Assessing climate policy mixes: an ecological stock-flow consistent perspective

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25th FMM Conference, 28-30 October 2021

- The achievement of the targets of the **Paris Agreement** requires the combination of different types of climate policies.
- A successful climate policy mix needs to include **policies** such as:
  1. Green fiscal policies (e.g. carbon tax, green public investment);
  2. Green monetary and financial policies (e.g. decarbonised QE, dirty penalising factor);
  3. Environmental regulation and 'transition to sufficiency'.
- The climate-economy macroeconomic literature has focused primarily on the isolated implementation of these policies. We still lack a thorough investigation of the effects of **climate policy mixes**.

A **ecological post-Keynesian stock-flow consistent (SFC)** perspective to the analysis of climate polices pays attention to:

- The dual role of private debt
- The financial fragility effects of climate change and climate policies
- The demand-side and supply-side impacts of climate change
- The long-run implications of fiscal and monetary policies
- The material stock-flow effects of economic production
- The assessment of climate policies based on multiple indicators

Outline

Outline

The **DEFINE** (Dynamic Ecosystem-FINance-Economy) model is a global ecological stock-flow consistent model.

Ecosystem

- Matter, waste and recycling
- Energy
- Emissions and climate change
- Ecological efficiency and technology

Macroeconomy and financial system

- Output determination
- Firms
- Households
- Banks
- Government sector
- Central banks

Balance sheet matrix

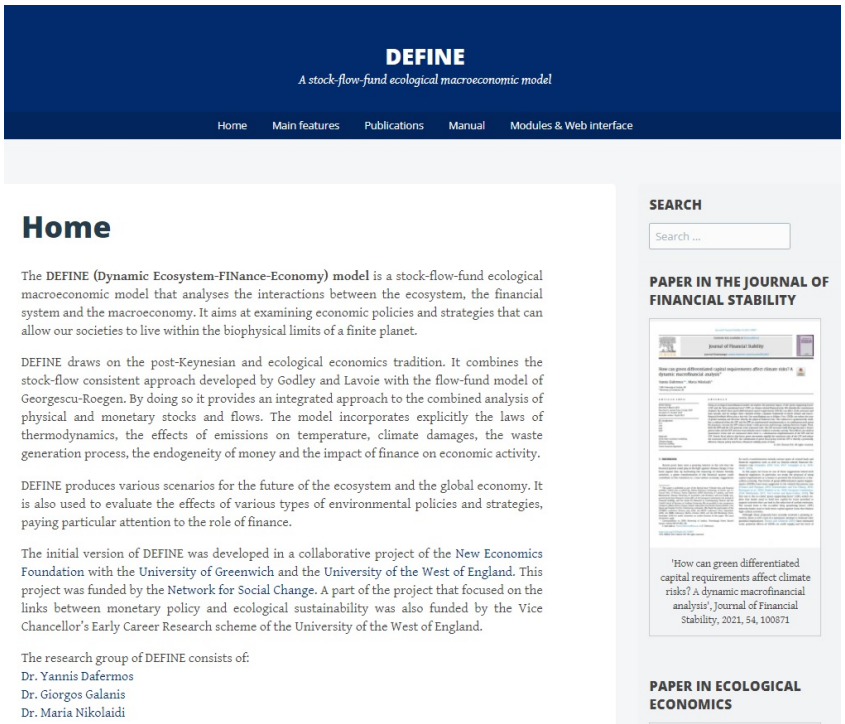
	Households	**Firms**	**Banks**	**Government sector**	**Central banks**	**Total**
Conventional capital		$+\Sigma K_{C(PRI)it}$		$+K_{C(GOV)t}$		$+K_{Ct}$
Green capital		$+\Sigma K_{G(PRI)it}$		$+K_{G(GOV)t}$		$+K_{Gt}$
Durable consumption goods	$+DC_t$					$+DC_t$
Deposits	$+D_t$		$-D_t$			0
Conventional loans		$-\Sigma L_{Cit}$	$+\Sigma L_{Cit}$			0
Green loans		$-\Sigma L_{Git}$	$+\Sigma L_{Git}$			0
Conventional bonds	$+\bar{p}_C b_{CHt}$	$-\bar{p}_C b_{Ct}$			$+\bar{p}_C b_{CCBt}$	0
Green bonds	$+\bar{p}_G b_{GHt}$	$-\bar{p}_G b_{Gt}$			$+\bar{p}_G b_{GCBt}$	0
Government securities	$+SEC_{Ht}$		$+SEC_{Bt}$	$-SEC_t$	$+SEC_{CBt}$	0
High-powered money			$+HPM_t$		$-HPM_t$	0
Advances			$-A_t$		$+A_t$	0
Total (net worth)	$+V_{Ht}$	$+V_{Ft}$	$+CAP_t$	$-SEC_t+K_{C(GOV)t}+K_{G(GOV)t}$	$+V_{CBt}$	$+K_{Ct}+K_{Gt}+DC_t$

