Introduction: Climate, transition and macro-financial dynamics

Climate macro & finance course 2022 - Lecture 1

Emanuele Campiglio

15 February 2021

University of Bologna

Aim of the course

- Present and discuss the research investigating the macro-financial implications of climate change and the low-carbon transition
- Two climate-related phenomena:
  - Climate change impacts (acute and gradual)
  - Structural change from high- to low-carbon economic system
- Macro-financial perspective
  - Some proper finance (e.g. asset pricing)..
  - ..but mostly macroeconomics with finance in it
  - Econ, finance, but also political economy and interdisciplinary research
  - Slightly more focus on transition side

Course structure

- First part
  - Six hours for both Frontiers and Econ
  - Frontiers: module within the D020 course
  - Two lectures of three hours
  - 15 and 22 February
- Second part
  - Nine hours for Econ
  - Frontiers very welcome to audit
  - Three lectures of three hours
  - 1, 8 and 15 of March

Course outline (1st part)

- Lecture 1: Setting the scene
  - Intro to course + introductions
  - Motivation and research background
  - The basics of climate change and decarbonisation+
  - Approaches to studying macro-financial implications of climate and transition
- Lecture 2: Conceptual and empirical approaches
  - Current conceptual understanding of climate-related impacts
  - Risk drivers; economic/financial transmission channels; macro impacts
  - Exposure to physical and financial asset stranding
  - Asset pricing and internalization of transition risks
  - Production and financial networks

Course outline (2nd part)

- Lecture 3: Climate economic modelling
  - Lecture 3. Climate economic modelling
  - The DICE model: structure and functioning
  - Integrated assessment modelling, large and small
  - Climate/transition scenarios
- Lecture 4: Macro-financial transition modelling
  - What do we need to understand
  - Overview of modelling approaches
  - Equilibrium modelling: CGE, DSGE, CAPM
  - Complexity modelling: SFC, ABM
- Lecture 5: Addressing macro-financial climate-related risks
  - Policy options: carbon pricing and beyond
  - Institutional implications of climate-related financial policies
  - Central banks and climate change

Main readings (on Teams)

- Closest paper to the course:
  - Campiglio and van der Ploeg 2022. Macroeconomic and Financial Risks of the Transition to a Low-Carbon Economy. Review of Environmental Economics and Policy (forthcoming)
- Other connected papers:
  - Bolton et al. 2020. The green swan. Central banking and financial stability in the age of climate change. Bank of International Settlements. (Link)
  - Semieniuk et al. 2021. Low-carbon transition risks for finance. WIREs Climate Change 12, e678. (Link)
  - Campiglio et al. 2018. Climate change challenges for central banks and financial regulators. Nature Climate Change 8, 462-468. (Link)
  - Baer, M., Campiglio, E., Deyris, J., 2021. It takes two to dance: Institutional dynamics and climate-related financial policies. Ecological Economics 190, 107210. Link

Students' role

- Diversity of backgrounds, knowledge and interests
  - $\rightarrow$ Some basics today
- Contributions welcome
  - Do you know a good paper on this?
- Short presentations in 2nd part of course
  - Based on relevant paper, part of the lecture
  - Papers to be discussed together
- Please be on time:
  - We start 5 mins, we end 5 mins to
- Please keep video on

Assessment

- Essay at the end of course
  - Reflections on topics/literature
  - Research-oriented
  - Options from me + topic proposals welcome
- Timeline
  - Topics by 15 March
  - Deadline: 30 March

Introductions

A bit more about me

- Associate prof. DSE since Sept 2020
- Assistant prof. at WU Vienna: 2016-2020
  - Research area on Climate Economics and Finance
- Postdoc at LSE: 2012-206
  - Grantham Research Institute + Geography Department
- PhD in Economics in Pavia: 2008-2012
  - Three essays on the sustainability of economic growth
- Researcher at New Economics Foundation: 2010-2012
  - The ‘Great Transition’ modelling project
- Bachelor and Master in International development and cooperation
  - Bocconi + Pavia

