$$\pi_t = 1 - \frac{1}{1 + a(1 - \kappa_t)\bar{\tau}_t}$$

where a represents vulnerability to transition risks

  - Transition disruption amplification: financial exposure; welfare system fragility; social turmoil; etc.

- Policy-maker then sets actual tax rate τ following:

$$\tau_t = c\bar{\tau}_t + (1 - c)\bar{\tau}_t(1 - \pi_t)$$

where $c \in [0, 1]$ is the policy-maker weight given to climate objectives against transition cost mitigation

Model timeline

- Time t_0:
  - Policy-maker announces a tax schedule $\bar{\tau}_{t_0+r} = \bar{\tau}_0(1+\bar{g}_\tau)^r$
  - Firms form initial beliefs
- At each following time t:
  - Firms observe accuracy of their previous expectations, confronting $E_{t-1}(\tau_t)$ with τ_t
  - Firms decide whether to switch belief (n_t is determined)
  - Firms decide how to invest ($\chi_{j,t}$ are determined $\rightarrow \kappa_t$)
  - Policy-maker observes κ_t and decides tax rate τ_t

Dynamics of the low-carbon capital share

- Simplifying assumptions for analytical tractability
  - $\bar{\tau}$ is treated as a fixed parameter
  - $\delta = 1$, $\eta = 1$
  - $\epsilon_s = 0 \rightarrow E_s(\tau_t) = \tau_0 \forall t$
  - $\epsilon_b = 1 \rightarrow E_s(\tau_t) = \bar{\tau} \forall t$
- κ evolves as follows:

$$\kappa_{t+1} = n_{b,t+1}(\chi_{b,t+1} - \chi_s) + \chi_s$$

where $n_{b,t+1}$ is a function of κ_t:

$$n_{b,t+1} = \frac{\exp\left[-\beta\left(\Pi - \bar{\tau}\right)\right]}{\exp\left[-\beta\left(\Pi - \bar{\tau}\right)\right] + \exp\left[-\beta\left(\Pi - \bar{\tau}_0\right)\right]}$$

$$\Pi = \bar{\tau}\left[c + \frac{(1-c)}{1 + a(1-\kappa_t)\bar{\tau}}\right]$$

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Steady states

- **Low-carbon steady state** ($\kappa \to 1$) exists if
  - Tax target $\bar{\tau}$ is higher than a threshold value

$$\bar{\tau} > f(\rho, \gamma, \theta_h) + \left(\frac{\theta_l - \theta_h}{\theta_h} \right)$$

Details

  - Commitment c is higher than a threshold value

$$c > \frac{1}{2} + g_l(\bar{\tau}_0, \beta, \chi_s) \left(\frac{1}{\bar{\tau}} \right) + h_l(a, \beta, \bar{\tau}_0, \chi_s) \left(\frac{1}{\bar{\tau}^2} \right)$$

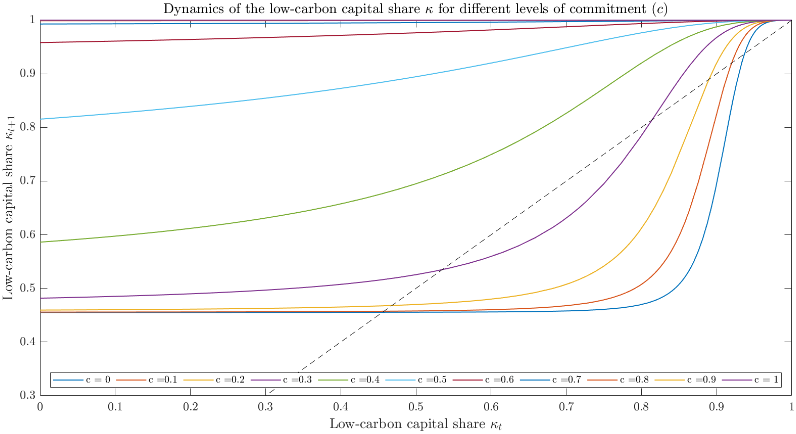
Details

- **High-carbon steady state** ($\kappa \to \chi_s$) exists if

$$c < \frac{1}{2} + g_h(\bar{\tau}_0, \beta, \chi_s) \left(\frac{1}{\bar{\tau}} \right) + h_h(a, \beta, \bar{\tau}_0, \chi_s) \left(\frac{1}{\bar{\tau}^2} \right)$$