Physical flow matrix

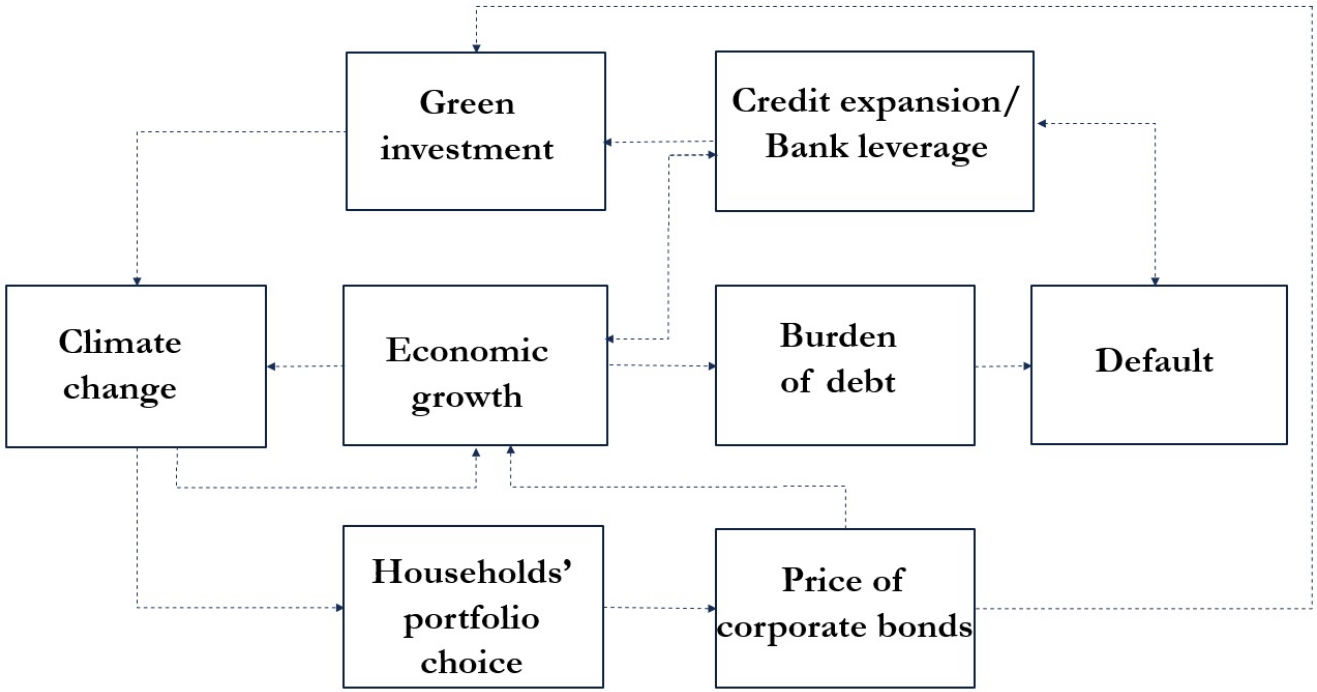
	Material balance	Energy balance
Inputs		
Extracted matter	$+M_t$	
Non-fossil energy		$+E_{NFt}$
Fossil energy	$+CEN_t$	$+E_{Ft}$
Oxygen used for fossil fuel combustion	$+O2_t$	
Outputs		
Industrial CO_2 emissions	$-EMIS_{INt}$	
Waste	$-W_t$	
Dissipated energy		$-ED_t$
Change in socio-economic stock	$-\Delta SES_t$	
Total	0	0

Material balance: $M_t+CEN_t+O2_t=EMIS_{INt}+W_t+\Delta SES_t$
Energy balance: $E_{NFt}+E_{Ft}=ED_t$

- Key **features** of the model: (a) both quantity and price rationing of credit; (b) distinction between green and dirty investment; (c) feedback effects of debt on economic activity; (d) temperature dynamics; (e) endogenous technical change; (f) material flow analysis; (g) damages affect both demand-side and supply-side factors.
- For more information see: www.define-model.org



Channels through which climate change and financial stability interact in the model



The Hot house world scenario

- Our baseline scenario is a **Hot house world** scenario that corresponds to IPCC's SSP2 and SSP3 mitigation scenarios with forcing levels of 6.0 W/m^2.
- The effects of **COVID-19** on economic growth in 2020 have been taken into account.
- We use a combination of calibration and estimation techniques. For example, we **econometrically** estimate some functions (such as investment, consumption and loans) using panel data for the global economy.
- We run the model for the period 2018-2100.

