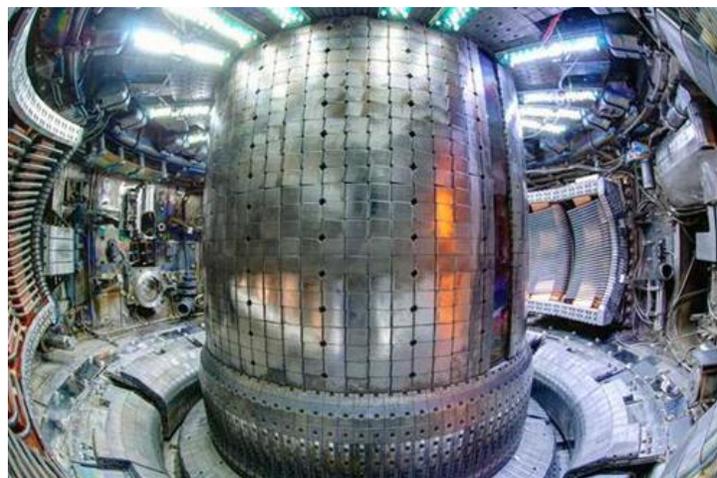




# Green Innovation Policies

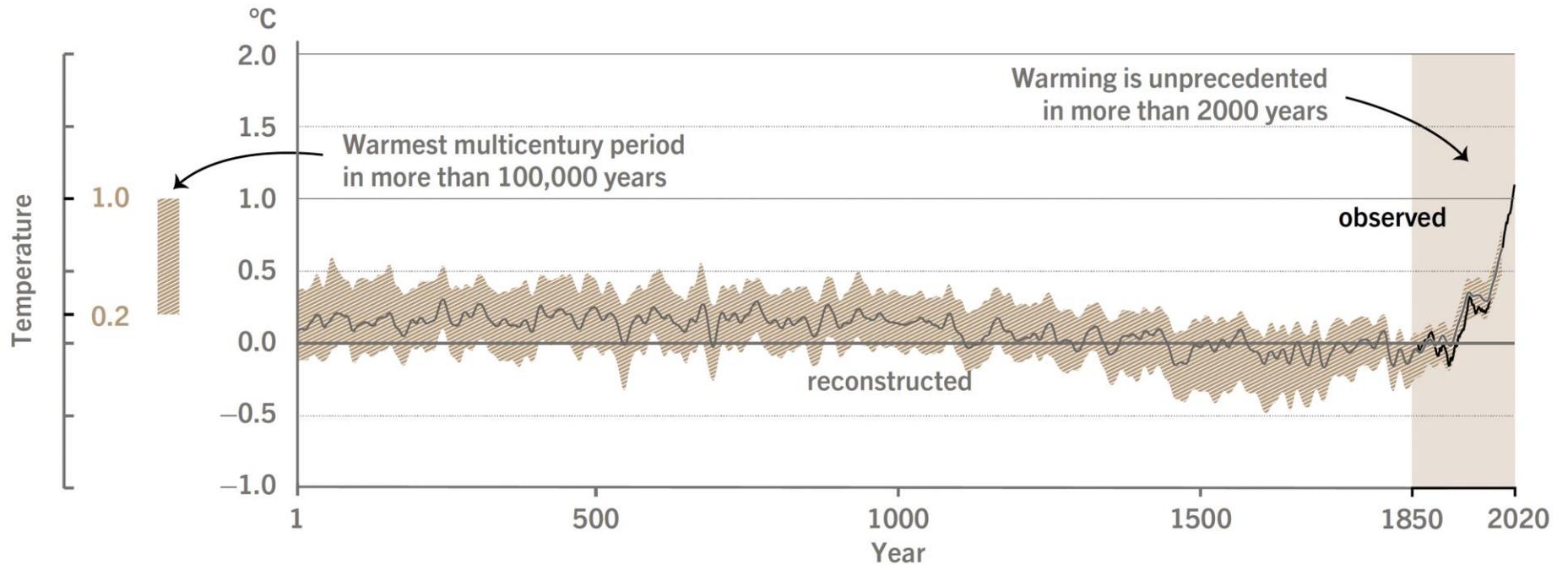
## Economics and Climate Change





# Climate Change is underway

Fig. 1 Changes in global surface temperature relative to 1850–1900



Notes: Change in global surface temperature (decadal average) as reconstructed (1–2000) and observed (1850–2020)