A bit more about my work

- Main research focus at the moment:
  - Dynamic links between low-carbon transitions and macro-financial dynamics
  - Policies and institutions for a rapid and smooth decarbonisation
- Main thread: SMOOTH project
  - ERC Starting Grant (2020-25)
  - University of Bologna and European Institute on Economics and the Environment
  - 'Sustainable finance for a smooth low-carbon transition'
  - Link to project website
- Personal research profiles:
  - Google Scholar
  - ResearchGate

A bit about you

- Who are you? What did you study?
- What is your PhD on?
- How much do you know about climate and technology?
- How much do you know about climate economics?
- What are you looking for in this course?

What are we studying?

Today's lecture outline

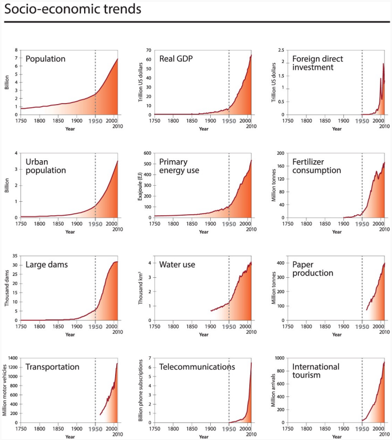
- Intro to course + introductions
- Motivation and research background
  - What the general problem is: Environmental constraints to human prosperity
  - Environmental and ecological econ: what do they study?
- Climate change and the low-carbon transition
  - Climate change: the physical basis
  - GHG emissions and the decarbonisation strategy
  - What implications do they have on macro-financial dynamics
- How do we study these issues?
  - Different methodological approaches: conceptual, empirical, modelling, political economy

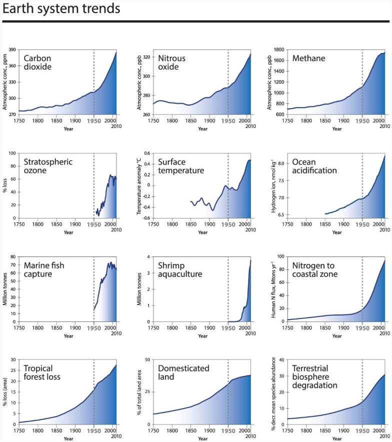
Where we are

Space rock with atmosphere (Figure source)

- We don't control any of that. And for million years: no significant human impact on planet dynamics.
- $\rightarrow$ Enter fossil fuels!

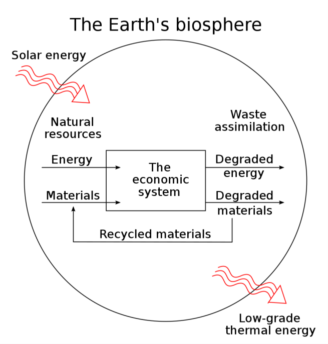
The great acceleration (Steffen et al. 2015)





What the problem is

- Environmental constraints to human prosperity
- Environmental constraints:
  - Inputs: materials, energy services, prices
  - Sinks: waste, air pollution, climate change
- Human prosperity:
  - What are the objectives of human societies?
  - Income, satisfaction of needs, human development



Source: Wikimedia; Originally in Hall et al (1986)

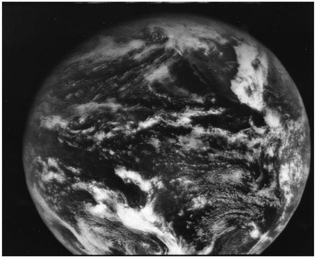
When was the problem posed? (I)

