Macroeconomics and the environment

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Outline

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Two different traditions in analysing environmental issues from an economics point of view:

- **Environmental economics**: Environmental problems are analysed as market failures that can be tackled by putting the right price on negative environmental externalities. This tradition relies on neoclassical economics.
- **Ecological economics**: The economy is considered to be a subsystem of the ecosystem and the implications of the laws of thermodynamics are explicitly taken into account. This tradition uses insights from many disciplines and has strong links with heterodox economics.

- In environmental economics a weak conception of sustainability is adopted: natural capital (like matter and energy sources) and human-made capital are assumed to be perfectly substitutable.
- On the contrary, ecological economics adopts a strong conception of sustainability: substitutability is assumed to be limited.
- **Weak sustainability**: technological innovation is the main solution to environmental problems.
- **Strong sustainability**: technological innovation is useful, but is not enough; more fundamental changes are necessary.

- **Environmental macroeconomics** analyses macroeconomic issues by relying on the tradition of environmental economics.
- **Ecological macroeconomics** is a relatively recent field which analyses macroeconomic issues by combining ecological economics with heterodox macroeconomics.
- **Post-Keynesian macroecononomics** has played a key role in the development of ecological macroeconomics.

Outline

Approach 1: Environmental modelling without environmental variables

- Standard macroeconomic models can be extended to include a distinction between (i) carbon-intensive and green sectors, (ii) green and conventional (private and public) investment, (iii) green and conventional financial products (such as bonds and loans).
- This approach is typically used to analyse **transition risks** and the macroeconomic and financial implications of **environmental policies**.

Approach 2: Environmental modelling with environmental variables

- Standard macroeconomic models can also be extended to include (i) carbon emissions, (ii) material flows and waste and (iii) the feedback effects of the environment on the macroeconomy.
- This approach is typically used to analyse the harmful effects of economic activity on the **environment** and the implications of **physical risks**.

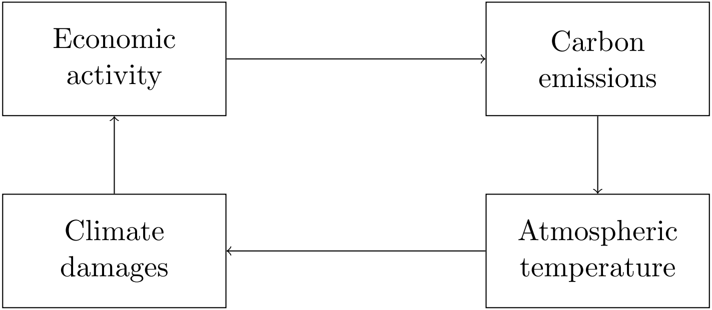
Mainstream vs ecological macroeconomic models

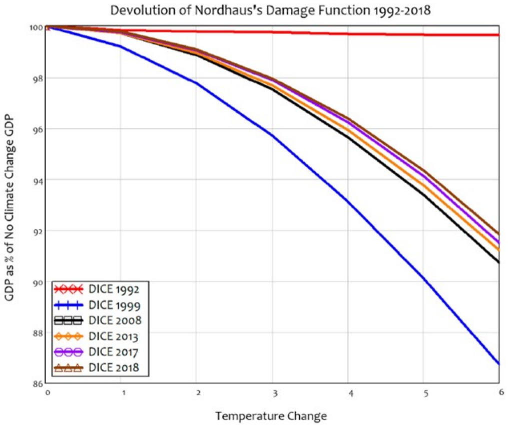
Mainsteam models	**Ecological macroeconomic models**
Supply-determined output (demand might matter only in the short run)	Demand-determined output (with supply-side constraints)
Banks are financial intermediaries (when they exist)	Money is endogenous
Utility and profit maximisation	Fundamental uncertainty/bounded rationality
Income distribution does not typically matter	Income distribution interacts with economic activity
Mitigation represents only a cost	Mitigation is both a cost and a source of income
Environmental problems as an externality/cost -benefit analysis	Economy as a subsystem of the ecosystem/systems-based analysis

Outline

- IAMs can be classified into (i) policy optimisation models and (ii) policy evaluation models.
- The Dynamic Integrated Climate Economy (DICE) model that has been developed by **William Nordhaus** is the most popular policy optimisation model.
- It combines an economy module, that relies on a standard neoclassical growth framework, with a climate module.
- The model has been extensively used for identifying **optimal carbon prices**.