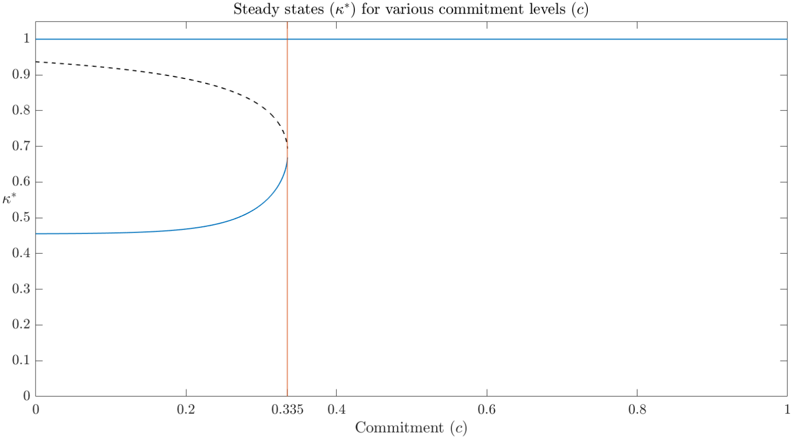
Details

Low commitment creates a high-carbon trap



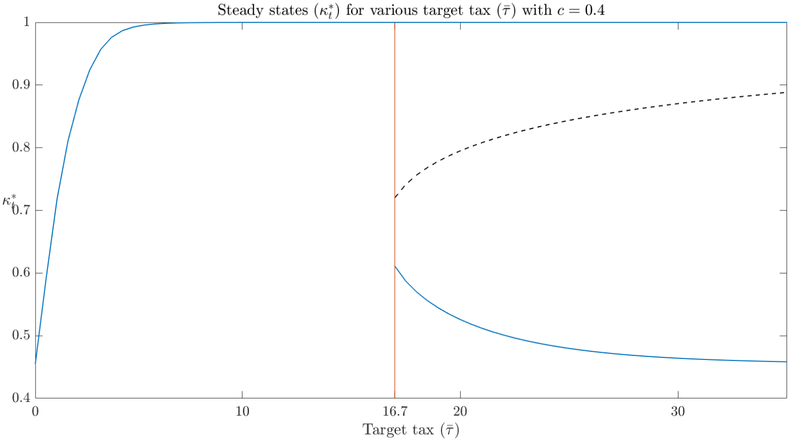
κ_{t+1} as a function of κ_t, for various values of c

Low commitment creates a high-carbon trap



Bifurcation diagram of c

When commitment is low, no ambitious announcements



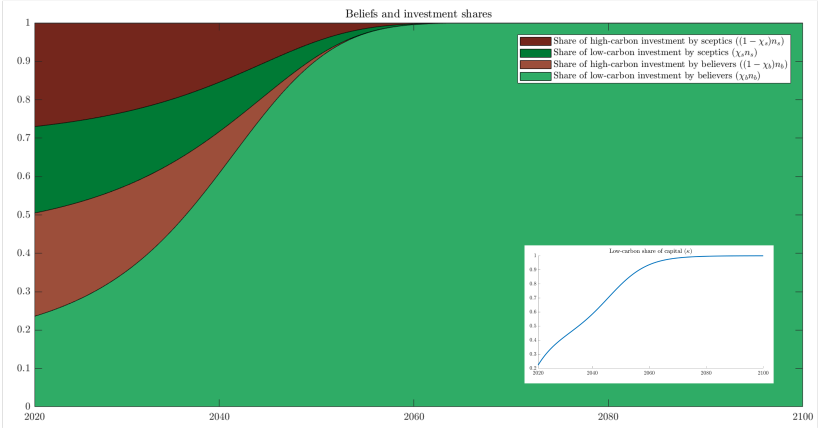
Bifurcation diagram of $\bar{\tau}$

Calibration strategy

- Technological parameters (e.g. production costs)
  - Calibrated to European power sector
- Investment and opinion behaviours
  - Esp. intensity of choice parameters β and γ
  - Literature + sensitivity analysis
- Policy parameters
  - Calibrated on IAM projections
  - Scenario analysis
- Time: 320 quarters (2020-2100)