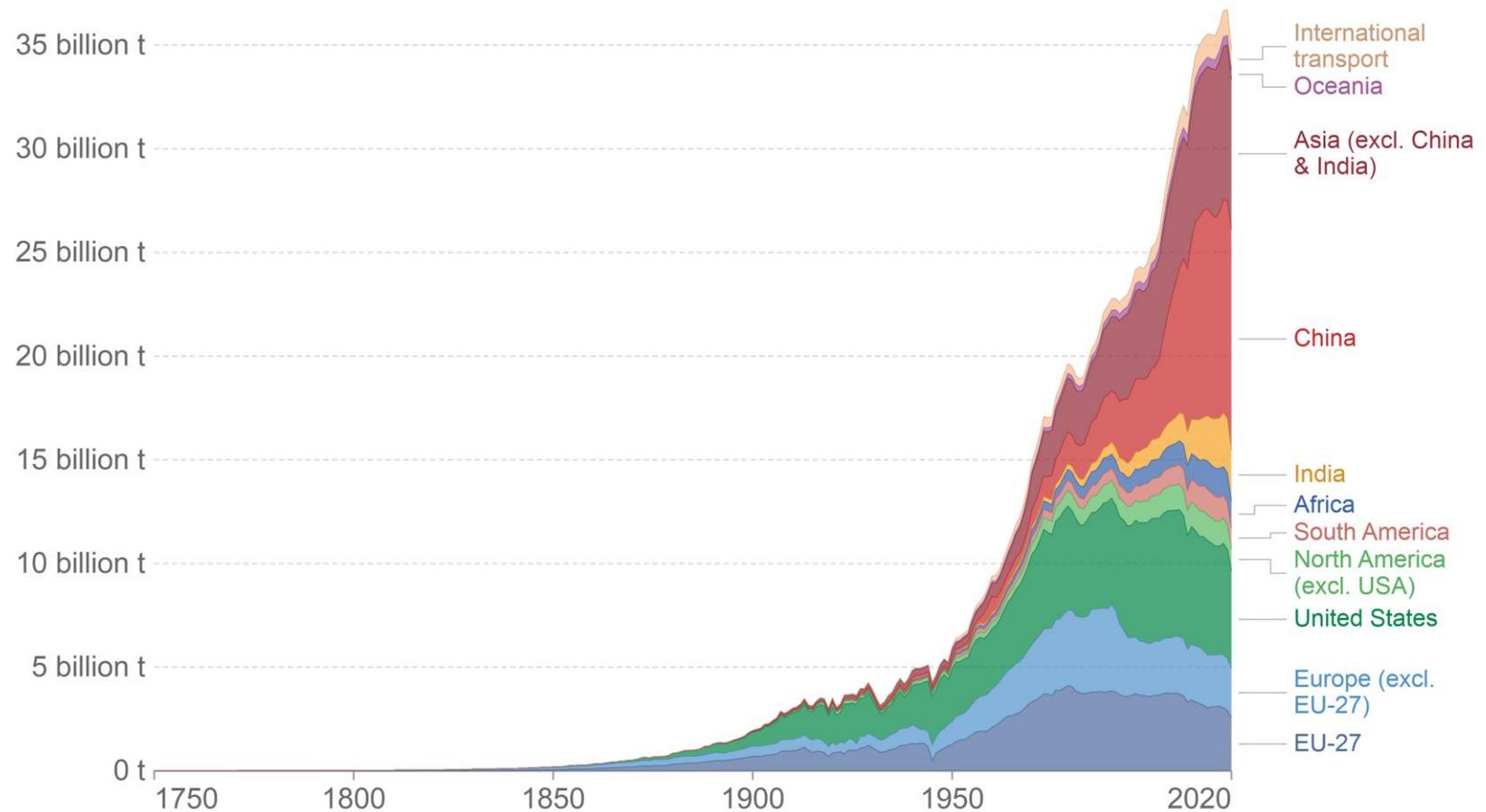
Source: IPCC report



# Rise in GHGs emissions

## Annual CO<sub>2</sub> emissions from fossil fuels, by world region

Our World  
in Data



Source: Global Carbon Project

OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY

Note: This measures CO<sub>2</sub> emissions from fossil fuels and cement production only – land use change is not included. 'Statistical differences' (included in the GCP dataset) are not included here.



# What do we need to do?

## Global greenhouse gas emissions and warming scenarios



- Each pathway comes with uncertainty, marked by the shading from low to high emissions under each scenario.
- Warming refers to the expected global temperature rise by 2100, relative to pre-industrial temperatures.

Annual global greenhouse gas emissions  
in gigatonnes of carbon dioxide-equivalents

150 Gt

100 Gt

50 Gt

0

Greenhouse gas emissions  
up to the present

1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100

**No climate policies**  
4.1 – 4.8 °C

→ expected emissions in a baseline scenario if countries had not implemented climate reduction policies.

**Current policies**  
2.7 – 3.1 °C

→ emissions with current climate policies in place result in warming of 2.7 to 3.1°C by 2100.

**Pledges & targets (2.4 °C)**

→ emissions if all countries delivered on reduction pledges result in warming of 2.4°C by 2100.