- Roots in classical political
  - T.R. Malthus (1798) ‘An Essay on the principle of population’
  - J.S. Mill (1848) on a stationary state
  - Jevons (1865) on ‘The coal question’ and the Jevons paradox
  - A.C. Pigou (1920) on externalities and the Pigouvian taxes
  - H. Hotelling (1931) ‘The Economics of Exhaustible Resources’ and the Hotelling rule
- To go deeper:
  - Sandmo 2015 on REEP: ‘The early history of environmental economics’

When was the problem posed? (II)

- From the 50s: increased environmental awareness
  - Great Smog of London in 1952 → UK Clean Air Act 1956
  - R. Carson (1962) 'The Silent Spring' on chemical pollution
  - First pictures of Earth from space → Moon landing in 1969
  - Oil crises in 1973 and 1979

Great smog of London, 1952; Source: Britannica



1966 image of Earth from ATS-1 satellite; Source: NESDIS

How was the issue addressed?

- Two large avenues of contributions
  - Environmental economics
  - Ecological economics
- Controversy born around substitutability of capital stocks
  - Capital approach to sustainable development
  - Man-made, human, natural and social capital
- Weak sustainability
  - High degree of substitatibility
  - Solow 1974 (link) : '(..) earlier generations are entitled to draw down the pool (optimally, of course!) so long as they add (optimally, of course!) to the stock of reproducible capital.'
- Strong sustainability
  - Low degree of substitutability
  - In particular, irreversibility of natural capital depletion

Environmental Economics

- Economists analysing environment-related problems:
  - P. Dasgupta, G. Heal, W. Nordhaus, J. Stiglitz, J. Hartwick, M. Weitzman..
  - Focus on markets, prices, technology, growth, substitutability, smoothness, efficiency
- Some problems:
  - Optimal resource depletion plans
  - Economic value of environmental goods and services
  - Cost-benefit analysis; discounting
  - Externalities and optimal policies
- Main academic community:
  - AERE (US); EAERE (Europe)
  - EAERE2022 organised by UniBo! (Link)
- To go deeper
  - Pearce 2002 on AREE: 'An Intellectual History of Environmental Economics'

Ecological economics

- Economists, but also social and environmental scientists
  - Multi- and inter-disciplinary approach
  - Focus on finiteness, limits, scale, stationarity, irreversibility
- Relevant contributions:
  - K. Boulding (1966) and 'The coming spaceship Earth'
  - N. Georgescu-Roegen (1971) 'The entropy law and the economic process'
  - Meadows et al. (1972) 'The Limits to Growth'
  - H. Daly (1977) 'Steady-state economics'
- Main academic community:
  - ISEE (intl.), ESEE (Europe)
- To go deeper
  - I. Ropke 2004-2005 on EcolEcon: 'The early history of modern ecological economics'; 'Trends in the development of ecological economics from the late 1980s to the early 2000s'

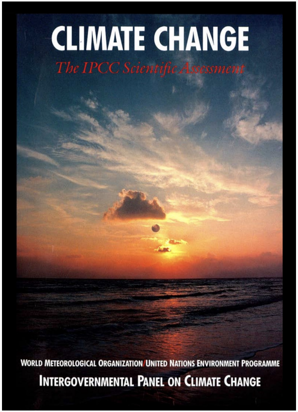
80s: Shift of focus from inputs..

- Resource scarcity less biting
  - Technological innovations
  - Exploration: large expansion of reserves
  - Energy-saving technologies, mass mobility
- Oil price fluctuations still relevant
- Geopolitical implications still relevant
- Main material constraints now:
  - Rare metals for electronics
  - Water

.. to sinks

- The Ozone layer scare
    - Montreal Protocol (1987)
- Environmental concerns
    - Oil spill and disasters
    - Loss of biodiversity
- Climate change
    - 1990: first IPCC report
    - $\rightarrow$ Main focus of this course