- **Households** maximise their welfare taking into account their time preferences and the impact of consumption on their utility.
- **Firms** produce output by using capital and labour. They maximise their profits. Their investment is financed through household saving (saving causes investment).
- Firms can spend money on a **backstop technology**, which allows them to reduce carbon emissions and contribute to climate mitigation.
- There is an **abatement cost function** according to which the cost of emission reductions depends on the emission reduction rate.
- No banks and no involuntary unemployment.


Economic activity
Carbon emissions
Atmospheric temperature
Climate damages



Source: Keen (2020)

Key results

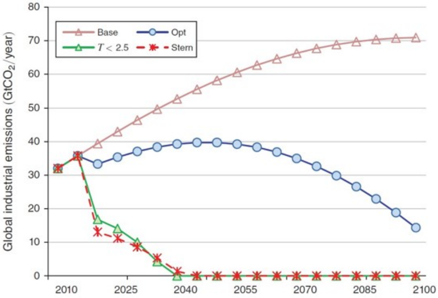


FIGURE 2. ACTUAL AND PROJECTED EMISSIONS OF CO_2 IN DIFFERENT SCENARIOS

Note: The two most ambitious scenarios require zero emissions before mid-century.

Cost-benefit analysis: the optimal carbon price balances the present value of the costs of abatement and the present value of the benefits of reduced climate damages.

Source: Nordhaus (2018)

Key results

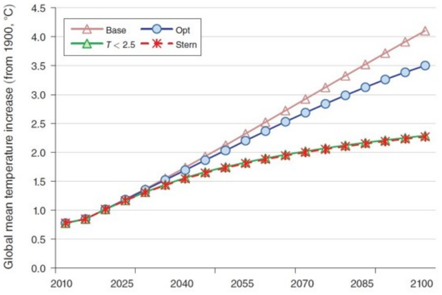


FIGURE 4. TEMPERATURE CHANGE IN DIFFERENT SCENARIOS

Note: The two most ambitious scenarios cannot limit temperature to 2.5°C in the best-guess projections.

The optimal temperature pathway leads to **3.5 degrees** at the end of the century!

Source: Nordhaus (2018)

Outline

- **Ecological stock-flow consistent (E-SFC)** models have been widely used to analyse the interactions between the economy and the ecosystem, as well as the macrofinancial implications of environmental policies.
- A distinct feature of SFC models is the emphasis that they place on the stock-flow interactions.
- E-SFC models have analysed the role of **green fiscal policy** (Bovari et al., 2018; Monasterolo and Raberto, 2018, 2019; Dafermos and Nikolaidi, 2019), **green monetary policy** (Dafermos et al., 2018), **green financial regulation** (Dafermos and Nikolaidi, 2021; Dunz et al., 2021) and **low growth** (Jackson and Victor, 2020).
- Ecological **agent-based** models (e.g. Lamperti et al., 2018) typically derive similar results as the SFC models but have the additional feature of agent-based interactions.

- The **Dynamic Ecosystem FINance-Economy (DEFINE) model** is an E-SFC model that analyses the interactions between the ecosystem, the macroeconomy and the financial system.
- **Firms** invest both in green and conventional capital and take out green and conventional loans from banks.
- **Banks** provide only a proportion of the demanded loans. Interest loan spreads are endogenous.
- **Households** receive several forms of income and invest in bonds, deposits and government securities.
- The **government sector** invests in conventional and green capital.
- **Central banks** set the base interest rate and buy conventional/green bonds issued by firms.