**2°C pathways**

**1.5°C pathways**

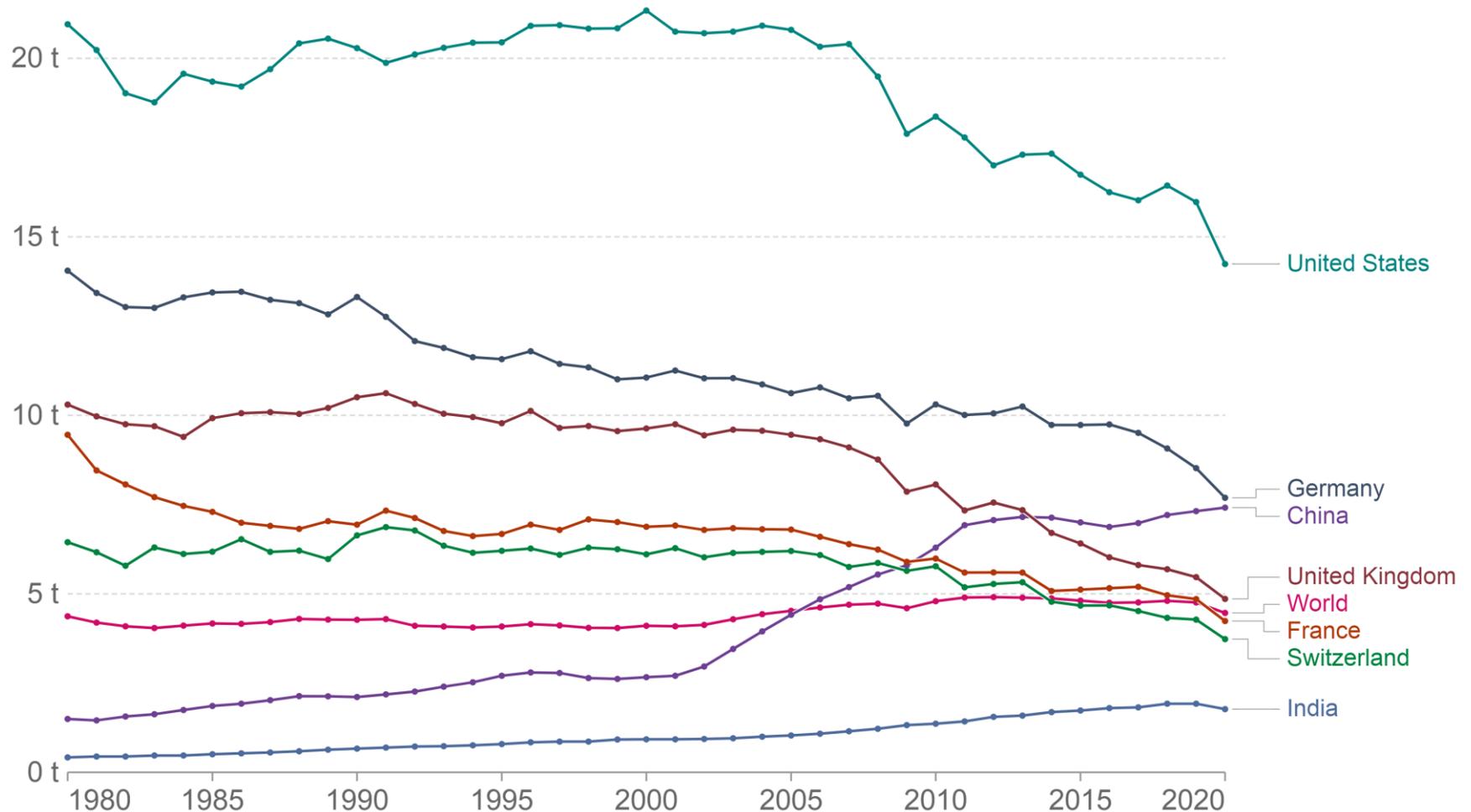


# But there are huge variations across countries

Our World  
in Data

## Per capita CO<sub>2</sub> emissions

Carbon dioxide (CO<sub>2</sub>) emissions from the burning of fossil fuels for energy and cement production. Land use change is not included.





# A simple decomposition

$$\text{Emissions} = \underbrace{\frac{\text{Emissions}}{\text{Energy}}}_{\text{Substitution between clean and dirty energy}} \times \underbrace{\frac{\text{Energy}}{\text{GDP}}}_{\text{Energy efficiency; Energy sobriety; Structural Change}} \times \frac{\text{GDP}}{\text{Population}} \times \text{Population}$$

Substitution  
between  
clean and  
dirty energy

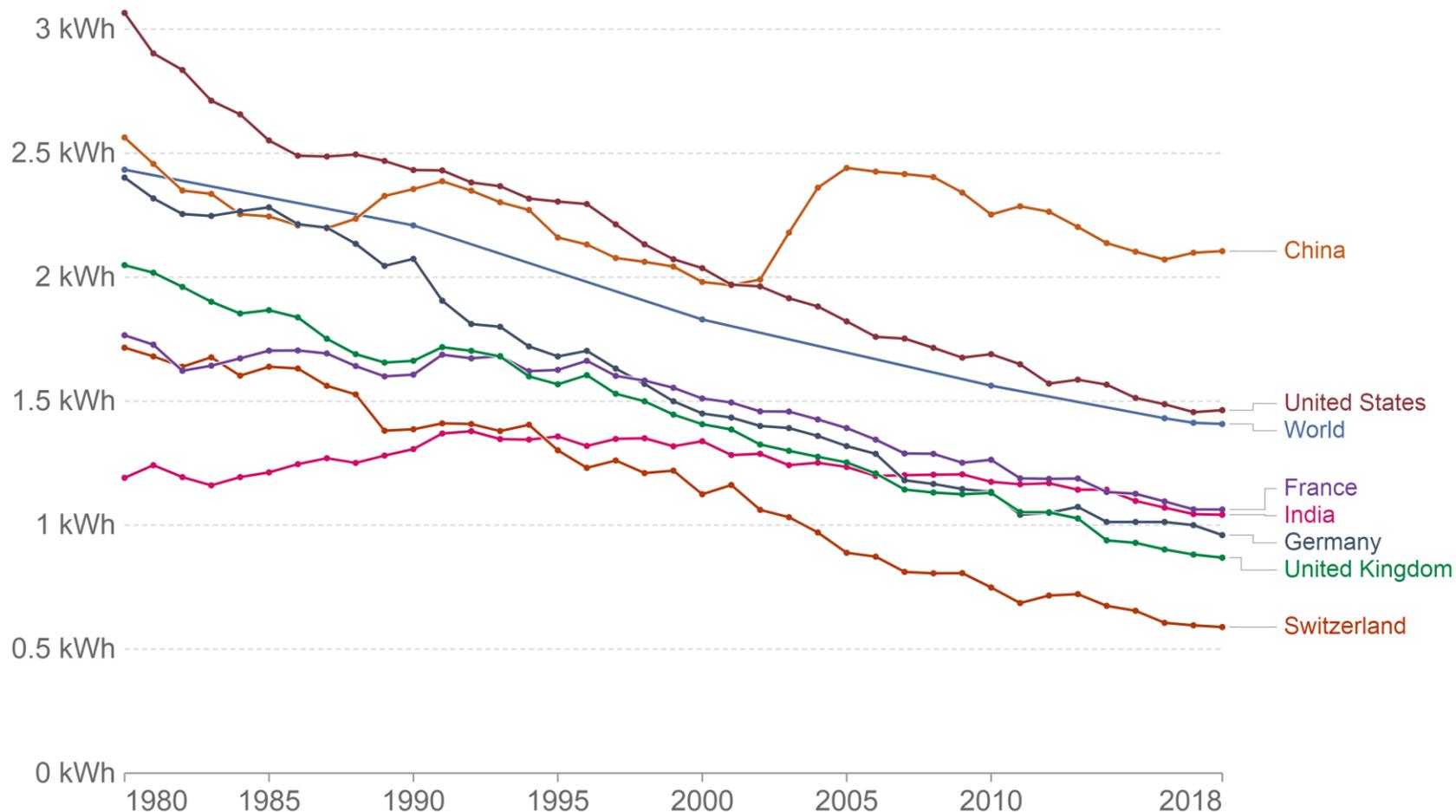
Energy efficiency;  
Energy sobriety;  
Structural Change



# Energy intensity is decreasing fast

## Energy intensity

Energy intensity is measured as primary energy consumption per unit of gross domestic product. This is measured in kilowatt-hours per 2011\$ (PPP).