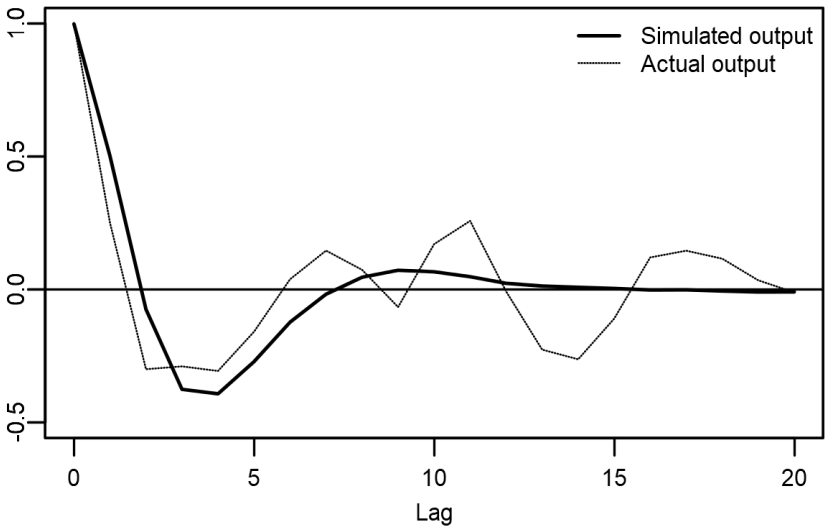
The Hot house world scenario

Key features of the Hot house world scenario

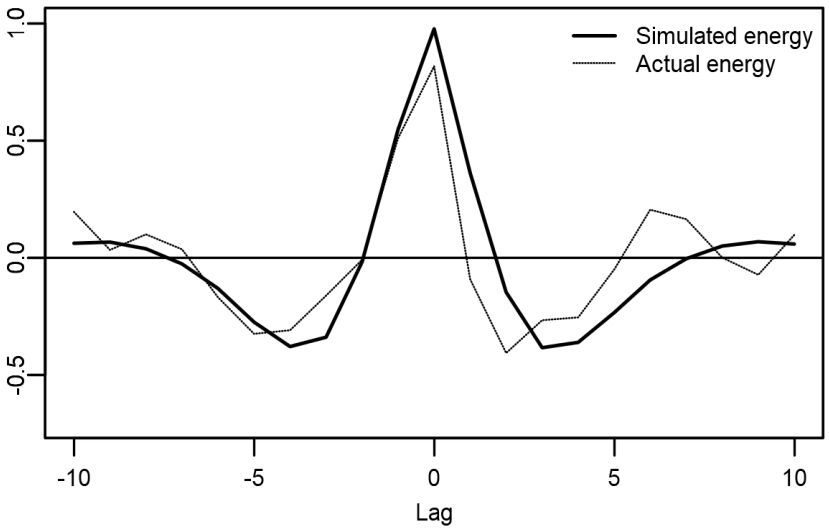
Variable	**2018 value**	**2050 value**	**Mean (2018-2050)**	**St. deviation (2018-2050)**
Economic growth (%)	3.04	2.19	2.69	1.54
Unemployment rate (%)	5.40	7.01	6.56	1.26
Population (billion people)	7.63	10.01	8.87	0.72
Share of non-fossil energy in total energy (%)	15.0	23.0	18.6	2.7
Energy intensity as a ratio of 2018 energy intensity	1.00	0.71	0.86	0.10
Material intensity as a ratio of 2018 material intensity	1.00	0.90	0.95	0.04
Carbon emissions ($GtCO_2$/year)	42.13	51.43	47.46	3.18
Carbon tax (2018 US\$/tCO_2)	1.24	36.10	20.36	11.25
Annual green energy investment (% of GDP)	0.58	0.97	0.83	0.12
Default rate on corporate loans (%)	3.70	3.94	3.75	0.24
Yield of conventional bonds (%)	5.00	4.91	4.14	0.47
Yield of green bonds (%)	5.00	4.82	4.22	0.51