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)	$+V_{Ht}$	$+V_{Ft}$	$+CAP_t$	$-SEC_t+K_{C(GOV)t}+K_{G(GOV)t}$	$+V_{CBt}$	$+K_{Ct}+K_{Gt}+DC_t$

- An integrated incorporation of environmental aspects into an SFC model requires the use of additional matrices, apart from the transactions and the balance sheet ones.
- In DEFINE, the **physical flow matrix** captures the flows of energy and matter.
- The **physical stock-flow matrix** captures the interaction between physical stocks and flows.
- These matrices draw on the work of Georgescu-Roegen (1971) and rely on material flow analysis and the laws of thermodynamics.

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

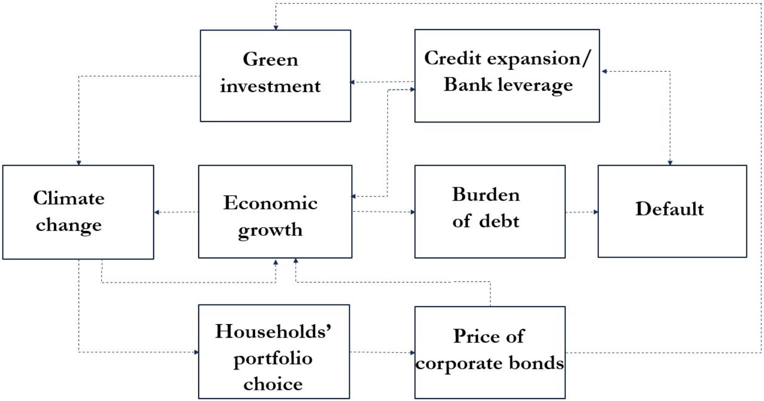
- Material balance: $M_t + CEN_t + O2_t = EMIS_{INt} + W_t + \Delta SES_t$
- Energy balance: $E_{NFt} + E_{Ft} = ED_t$

Physical stock-flow matrix

	Material reserves	Fossil energy reserves	Cumulative CO_2 emissions	Socio-economic stock	Cumulative hazardous waste
Opening stock	REV_{Mt-1}	REV_{Et-1}	$CO2_{CUMt-1}$	SES_{t-1}	HW_{CUMt-1}
Additions to stock					
Resources converted into reserves	$+CON_{Mt}$	$+CON_{Et}$			
CO_2 emissions			$+EMIS_t$		
Production of material goods				$+MY_t$	
Non-recycled hazardous waste					$+hazW_t$
Reductions of stock					
Extraction/use of matter or energy	$-M_t$	$-E_{Ft}$			
Demolished/disposed socio-economic stock				$-DEM_t$	
Closing stock	REV_{Mt}	REV_{Et}	$CO2_{CUMt}$	SES_t	HW_{CUMt}

- Material reserves: $REV_{Mt-1}+CON_{Mt}-M_t=REV_{Mt}$
- Fossil energy reserves: $REV_{Et-1}+CON_{Et}-E_{Ft}=REV_{Et}$
- Cumulative CO_2 emissions: $CO2_{CUMt-1}+EMIS_t=CO2_{CUMt}$
- Socio-economic stock: $SES_{t-1}+MY_t-DEM_t=SES_t$
- Cumualative hazardous waste: $HW_{CUMt-1}+\text{haz}W_t=HW_{CUMt}$

Key channels through which climate change and financial stability interact in DEFINE

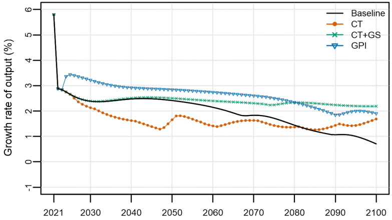


Green fiscal policies

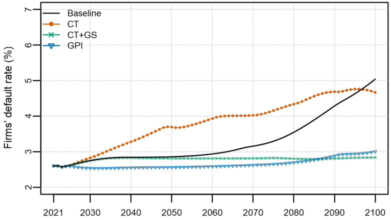
1. **Carbon Tax (CT)**: An increase in carbon taxes after 2024, without revenue recycling.
2. **Carbon Tax+Green Subsidies (CT+GS)**: Carbon taxes are recycled in the form of green subsidies that are provided to firms. The level of carbon taxes is the same as in the first scenario.
3. **Green Public Investment (GPI)**: Green public investment increases after 2024 from around 0.2% to 0.8% of GDP per year.