Exxon Valdez spill (1989) Source: NOAA

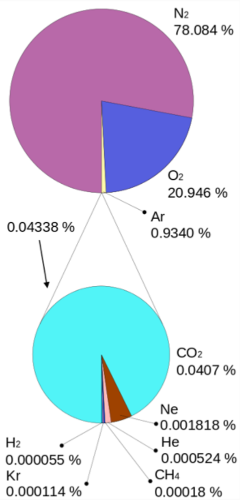


Source: IPCC 1990

Climate change

Atmospheric composition

- Mostly nitrogen (N_2), oxigen (O_2), argon (Ar) + 'trace gases' + water vapour
- Some trace gases and water vapour are 'greenhouse gases' (GHG)
    - Able to absorb and emit infrared radiation
    - Responsible for the Earth's greenhouse effect (without them average temperature 30°C lower..)



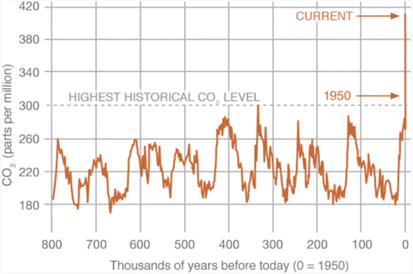
Composition of Earth's atmosphere by volume (dry air). Source: Wikimedia

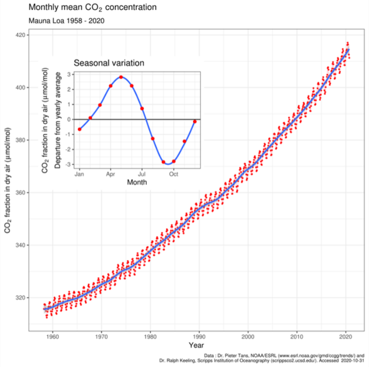
Human activity can change atmospheric composition

- Human production/consumption activities produce greenhouse gases (GWP: global warming potential)
    - Carbon dioxide (CO_2); GWP=1
    - Methane (CH_4); GWP=28
    - Nitrous oxide (N_2O); GWP=265
    - Fluorinated gases (SF_6, HFCs, PFCs); GWP up to 23500
- CO_2e ('CO_2 equivalent'): GHGs weighted by their GWP
    - E.g. 1 ton of CH_4 = 28 tons of CO_2e
- CO_2e is 3.67 heavier than carbon (C)
    - I.e. 1 tC corresponds to 3.67 tCO_2

CO_2 concentration

- February 2022 concentration: 418ppm (Source: NASA)





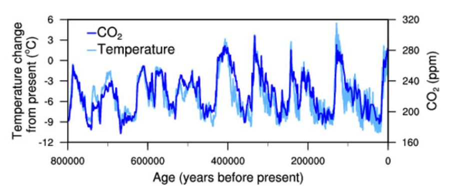
Sources: NASA (left); Wikimedia (right)

Climate impacts

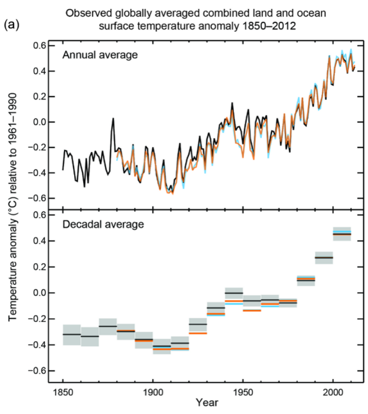
- Acute hazards: point events triggered/exacerbated by climate
  - Extreme weather events (hurricanes, heat waves)
  - Floods, wildfires
- Chronic hazards: progressive shifts in climate patterns
  - Increase in temperatures
  - Rise of sea levels
  - Changes in precipitation and humidity patterns
  - Biodiversity loss (e.g. due to ocean acidification)
- Impacts on human societies
  - Changes in agricultural productivity (crop yields)
  - Availability of water
  - Effects on human health and labour productivity
  - Human security (climate-driven conflicts and displacement)

Temperature rise

- CO_2 concentration associated with higher temperatures (and viceversa)
- Other temperature drivers exist (e.g. Milankovitch cycles)