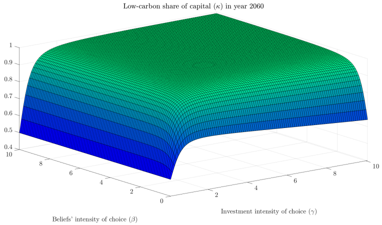
Details

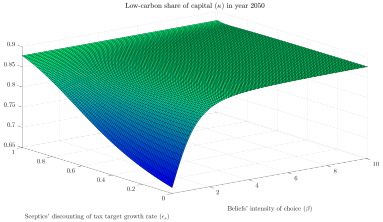
Benchmark scenario



Evolving shares of low/high-carbon investments by sceptics/believers

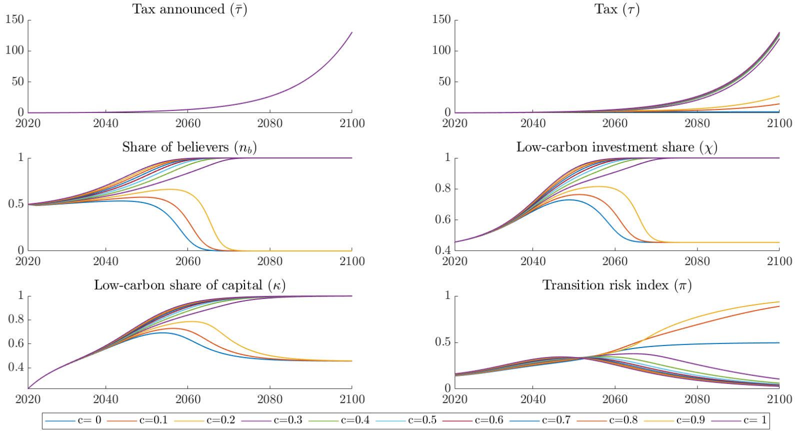
Belief/investment intensity of choice and beliefs polarisation



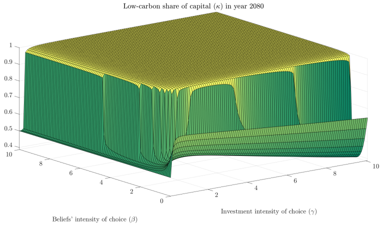


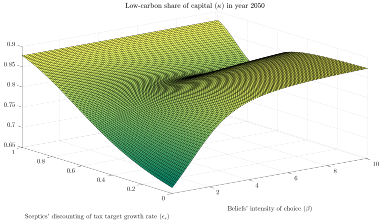
Low-carbon capital share κ as a function of β and γ (left), ϵ_s and β (right)

Transition dynamics under various commitment levels



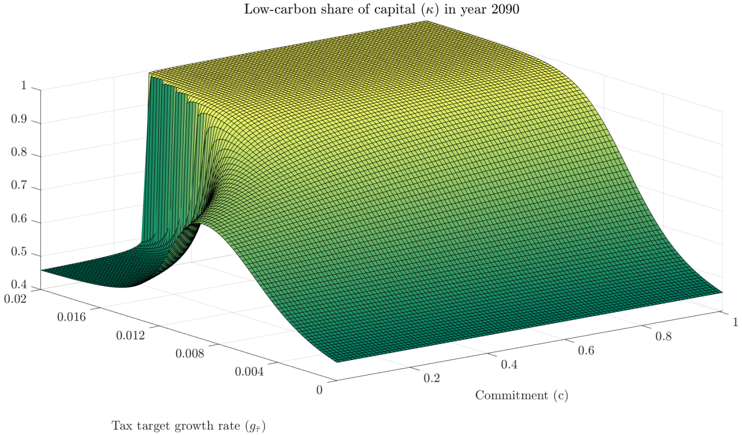
Interaction between commitment, belief/investment intensity of choice and beliefs polarisation





Low-carbon capital share κ as a function of β and γ (left), ϵ_s and β (right)

Commitment and tax announcements



Low-carbon capital share κ as a function of g_τ and c

Conclusions

- A low-carbon steady state exists if the tax target and the policy-maker's commitment to climate policy are sufficiently high
- Ambitious tax targets coupled with low commitment leads to the emergence of multiple steady states, including a high-carbon one
- Policy uncertainty and heterogeneity of beliefs might delay transition even in the absence of transition risks
- Under weak commitment, polarised beliefs lead to a faster transition
- A policy-maker willing to minimise transition risks (low commitment to climate objectives) might delay climate policy, increasing future transition risks and preventing the green transition

Thank you!