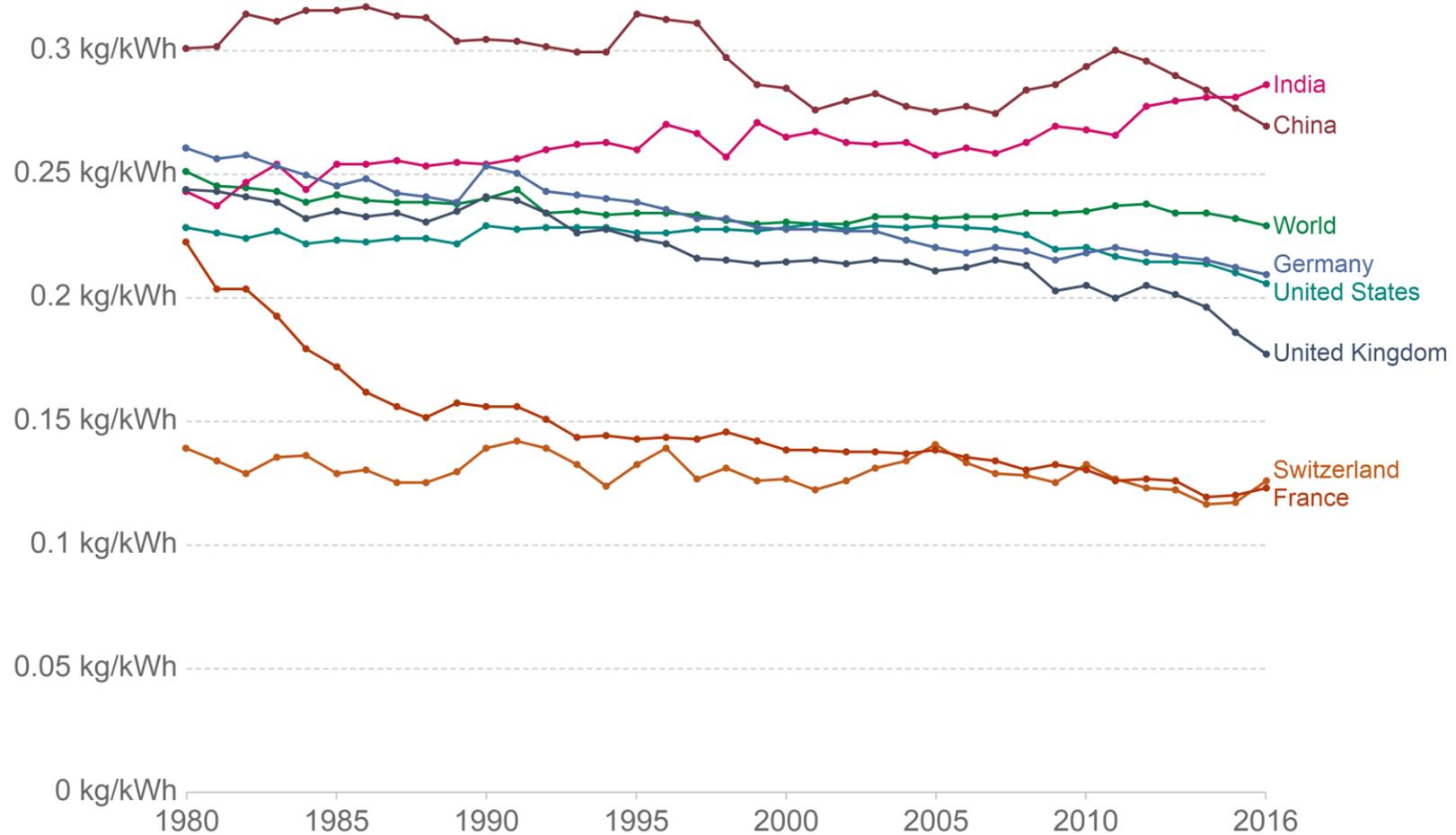




# Carbon intensity of energy is only decreasing in some countries

## Carbon intensity of energy production

Carbon intensity of energy production is measured as the quantity of carbon dioxide emitted per unit of energy production. This is measured in kilograms of CO<sub>2</sub> per kilowatt-hour.