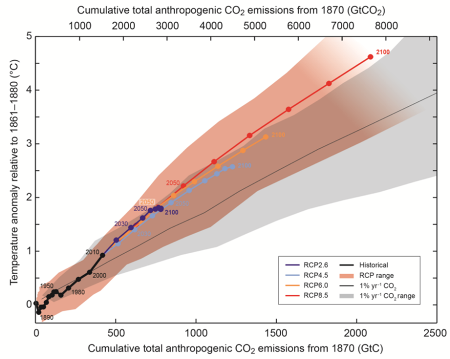
Source: NOOA



Source: IPCC (2013)

Temperature and cumulative emissions

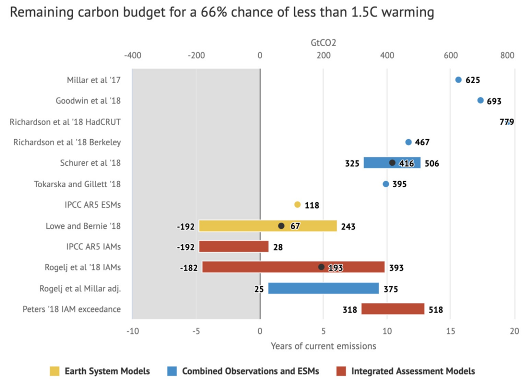
- Temperature change is a roughly linear function of cumulative CO_2 emissions
- Transient Climate Response to Cumulative Emissions (TCRE) is independent of time and concentration
- Matthews et al. (2018): TCRE in the 0.8-2.4°C range per trillion tons of carbon



Source: IPCC (2013)

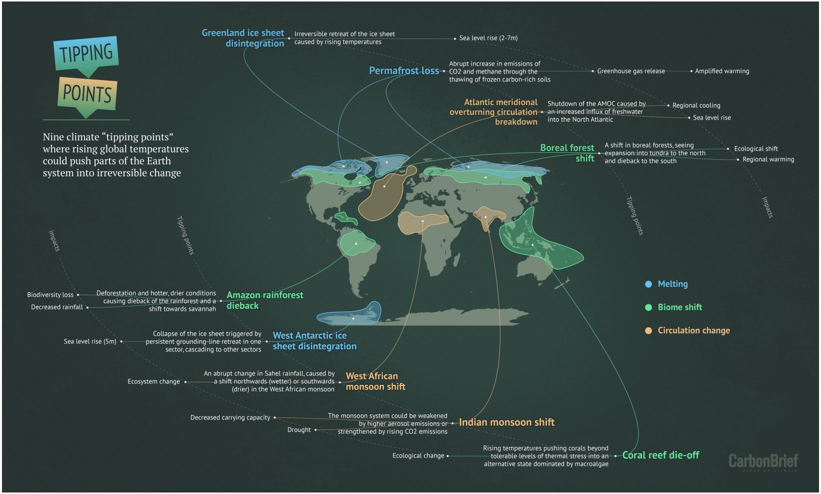
Temperature targets → Cumulative emission limits

- 'Carbon budget' concept
  - Allen et al. (2009), Meinshausen et al. (2009)
  - Roughly linear relationship (Matthews et al, 2009)
  - Large uncertainties on values (see Rogelj et al, 2019)



Source: Carbon Brief (2018)