The Hot house world scenario

Auto-correlation: output

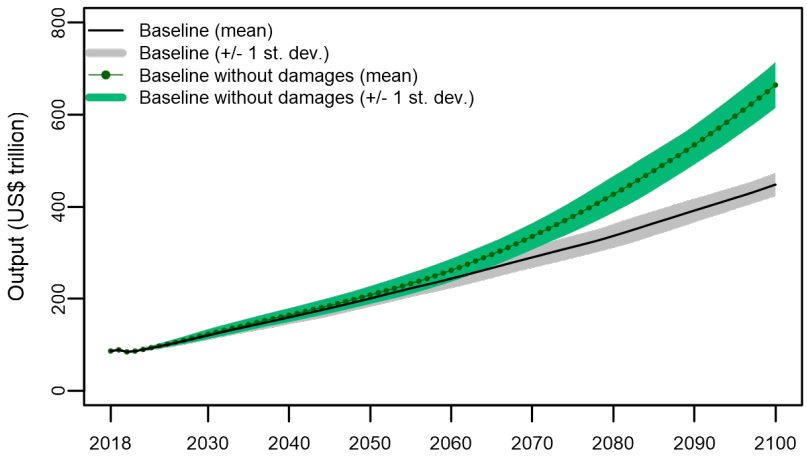


Cross-correlation: energy and output

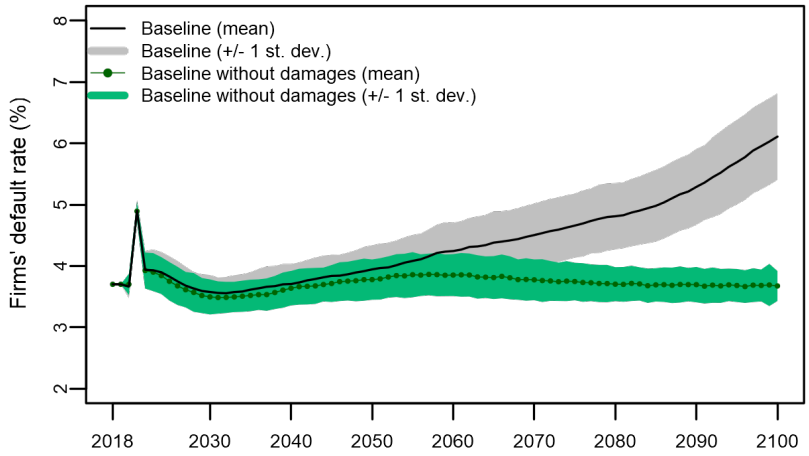


The Hot house world scenario

Output



Default rate



Outline

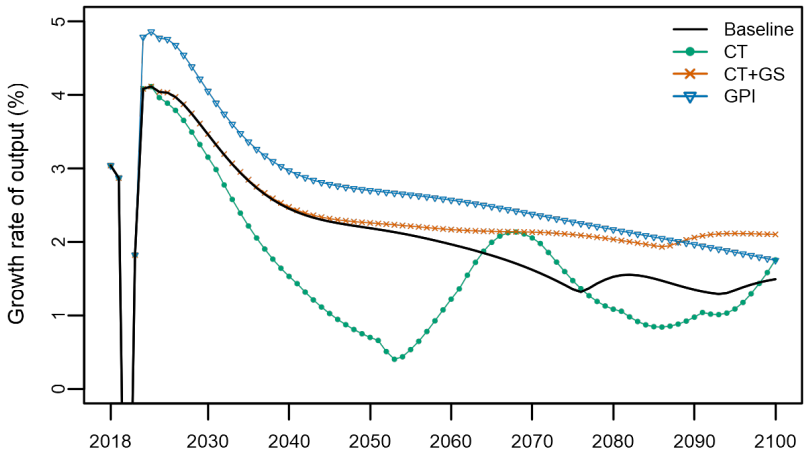
Green fiscal policies

- Three green fiscal policies are introduced in 2022:
  1. **Carbon tax**: The carbon tax increases in line with the SSP3 4.5 W/m^2 scenario.
  2. **Carbon taxes+Green public subsidies**: Carbon taxes are recycled in the form of green subsidies.
  3. **Green public investment**: The green investment of the government increases from 0.2% to 1% (as a proportion of GDP).

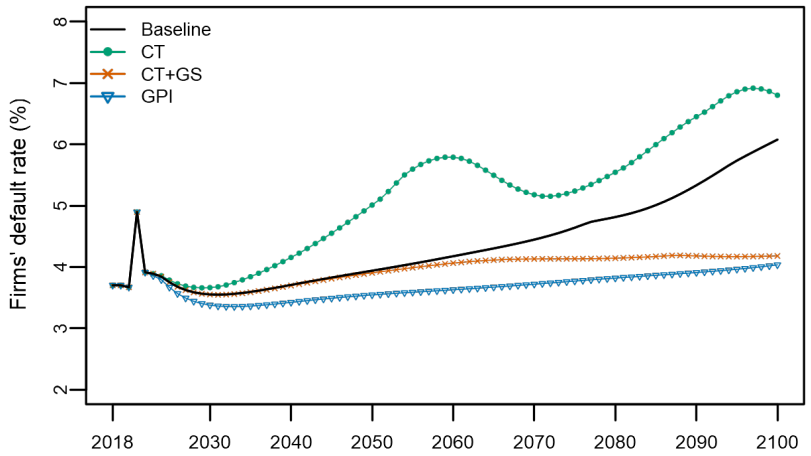
SFC models: Bovari et al. (2018), Dafermos and Nikolaidi (2019), D'Alessandro et al. (2018), Jackson and Victor (2021), Mercure et al. (2018), Monasterolo and Raberto (2018, 2019), Naqvi and Stockhammer (2018); **ABMs**: Lamperti et al. (2020); **IAMs/DSGE models**: Diluiso et al. (2021), Kalkhul et al. (2013), Wei et al. (2019)