# Taking stock

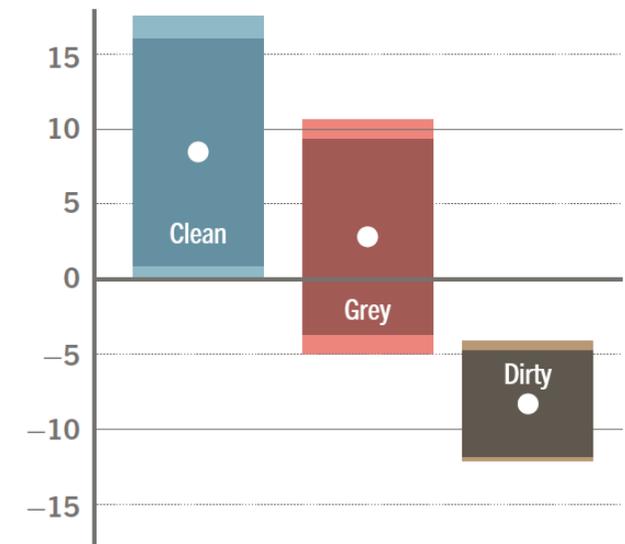
- “Technology” in a broad sense allows to reduce CO<sub>2</sub> emissions without large reductions in GDP:
  - US emissions would fall by 70% if the US used the same technologies as France (though the transition would be costly).
  - UK emissions per capita declined by 48% between 1990 and 2019 while GDP per capita increased by 52%.
  - So far energy-saving technical change / structural transformation have done most of the job... but to reduce emissions more, one needs to develop and adopt clean substitutes.
- Is it possible to induce more green innovation?

# Gas prices and innovation in the car industry



- Car industry is a good example where clean alternatives to fossil fuels exist.
- We analyze how an increase in gas prices favor clean innovation and hurts dirty innovation.
  - We measure innovations using patents and classify them
  - Showing a causal effect at the country level is impossible;
  - So we compare how firms in the car industry behave differently over time depending on the average gas price / tax in the countries that they sell to.
  - ``Shift-share`` measure.

Fig.10 Effect of a 10% increase in fuel prices



Notes: The bars denote the 90% and 95% confidence interval.

Source: Aghion, Dechezleprêtre, Hémous, Martin, and van Reenen (2016)



# Montreal Protocol effect

- In the 80s, CFC emissions were causing a reduction in the ozone layer.
- Countries reached an agreement at Montreal in 1987 to progressively reduce CFCs.
- Dugoua (2022) compares the evolution of patents and scientific articles on CFC substitutes versus other similar chemicals.
- CFCs got removed very quickly and the ozone layer is recovering.

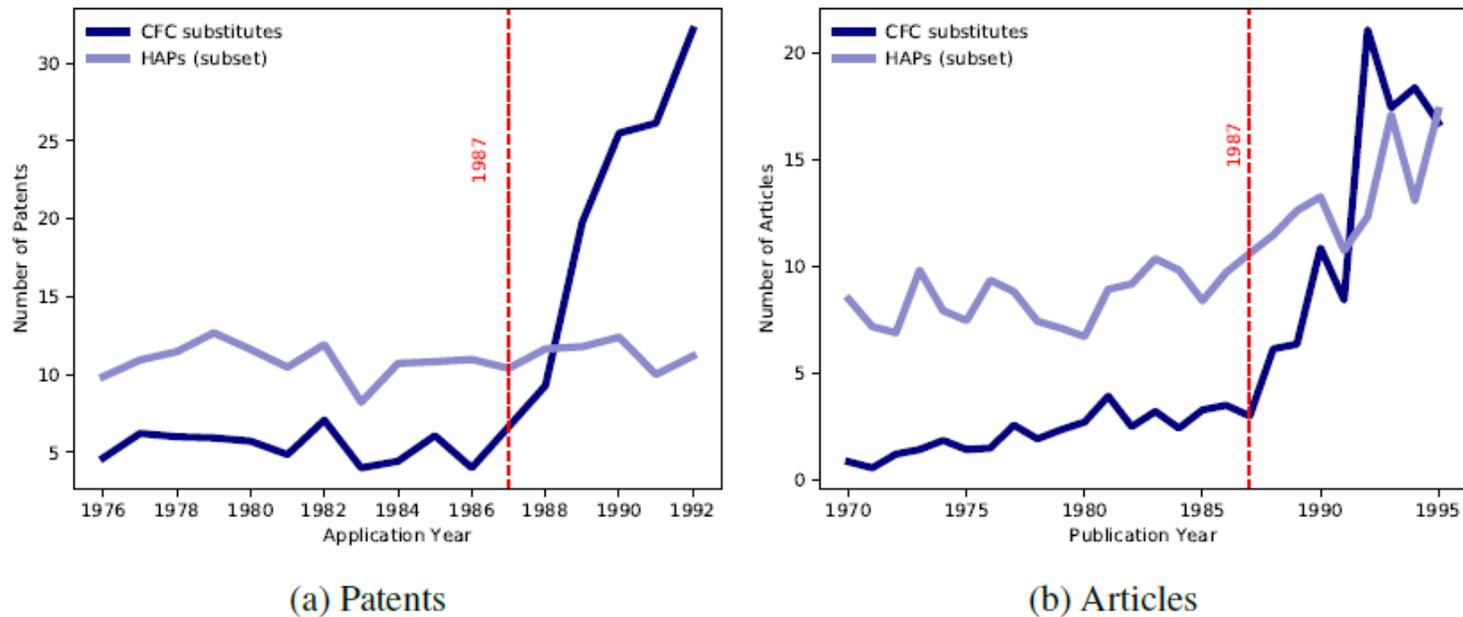


FIGURE 4

## Pre-Trends in Counts of Documents Mentioning CFC Substitutes and HAPs

*Note:* The graphs display the pre-trends for the treated group (CFC substitutes) and the control group constructed using a subset of the HAP molecules that have counts and pre-trends closest to the average CFC substitutes.