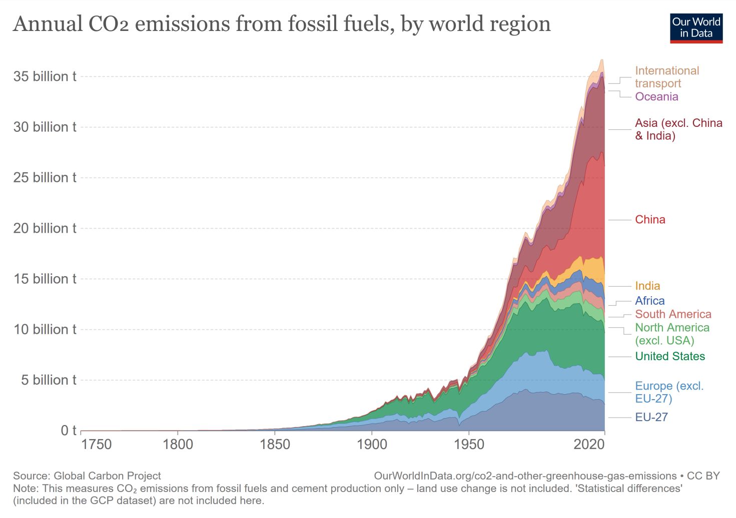
Tipping points



Source: Carbon Brief (2020)

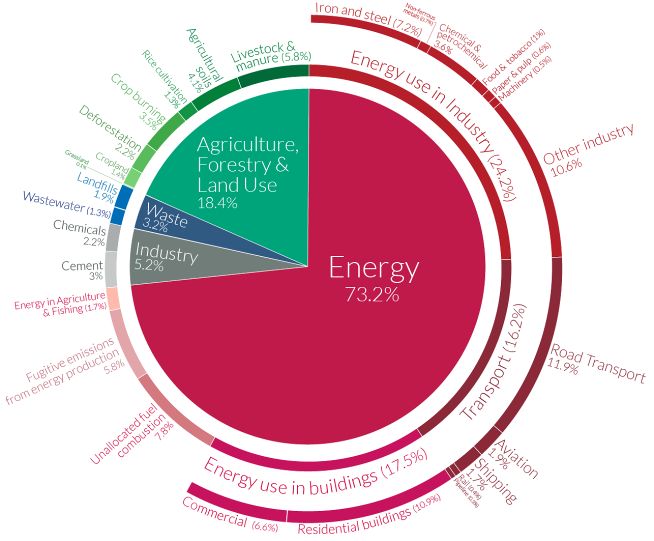
Decarbonisation

How have emissions changed in the past?



CO_2 emissions from fossils and cement. Source: Our World in Data

Where do emissions come from now?



Global GHG emissions by sector in 2016. Source: Our World in Data

How should emissions change in the future?

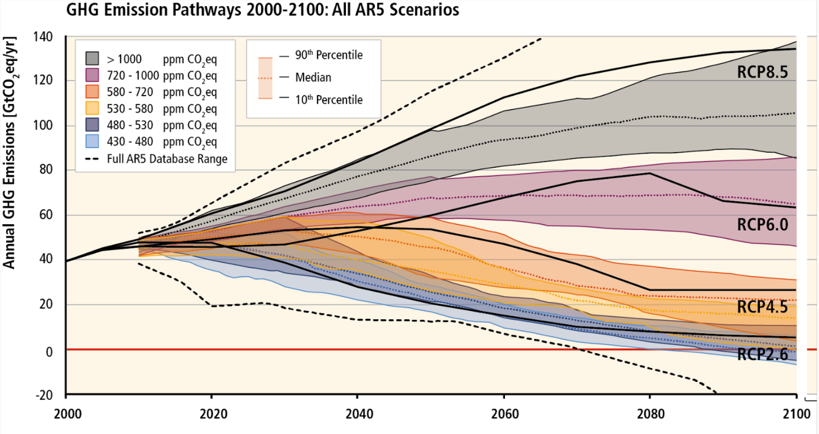


Figure: Emission reduction pathways. Source: IPCC (2014)

- Kaya identity $CO_2 \equiv P\frac{Y}{P}\frac{E}{Y}\frac{CO_2}{E}$
  - CO_2: emissions; P: population; Y: income; E: energy