Green fiscal policies

Growth rate of output



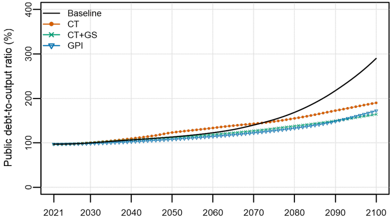
Default rate



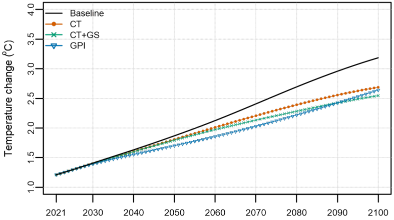
Source: Dafermos and Nikolaidi (2022)
CT: Carbon Tax
CT+GS: Carbon Tax + Green Subsidy
GPI: Green Public Investment

Green fiscal policies

Public debt-to-GDP ratio



Atmospheric temperature



Source: Dafermos and Nikolaidi (2022)
CT: Carbon Tax
CT+GS: Carbon Tax + Green Subsidy
GPI: Green Public Investment

Green fiscal policies

Type of indicator	Indicator	Carbon Tax		Carbon Tax+Green Subsidy		Green Public Investment	
		Short run	Long run	Short run	Long run	Short run	Long run
Ecological	Temperature	Mildly declines	Declines	Mildly declines	Declines	Mildly declines	Declines
	Waste per capita	Mildly declines	Declines	Mildly declines	Declines	Mildly declines	Mildly increases
Macroeconomic-social	Unemployment rate	Mildly increases	Increases	Mildly declines	Declines	Mildly declines	Declines
	Wage share	Mildly declines	Declines	Mildly increases	Increases	Mildly increases	Increases
Financial	Default rate	Increases	Mildly declines	Mildly declines	Declines	Mildly declines	Declines
	Banks' leverage ratio	Increases	Mildly declines	Mildly declines	Mildly declines	Mildly declines	Declines
	Public debt-to-output ratio	Increases	Declines	Declines	Declines	Declines	Declines

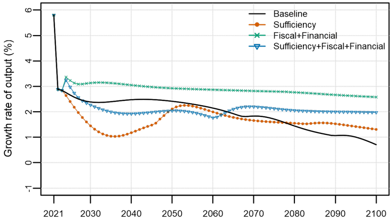
Source: Dafermos and Nikolaidi (2022)

Sufficiency policies and climate policy mixes

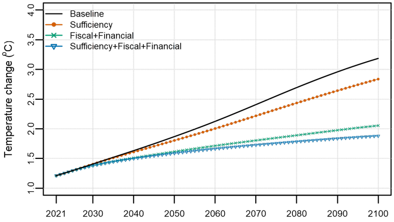
- **Sufficiency scenario**: Policies that reduce consumption are introduced gradually over the period 2024-2100 and lead to a reduction in the propensities to consume by 15% in 2100 compared to their 2024 levels (this is combined with a reduction in working hours).
- Two climate policy mixes:
  1. **Fiscal+Financial scenario**: We combine green fiscal policies and green monetary/financial policies.
  2. **Sufficiency+Fiscal+Financial scenario**: We combine the sufficiency policies with the macroeconomic and financial policies of the previous scenario.