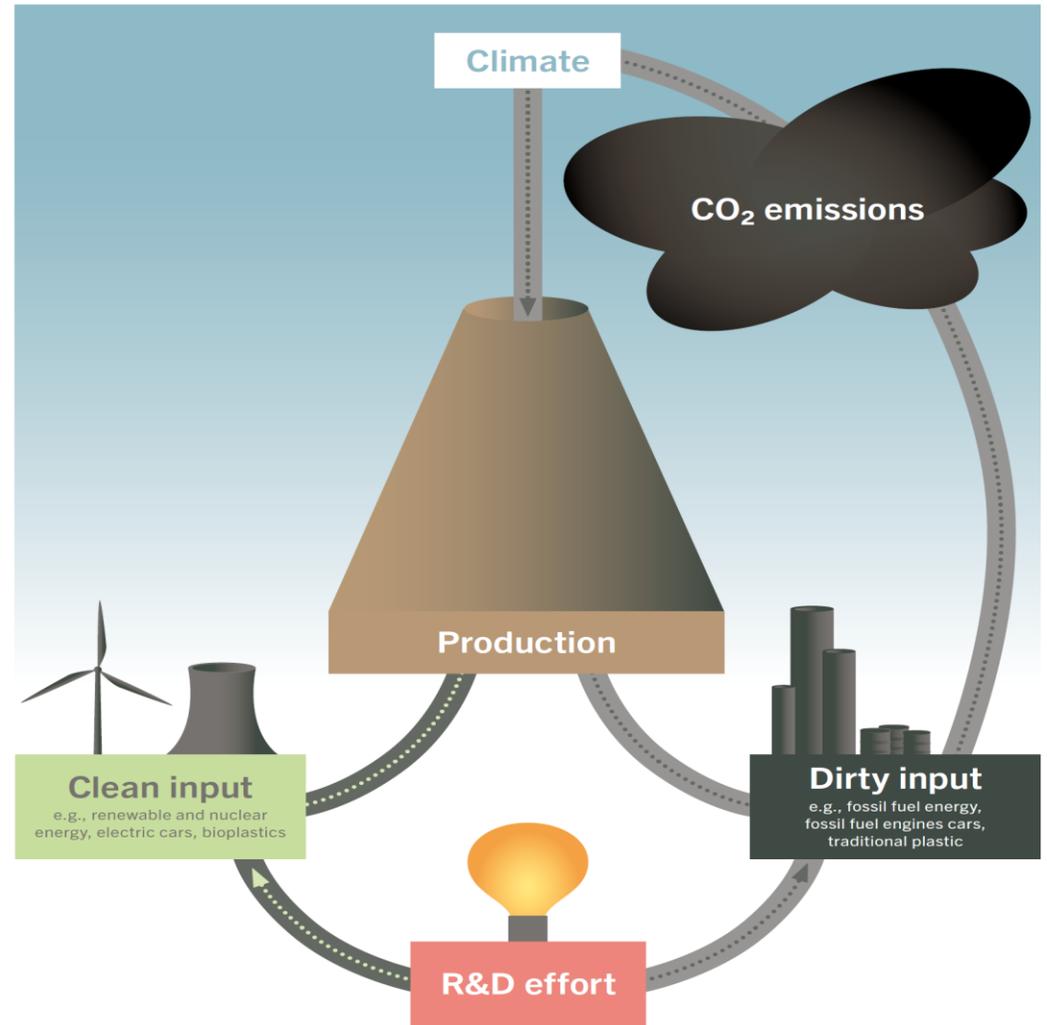


# Taking stock and next steps

- Is it possible to induce more green innovation?
  - Yes
- What does this imply for climate policy?

# Lessons from AABH (1)

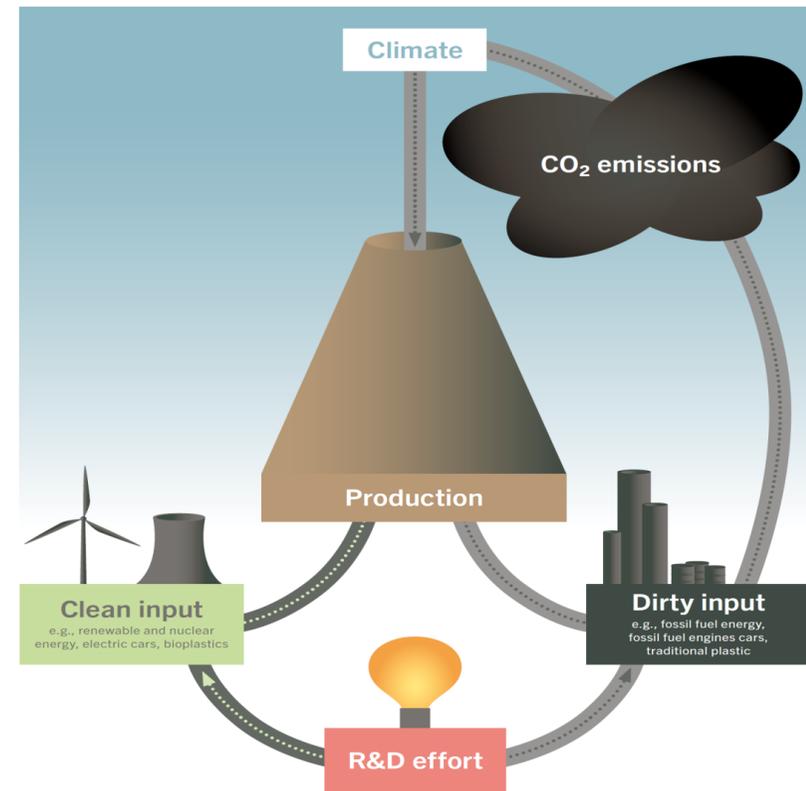
- AABH (2012) ask if innovation is endogenous, how does that affect climate policy?
  - They introduce directed technical change in a climate model.
  - A final good can be produced with a clean and a dirty input which are substitute.
  - What do we learn from this framework?
- 1<sup>st</sup> lesson: there is path dependence in innovation.
  - In laissez-faire, innovation would be directed toward dirty technologies.



Innovation is endogenous and targets the sector with the largest profits.