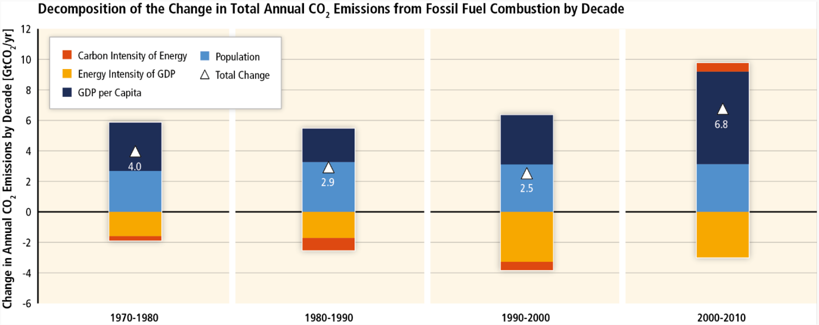
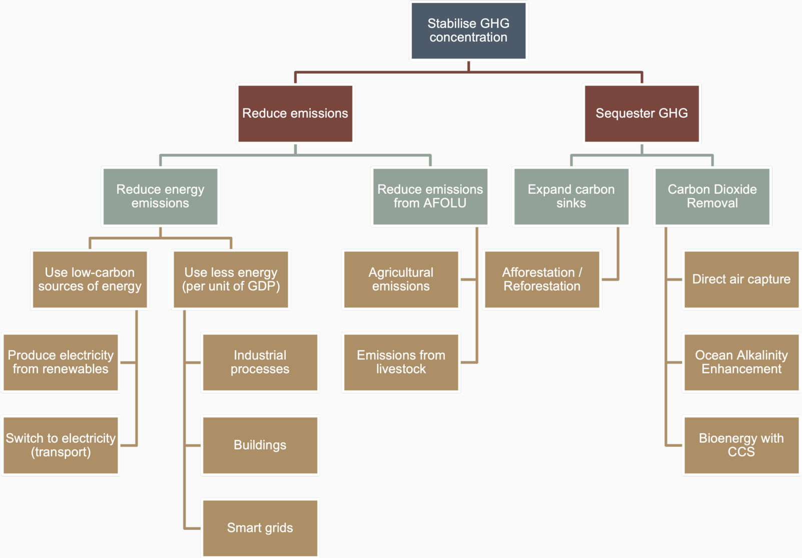


Figure: Source: IPCC (2014)

Levers to reduce emissions

- Reduce population
    - Population control measures, but very slow
    - Freedom issues (eg. one child policy in China)
- Reduce income
    - Degrowth; discussion on income-welfare links
    - Politically unpalatable and only applicable to high-income countries
- Improve production processes
    - Reduce energy intensity of GDP
    - Reduce emissions intensity of energy
    - This is what we refer to as ‘green growth’ or ‘decoupling’

Technological mitigation options



The tree of technological options to stabilise GHG concentration

What does a low-carbon transition mean?

- Decarbonise electricity
  - Wind, solar and other renewable energies
- Electrification
  - E.g. Electric vehicles. But what about international transport
- New manufacturing processes
  - E.g. Electric arc furnaces; bio-plastics
- New agricultural/farming techniques
  - E.g. Nitrogen-fixing rotations (More details)
- Negative emission technologies
  - Carbon capture and storage
  - Direct air capture
- Radical breakthroughs
  - Geoengineering
  - Nuclear fusion

What does this mean for us?

- Human productive activities currently based on fossil fuels
- For some activities, there are alternatives:
  - Electricity: renewable energies
  - Manufacturing: electric arc furnaces; bioplastic
  - Heating/cooking: electrification
  - International transport?
- Costs: these technologies are expensive!
  - Fossil-based technologies often still more convenient
- All of these produce essential intermediate inputs for all other sectors
  - Systemic implications of defossilisation?