Sufficiency policies and climate policy mixes

Growth rate of output



Atmospheric temperature



Source: Dafermos and Nikolaidi (2022)

Sufficiency policies and climate policy mixes

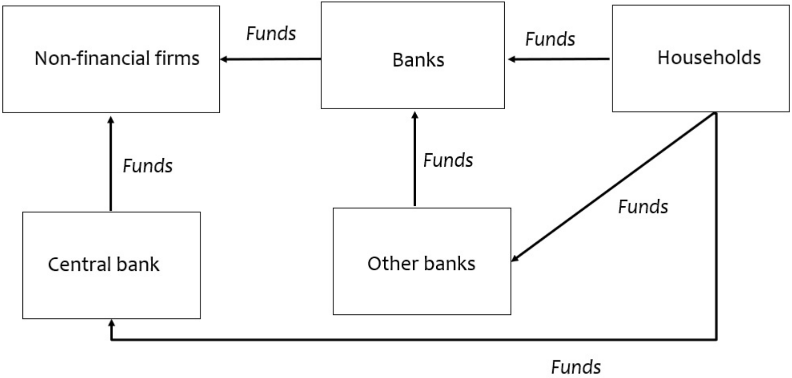
Type of indicator	Indicator	Sufficiency policies		Fiscal+Financial policies		Sufficiency +Fiscal+Financial policies	
		Short run	Long run	Short run	Long run	Short run	Long run
Ecological	Temperature	Mildly declines	Declines	Declines	Declines	Declines	Declines
	Waste per capita	Mildly declines	Declines	Declines	Declines	Declines	Declines
Macroeconomic-social	Unemployment rate	Mildly increases	Declines	Mildly declines	Declines	Mildly declines	Declines
	Wage share	Mildly declines	Increases	Mildly increases	Increases	Mildly increases	Increases
Financial	Default rate	Increases	Declines	Mildly declines	Declines	Mildly increases	Declines
	Banks' leverage ratio	Mildly increases	Increases	Mildly declines	Declines	Mildly increases	Mildly increases
	Public debt-to-output ratio	Mildly increases	Increases	Mildly declines	Declines	Mildly increases	Mildly increases

Source: Dafermos and Nikolaidi (2022)

Outline

- **Environmental Stochastic General Equilibrium (E-DSGE)** models have been used to examine environmental issues in the context of business cycle analysis.
- A distinction can be made between: (i) **DSGE models without finance** and (ii) **DSGE models with finance**.
- In DSGE models without finance, a standard DSGE model is combined with a damage function and a carbon pricing framework. *Main purpose*: identify a carbon price that makes the business cycle smoother.
- In DSGE models with finance, environmental issues are examined in the context of a **financial accelerator** framework.

Financial intermediation in Gertler and Kiyotaki (2011)

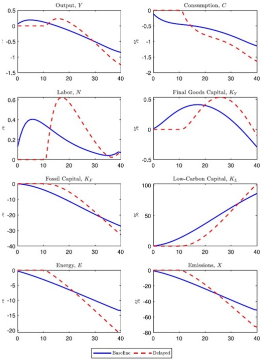


A DSGE model with fin. accelerator and carbon taxes

- Diluiso et al. (2021) have developed a model that combines the financial accelerator framework with carbon taxes and climate finance policies.
- Two types of **energy producers**: low-carbon and fossil energy producers.
- **Banks** lend funds to firms obtained from households. The model includes emissions but not environmental damages.

A DSGE model with fin. accelerator and carbon taxes

- The figure shows the effects of an increase in carbon taxes.
- Due to rational expectations, the increase in the carbon tax leads **firms to increase production** in the first years.
- In their attempt to maximise their intertemporal utility, **workers also supply more labour and save more**.
- As a result of these developments, **inflation also declines**.



Source: Diluiso et al. (2021)
Note: Baseline is the orderly scenario and Delayed is the disorderly scenario in which the mitigation policy is implemented with a 3-year delay.

A DSGE model with green QE

- In Ferrari and Nispi Landi (2020) a distinction is made between **green** and **brown** firms both of which issue bonds bought by banks and the central bank.
- Green and brown bonds are not perfect substitutes.