## Lessons from AABH (2)

- 2<sup>nd</sup> lesson: climate policies (carbon tax, research subsidies) can redirect innovation.
- 3<sup>rd</sup> lesson: delaying intervention is costly.
  - A larger gap between clean and dirty technologies means that it will take more time for clean to catch up;
  - And catch-up is associated with slow growth.
- 4<sup>th</sup> lesson: optimal policy involves both a carbon tax and subsidies to clean research:
  - Market discounts future benefits of innovation more heavily than a social planner (short patents, imitation, building on the shoulder of giants externality)
  - Most of the social value of clean technologies occur in the future (once energy transition has occurred)
  - Most of the social value of dirty technologies occur today.
  - Market favors too much dirty innovation relative to clean even with Pigovian taxation.





# What if only part of the world is willing to implement an environmental policy?

- If the EU imposes a high carbon price, “carbon leakage” is an important concern.
  - Energy-intensive manufacturing may move to countries with a lower carbon price (US, China,...).

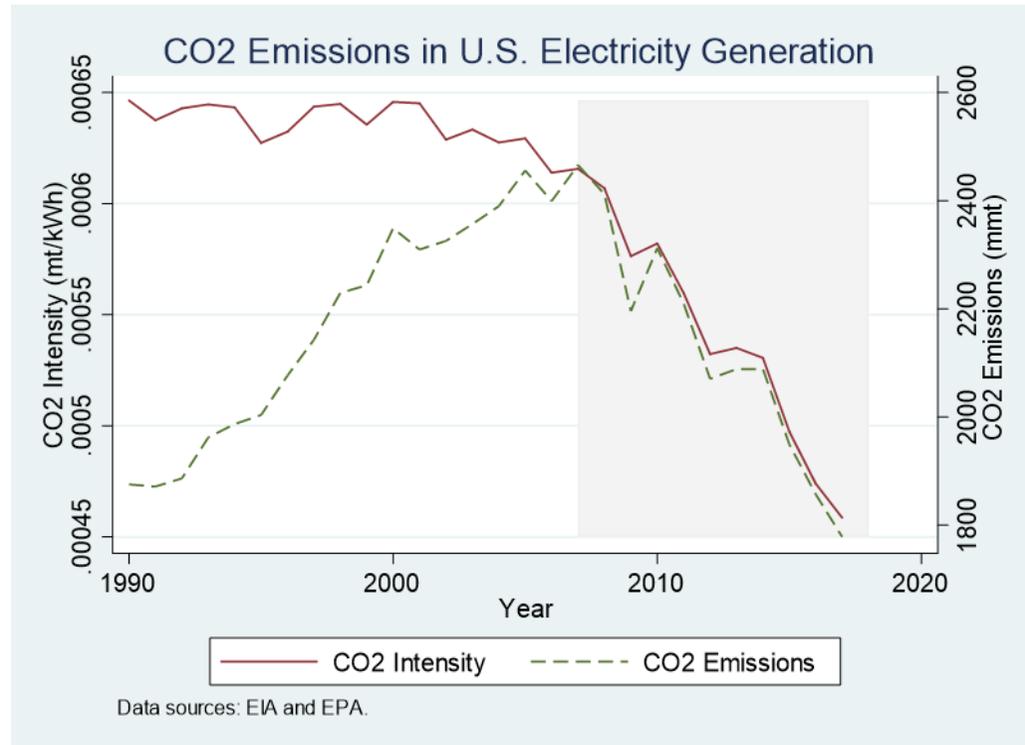
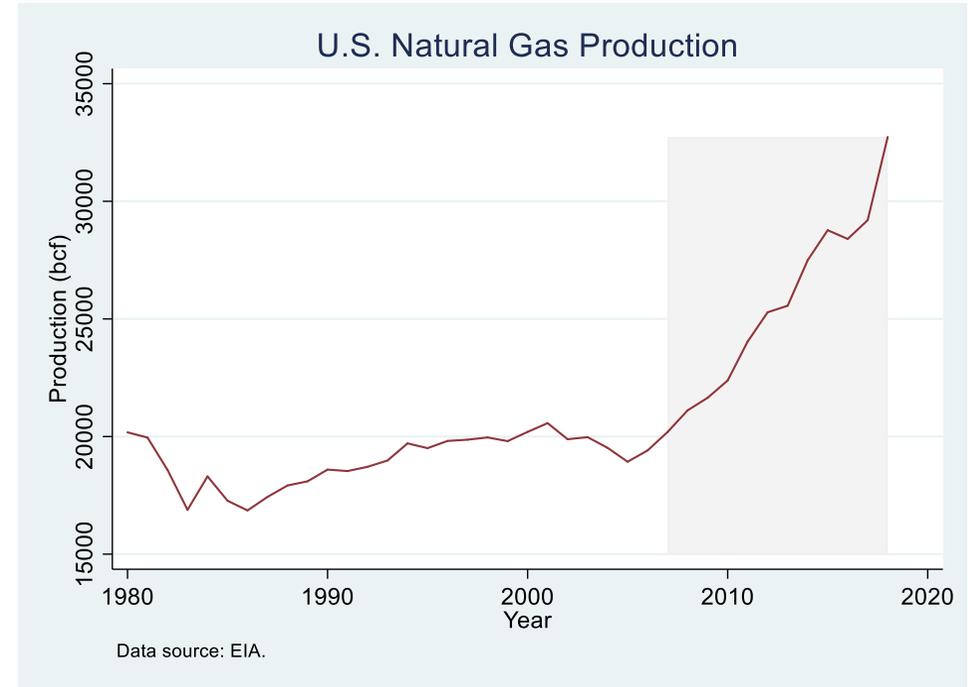


vs



- But what about innovation?
  - The market for energy-intensive good becomes larger in the US which increases fossil fuel innovations there.
  - The market for energy-intensive good becomes smaller in Europe which decreases innovation in clean energy there.
- Consider instead a “Green industrial policy” which combines carbon pricing with carbon tariffs and subsidies to develop clean technologies:
  - Energy-intensive industries do not move as much to the US
  - Development of clean substitutes in the EU may spill over to the US leading to a decrease in emissions in both countries.