This is not the first technological shift (UK example)

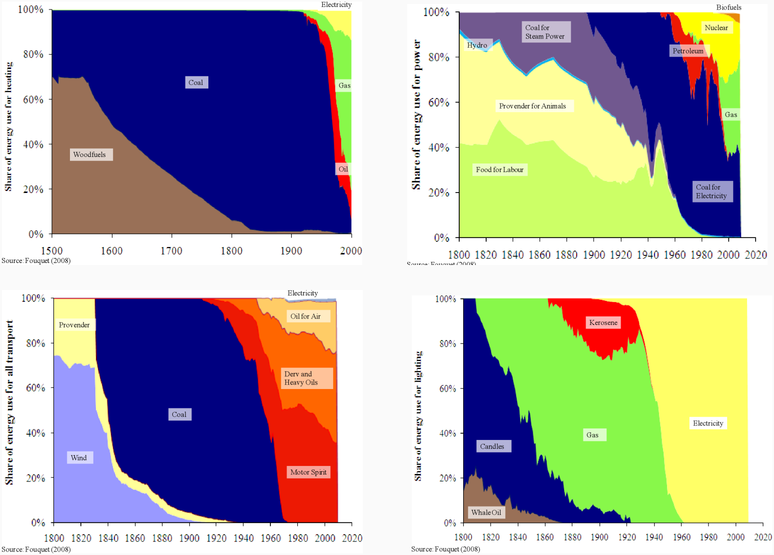


Figure: Source: Fouquet (2008)

However, a major difference

- Technological transitions historically driven by the emergence of new, more productive, more profitable technologies
  - Market players move there by their own
  - There will be losers, but societal gains outweigh costs
- Low-carbon transition likely to require strong policy interventions to promote (still) unattractive technologies
  - Market players need to be pushed there
  - There will be losers; who benefits?

The big trade-off

- Two seemingly contrasting objectives
  - Limit chances of disruptive climate-driven impacts
  - Limit chances of prosperity loss due to technological transition
- Two extreme scenarios
  - BAU: we continue with fossil-based technologies $\rightarrow$ climate damages
  - Immediate transition: we stop using fossil fuels today $\rightarrow$ economic disruptions
- Window of opportunity
  - A rapid and smooth transition: is it possible?

Studying macro-financial transitions

Approaches to study macro-financial transitions

- 1. Conceptual frameworks and qualitative approaches
  - How could climate/transition affect macro-financial dynamics?
  - E.g. what channels to inflation? what channels to financial instability?
  - $\rightarrow$ Development of conceptual/theoretical frameworks (eg. Green Swan, Climate Minsky moment, orderly/disorderly transition, green bubble, etc.)
  - Lecture 2
  - Main reading: Semieniuk et al. (2021)

Approaches to study macro-financial transitions

- 2. Empirical analysis
  - How relevant/likely are the theoretical transition patterns above?
  - $\rightarrow$ Study the empirical evidence.
  - Three main categories
    - Exposure of physical assets to the risk of stranding
    - Exposure of financial institutions
    - Econometrics and asset pricing (are risk internalised?)
  - Lecture 2
  - Main reading: Campiglio and van der Ploeg (2022)

Approaches to study macro-financial transitions

- 3. Prospective modelling
  - Methodologies to explore the future
  - $\rightarrow$ Attach dynamic behavioural assumptions to starting set of data
  - Different ways to do that: modelling schools of thought
  - Two main sets of approaches
    - Equilibrium modelling: IAM, CGE, DSGE, CAPM
    - Complexity modelling: SFC, ABM
  - Lectures 3 and 4
  - Main reading: Campiglio and van der Ploeg (2022)

Approaches to study macro-financial transitions

- 4. Political economy implications
  - Ok, so what to do we do about it?
  - $\rightarrow$ Policy analysis; policy coordination; social acceptability
  - The current status of climate-related financial policies: geographical heterogeneity
  - Can the most promising policies be implemented?
  - $\rightarrow$ Institutional analysis; Institutional change
  - Lecture 5
  - Main reading: Baer et al. (2021)

Next lecture: 22 February, 14.00CET