Green fiscal policies

Growth rate of output



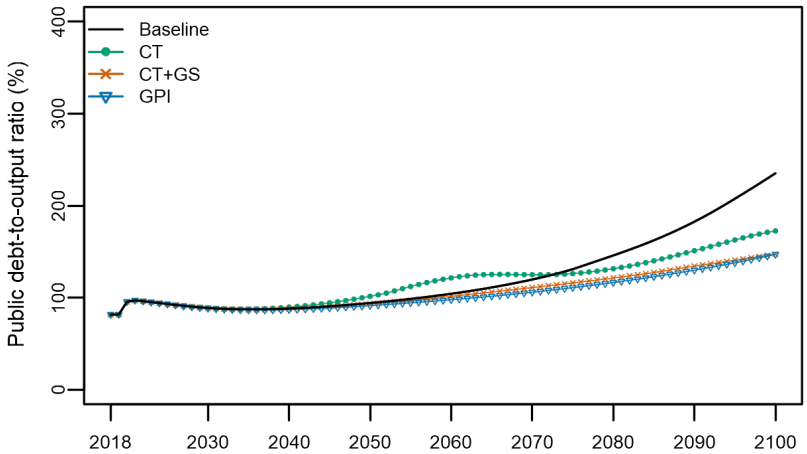
Default rate



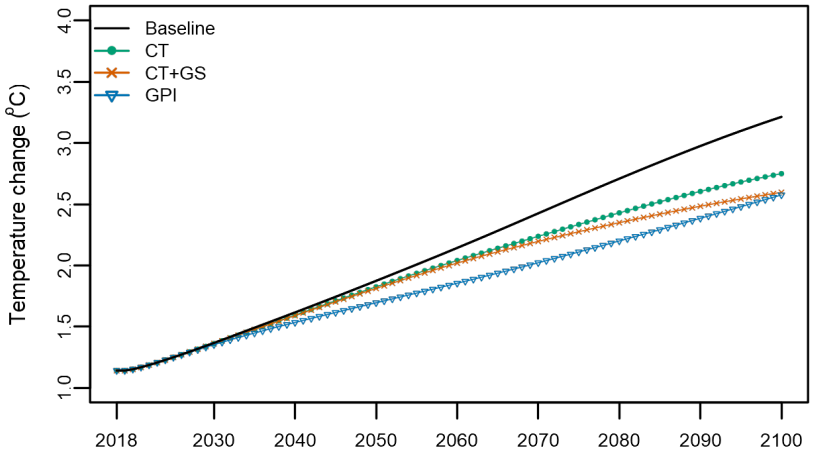
CT: Carbon Tax
CT+GS: Carbon Tax + Green Subsidy
GPI: Green Public Investment

Green fiscal policies

Public debt-to-GDP ratio



Atmospheric temperature



CT: Carbon Tax
CT+GS: Carbon Tax + Green Subsidy
GPI: Green Public Investment

Green fiscal policies

Comparative evaluation

Category	Indicators	Carbon tax		Carbon tax+Green subsidy		Green public investment	
		Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
Financial	Default rate	Increases moderately	Increases	Declines moderately	Declines	Declines moderately	Declines
	Banks' leverage ratio	Increases moderately	Increases	Declines moderately	Declines	Declines moderately	Declines
	Public indebtedness	Inreases	Declines	Declines	Declines	Declines	Declines
Macroeconomic /social	Unemployment rate	Increases moderately	Increases	Declines moderately	Declines	Declines moderately	Declines
	Wage share	Declines moderately	Declines	Increases moderately	Increases	Increases moderately	Increases
Ecological	Atmosperic temperature	Declines moderately	Declines	Declines moderately	Declines	Declines moderately	Declines
	Material use and waste	Declines moderately	Declines	Declines moderately	Declines	Declines moderately	Increases moderately

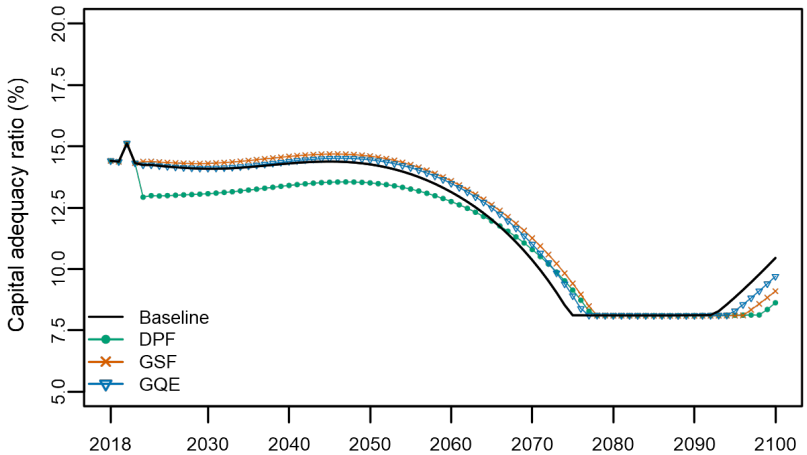
Green monetary/financial policies

- The following monetary/financial policies are introduced in 2022:
  1. **Dirty penalising factor**: the risk weight on dirty loans increases by 25 percentage points
  2. **Green supporting factor**: the risk weight on green loans declines by 25 percentage points
  3. **Green QE**: central banks around the globe purchase 40% of the outstanding **green bonds**