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Additional slides

First condition for $\kappa \to 1$

- The tax target is high enough:

$$\bar{\tau} > \frac{1}{A\gamma\theta_h} |\ln \epsilon_1| + \left(\frac{\theta_l - \theta_h}{\theta_h}\right),$$

where

- ϵ_1 is any sufficiently small number
- $\frac{\theta_l - \theta_h}{\theta_h}$ is the percentage difference between low- and high-carbon production costs
- $A \equiv \frac{1-\rho^{R+1}}{1-\rho}$

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Second condition for $\kappa \to 1$

Policy-maker's commitment to climate objectives is high enough:

$$c > \frac{1}{2} + C\left(\frac{1}{\bar{\tau}}\right) + D\left(\frac{1}{\bar{\tau}^2}\right),$$

where

- $C = \frac{\bar{\tau}_0\beta + |\ln(\epsilon_2)|}{2\beta} - \frac{1}{2a(\tilde{\epsilon}_l + \epsilon_2\chi_s)}$
- $D = \frac{-|\ln(\epsilon_2)|}{2a\,\beta\,(\tilde{\epsilon}_l + \epsilon_2\chi_s)} - \frac{\bar{\tau}_0}{2a(\tilde{\epsilon}_l + \epsilon_2\chi_s)}$
- $\epsilon_2, \tilde{\epsilon}_l$ are any sufficiently small numbers

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Carbon-intensive steady state

- If commitment is too low, a carbon-intensive steady state exists:
$$c < \frac{1}{2} + E\left(\frac{1}{\bar{\tau}}\right) + F\left(\frac{1}{\bar{\tau}^2}\right), \qquad (1)$$
  - $E = -\frac{\ln\left(\frac{1}{\epsilon_2}\right)}{2\,\beta} + \frac{\bar{\tau}_0}{2} + \frac{1}{2\,(\tilde{\epsilon}_h + \chi_s(1-\epsilon_2))}$
  - $F = -\frac{\ln\left(\frac{1}{\epsilon_2}\right) + \bar{\tau}_0\beta}{2\,a\,\bar{\tau}^2\,\beta\,(\tilde{\epsilon}_h + \chi_s(1-\epsilon_2))}$
  - $\tilde{\epsilon}_h$ is a sufficiently small number.
- $\Rightarrow$ for $\bar{\tau} \to \infty$, the threshold of c converges to $\frac{1}{2}$
- For lower values of $\bar{\tau}$ from bifurcation analyses we observe the existence of a trade-off between the tax target and c!

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Calibration: Production

- Exogenous macro landscape: $g_Y \approx 2\%$ per year
- European power sector (LCOE data from IEA)

Parameter	Symbol	Value
Output growth rate	g_Y	0.5%
Depreciation rate	δ	3%
Initial low-carbon capital share	κ_0	0.21
Low- to high-carbon production cost	$\frac{\theta_l}{\theta_h}$	1.33

Calibration: Beliefs and decisions

- Initial belief shares
  - Endogenously determined but in line with Refinitiv Carbon Market Survey)
- Belief intensity of choice
  - $\beta = 1$ following Hommes (2021) + sensitivity analysis
- Investment intensity of choice $\gamma = 2$
  - χ to fit initial investment shares values
  - transition as planned with full commitment

Parameter	Symbol	Value
Discount rate	ρ	0.5%
Planning horizon	R	120
Initial shares of belief types	$n_{b,0};n_{s,0}$	0.3; 0.7
Policy trust parameters	$\epsilon_b;\epsilon_b$	1; 0
Intensity of belief choice	β	1
Memory parameter	η	0.5
Intensity of investment choice	γ	2

Calibration: Policy decisions

- Current tax $\bar{\tau}_0$ calibrated on 2020 EU-ETS allowance prices
- Announced growth rate $\bar{g}_\tau$ calibrated on optimal mitigation pathways to reach 1.5-2°C
  - ENGAGE project involving 16 IAMs
- $a = 1$ to have low transition risk costs in 2020 ($\pi_0 \approx 0.15$) and have $\pi_0 \approx 0.5$ for $\bar{\tau} \approx 1.2$

Parameter	Symbol	Value
Announced initial tax rate	$\bar{\tau}_0$	0.24
Announced tax growth rate	$\bar{g}_\tau$	0.02
Transition risk index parameter	a	1
Policy-maker tax commitment	c	[0,1]

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