Banks

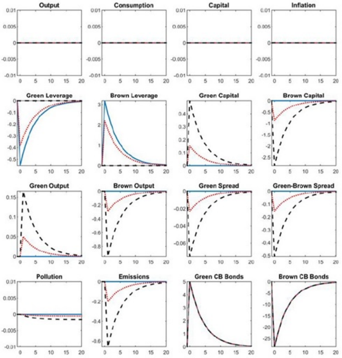
Assets	Liabilities
Green bonds b^G_{Ft}	Net worth n_t
Brown bonds b^B_{Ft}	Deposits d_t

Central Bank

Assets	Liabilities
Green bonds b^G_{Pt}	Pub. bonds d_{Pt}
Brown bonds b^B_{Pt}	

A DSGE model with green QE

- Only brown firms generate carbon emissions. The concentration of carbon affects a **damage function** which in turn affects **total factor productivity**.
- The figure shows the effects of a green QE that takes the form of an increase in green bonds bought by the central bank, accompanied by a decline in brown bonds.
- Ferrari and Nispi Landi (2022) have developed a similar model in which households face green-bond utility and brown-bond disutility.



Source: Ferrari and Nispi Landi (2020)

Outline

- Climate change has been a prominent topic in central banking in recent years.
- Several central banks around the world have run **climate stress tests**, using scenarios that rely on IAMs and New Keynesian approaches.
- The Bank of England and the ECB have recently decided to decarbonise their QE programmes. Central banks in China and Bangladesh have supported green finance for many years.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PRESS RELEASE

ECB takes further steps to incorporate climate change into its monetary policy operations

4 July 2022

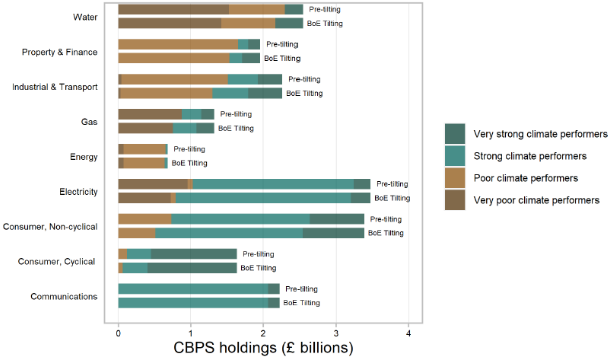
- ECB to account for climate change in its corporate bond purchases, collateral framework, disclosure requirements and risk management, in line with its climate action plan
- Measures aim to reduce financial risk related to climate change on the Eurosystem's balance sheet, encourage transparency, and support the green transition of the economy
- Measures to be regularly reviewed to check that they are fit for purpose and aligned with the objectives of the Paris Agreement and the EU's climate neutrality objectives

Question 1: Will central banks primarily rely on risk exposure approaches or will climate footprint approaches become more prominent?

- According to risk exposure approaches, central banks need to take action to reduce the exposure of the balance sheets of financial institutions to climate risks. *Key concern: How to protect finance from climate risks.*
- In climate footprint approaches, banks decarbonise monetary and financial tools based on the climate footprint of assets. *Key concern: How to protect climate from finance.*

Question 2: Will central banks drop market neutrality to intensify climate mitigation efforts?

Decomposition of Corporate Bond Purchase Scheme holdings by climate bucket and Bank of England sectors, pre-tilting and BoE Tilting



Source: Dafermos et al. (2022)

Question 3: Will central banks' climate responses have adverse side effects on the fight against climate change?

- Climate stress tests and financial regulation in the future might penalise borrowers that are exposed to physical risks.
- This might reduce their access to finance and increase their cost of borrowing, undermining climate adaptation.

Key question 4: How will climate change affect the ability of central banks to target inflation?

- Climate change can affect the transmission channels of monetary policy making interest rate manipulation an even less effective tool for controlling inflation.
- New sources of inflation: (i) **climateflation**: inflation caused by climate-related events; (ii) **fossilflation**: inflation caused by the high cost of fossil fuels due to climate policies like carbon pricing.

Outline

Areas for future research in the macroeconomics of the environment:

- Non-climate environmental problems, such as biodiversity and water stress
- Degrowth, consumption patterns, circular economy and environmental regulation
- Links between environmental policies and balance of payment constraints
- Sectoral dynamics and inequality
- Country-specific E-SFC models
- Global North-Global South interactions and global climate justice
- Climate adaptation finance