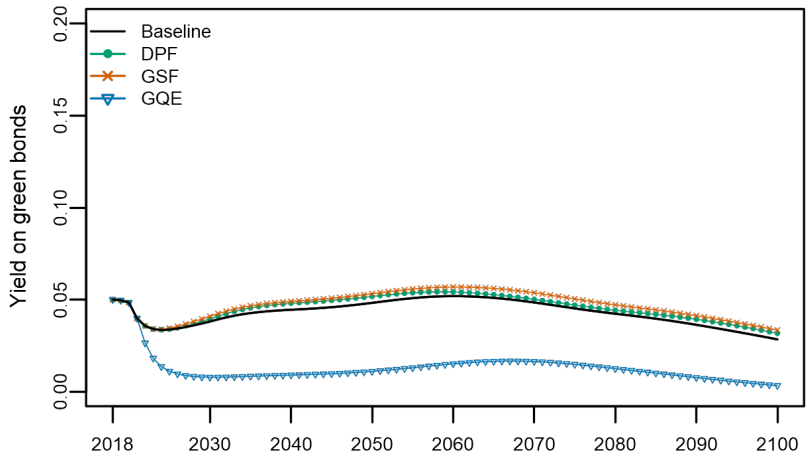
SFC models: Dafermos et al. (2018), Dafermos and Nikolaidi (2021), Dunz et al. (2021), Monasterolo and Raberto (2018); **ABMs**: Lamperti et al (2021); **IAMs/DSGE models**: Ferrari and Landi (2020), Diluiso et al. (2021)

Green monetary/financial policies

Capital adequacy ratio



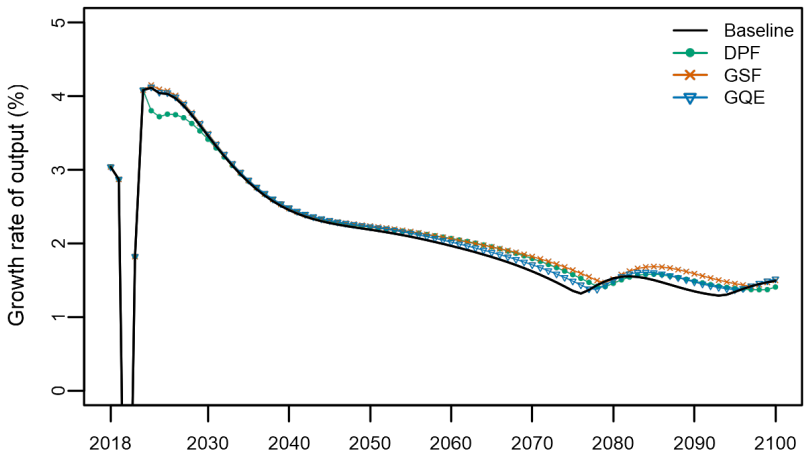
Yield on green bonds



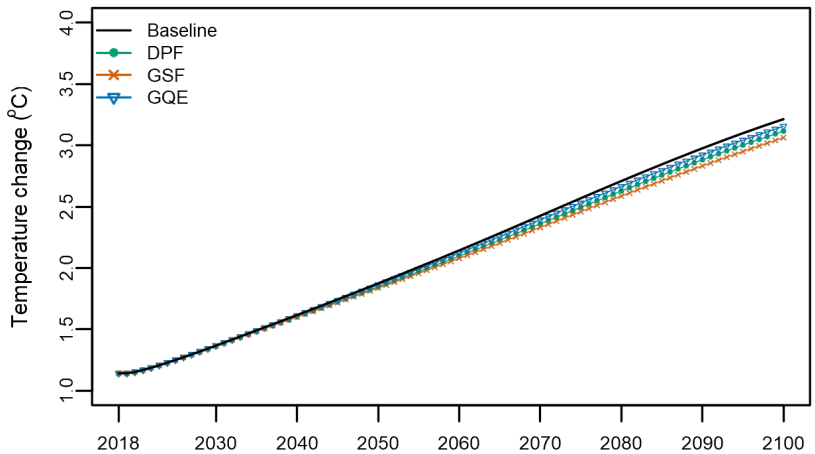
DPF: Dirty Penalising Factor
GSF: Green Supporting Factor
GQE: Green Quantitative Easing