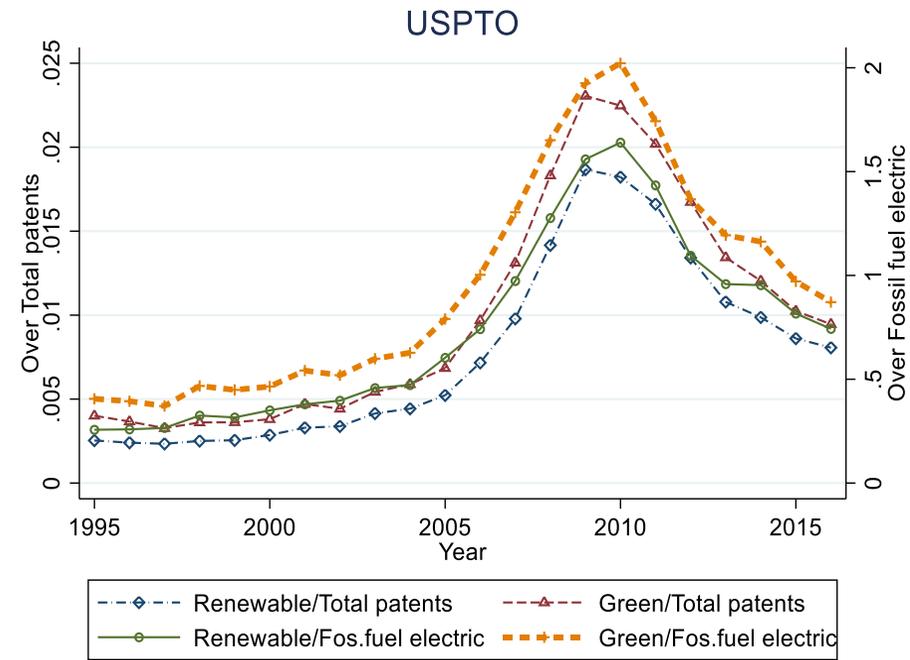
# What are the implications for an intermediate technology (shale gas)?



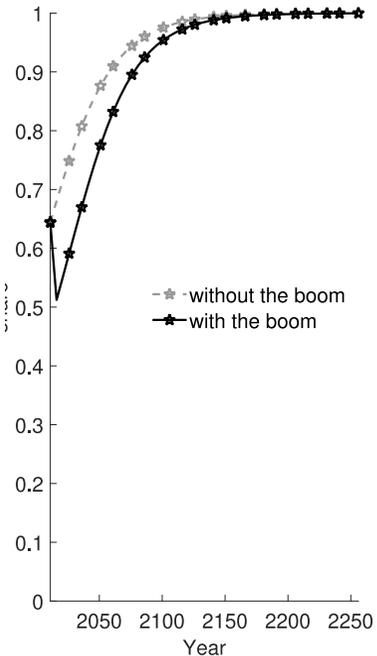


# The collapse of green innovation

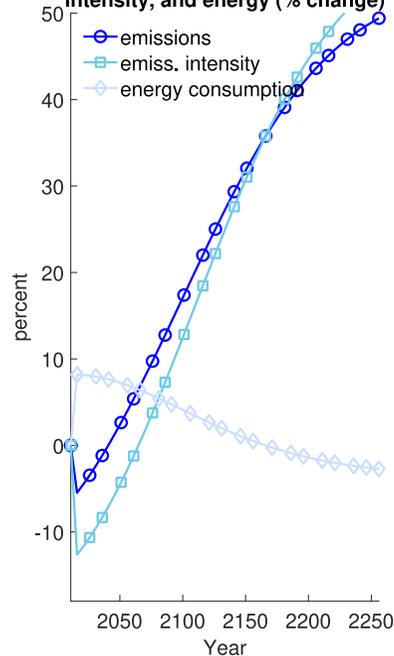
- Number of patents in renewables has collapsed since the shale gas revolution.



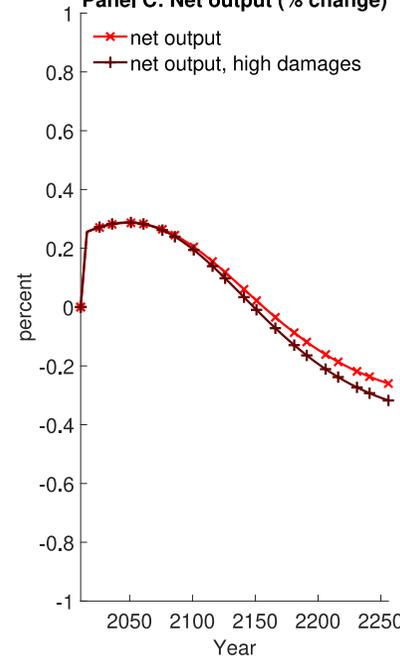
Panel A: Share of scientists in green



Panel B: Emissions levels, intensity, and energy (% change)



Panel C: Net output (% change)



- We estimate that in the long-run, the shale boom will actually lead to an increase in emissions (unless policy reacts).
- Policy should react by increasing support to clean technologies.



# Conclusions

- Innovation is key to tackle climate change;
  - Innovation responds to market incentives
  - But that is a call for more not less governmental action.
  - (Of course, it is not only about innovation).
- Taking into account the response of innovation:
  - Calls for research subsidies on top of carbon pricing;
  - Calls for an earlier interventions;
  - Favors a local green industrial policy over a simple unilateral carbon tax;
  - Calls for caution when deploying ``bridge'' technologies such as natural gas.