Green monetary/financial policies

Growth rate of output



Atmospheric temperature



DPF: Dirty Penalising Factor
GSF: Green Supporting Factor
GQE: Green Quantitative Easing

Green monetary/financial policies

Comparative evaluation

Category	Indicators	Dirty penalising factor		Green supporting factor		Green quantitative easing	
		Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
Financial	Default rate	Increases moderately	Declines moderately	Declines moderately	Declines moderately	Declines moderately	Declines moderately
	Banks' leverage ratio	Declines moderately	Declines	Increases moderately	Declines moderately	Declines moderately	Declines
	Public indebtedness	Increases moderately	Declines moderately	Declines moderately	Declines moderately	Declines moderately	Declines moderately
Macroeconomic /social	Unemployment rate	Increases moderately	Declines moderately	Declines moderately	Declines moderately	Declines moderately	Declines moderately
	Wage share	Declines moderately	Increases	Increases	Increases	Increases	Increases
Ecological	Atmosperic temperature	Declines moderately	Declines moderately	Declines moderately	Declines moderately	Declines moderately	Declines moderately
	Material use and waste	Declines moderately	Declines moderately	Declines moderately	Declines moderately	Declines moderately	Declines moderately

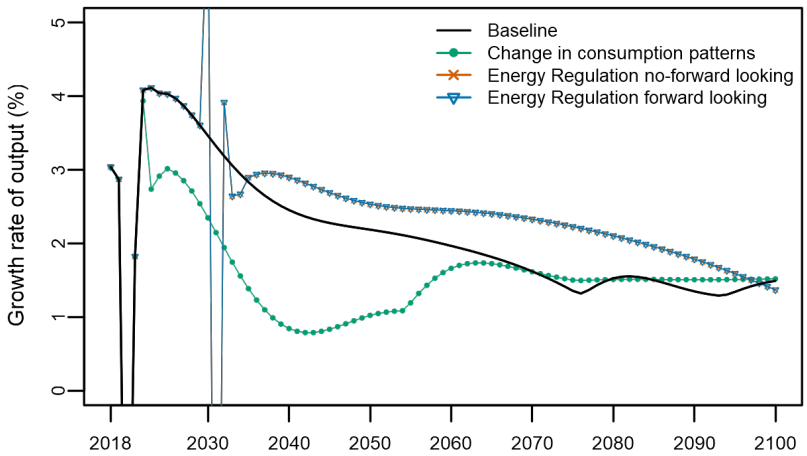
Regulation/Transition to sufficiency

- Three scenarios:
  1. **Change in consumption patterns**: Gradual decline in consumption along with a reduction in working hours after 2022.
  2. **Energy regulation – no forward-looking action**: The energy capital in the mining and utilities sector is banned in 2030; the announcement is made in 2022 but is not considered credible.
  3. **Energy regulation – forward-looking action**: Same as above, but the announcement is perceived as credible.

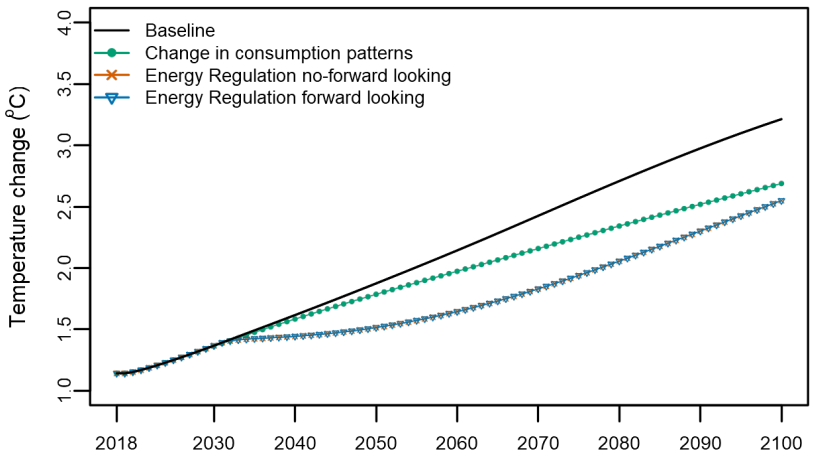
SFC models: Dafermos, Monserand and Nikolaidi (2021), D'Alsessandro et al. (2018), Nieto et al. (2020); **Other models**: Mercure et al. (2018), Pollin et al. (2014)

Regulation/Transition to sufficiency

Growth rate of output



Atmospheric temperature



Regulation/Transition to sufficiency

Comparative evaluation

Category	Indicators	Transition to sufficiency		Regulation -- no forward-looking action		Regulation -- forward-looking action	
		Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
Financial	Default rate	Inreases	Declines	Inreases moderately	Declines	Declines	Declines
	Banks' leverage ratio	Increases	Declines	Declines	Increases	Declines	Increases
	Public indebtedness	Inreases moderately	Increases	Inreases moderately	Declines	Inreases moderately	Declines
Macroeconomic /social	Unemployment rate	Increases	Declines	Declines	Declines	Declines	Declines
	Wage share	Declines	Increases	Increases	Increases	Increases	Increases
Ecological	Atmospheric temperature	Declines moderately	Declines	Declines moderately	Declines	Declines moderately	Declines
	Material use and waste	Declines	Declines	Declines	Declines	Declines	Declines

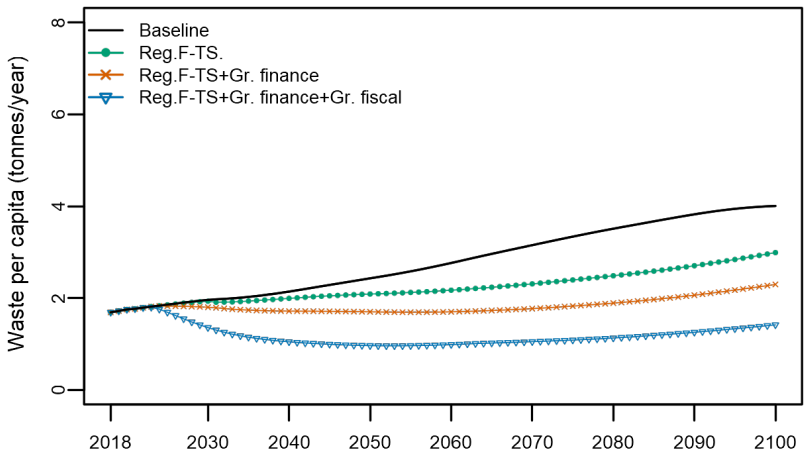
Outline

Effects of climate policy mixes

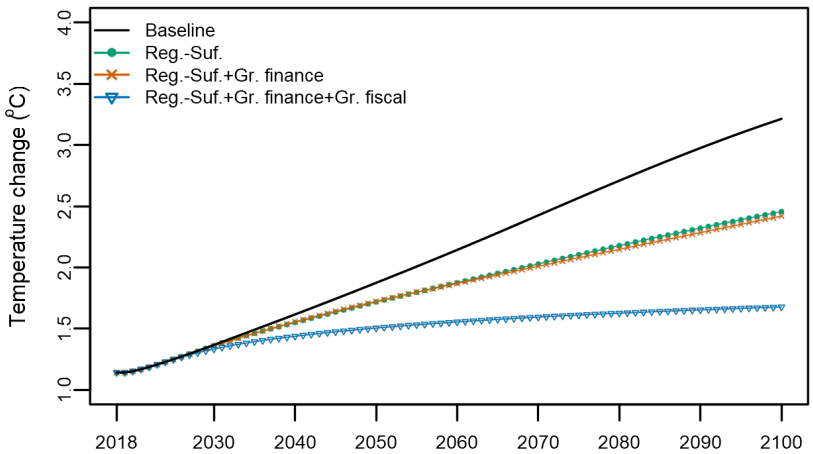
- Three types of policy mixes:
  1. Regulation/Transition to sufficiency mix
  2. Regulation/Transition to sufficiency mix+Green finance mix
  3. Regulation/Transition to sufficiency mix+Green finance mix+Green fiscal mix

Effects of climate policy mixes

Waste per capita



Atmospheric temperature



R-TS: Regulation/Transition to sufficiency mix
R-TS+Gr. finance: All of the above+dirty penalising factor+green supporting factor+green Quantitative Easing
R-TS+Gr. finance+Gr. fiscal: All of the above+carbon taxes+green subsidies+green public investment

Effects of climate policy mixes

Comparative evaluation

Category	Indicators	Regulation/Transition to sufficiency mix		Reg./TS+Green finance mix		Reg./TS+Green finance+Green fiscal mix	
		Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
Financial	Default rate	Increases moderately	Declines	Declines	Declines	Declines	Declines
	Banks' leverage ratio	Increases moderately	Increases	Increases moderately	Increases moderately	Increases moderately	Increases moderately
	Public indebtedness	Increases moderately	Increases	Increases moderately	Increases	Increases moderately	Increases
Macroeconomic /social	Unemployment rate	Increases	Declines	Increases moderately	Declines	Increases moderately	Declines
	Wage share	Decreases	Increases	Declines moderately	Increases	Decreases moderately	Increases
Ecological	Atmosperic temperature	Declines moderately	Declines	Declines moderately	Declines	Declines moderately	Declines
	Material use and waste	Declines	Declines	Declines	Declines	Declines	Declines

Outline

Future research:

- Household debt and housing market
- Forward-looking expectations
- Climate adaptation policies
- Country-specific ecological SFC models
- Interactions between fiscal policies (e.g. public investment can affect consumption patterns)
- Political economy of climate policy mixes