Second best and political constraints on greening the economy

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First best: price carbon consumption

- Tackle global warming externality via a global carbon tax or national carbon taxes with border tax adjustments.
- .. or have emissions trading scheme if done globally.
- If there are other market failures, tackle them with appropriate instruments:
  - E.g., learning by doing in renewable energy production via a feed-in subsidy,
  - Spill-overs in green R&D (not covered by patent markets) via a green R&D subsidy,
  - Income distribution correction via income tax.

How does carbon pricing work?

- *It curbs demand for fossil fuel: less car trips, heating a degree less, etc. It encourages to leave more fossil fuel in the crust of the earth.*
- It induces substitution from carbon-intensive fossil fuel (tar sands?, coal, crude oil) to less carbon-intensive fossil fuel (gas).
- *It induces substitution away from fossil fuel to renewables and brings forward the carbon-free era.*
- It encourages CCS and limits slash and burn of forests.
- It encourages R&D into clean fuel alternatives and into energy-saving technology.
- It encourages households, firms and government to spend more on CO2 mitigation as well as on CO2 adaptation (dykes, etc.).

Problem 1: Spatial carbon leakage

- Carbon leakage: if Kyoto countries put a price on CO2 emissions, some of it will be shifted to producers especially if fuel demand is elastic and supply inelastic. Gift to non-Kyoto countries! Renders CO2 policy ineffective unless it truly is a global deal incl. at least China and India.
- There may allow be pollution flight via dirty FDI.
- Deindustrialization in UK and OECD has led to lower energy ratio and thus to lower emissions (not climate policy) but a lot of the energy-intensive commodities are now produced in China and elsewhere.

International challenges

- Carbon leakage: emission pricing by Kyoto countries reduces energy prices in non-Kyoto prices and thus boosts energy demand there. This offsets the reduction in emissions in the Kyoto countries.
- Problem is complicated, since the big polluters are rich and big polluters to be (China, India) want to develop.
- Carbon taxes should only be equated across all countries if transfers are non-distorting which they are not.
- Coase: property rights are essential. Negotiate and buy up forests, coal, gas or oil works in theory but not in practice due to large number of parties concerned, due transaction costs and due to sheer cost of buying it all up.
- A single carbon tax floor among major emitters may be more promising and easier to negotiate than multiple country-level emission targets.

Problem 2: Green Paradox

Anticipation of green policies: sheiks pump oil faster to avoid capital losses, which accelerates global warming.
This weak Green Paradox is especially strong if demand is very elastic and supply fairly inelastic.
Focus on demand for carbon ignores supply of carbon. Is Green Paradox a ‘red herring’?
What matters is cumulative emissions which should be kept below 1 TtC to ensure global warming remains below 2 degrees Celsius. So need to keep more fossil fuel unexploited in the crust of the earth: Sheikh Yamani!

Welfare goes up if price elasticity of demand is low, of supply is high, and ecological discount rate is high.

Most policies aim to curb demand for fossil fuel

- E.g., higher petrol taxes, home insulation, lighter cars
- Green electricity: wind, water, solar, biomass, hybrid cars
- Nuclear: electricity generation and hydro power
- Other green energy sources: pellet heating, biodiesel, heat pumps, solar, geothermal
- Efficient combustion: common-rail diesel engines, optimized power plants
- But challenge is *to leave more fossil fuel unused in the crust of the earth*. How? Bribing coal and rain forest owners? Making carbon more expensive?

Problem 3: Policy failure and capture

- Non-price controls are susceptible to capture: energy efficiency standards, mandatory sequestration, renewable mandates, etc.
- Bio-fuel mandate puts up land price & creates food poverty.
- Price mechanisms also: e.g., ETS – grandfathering; if coal is excluded from tax or subsidised, a carbon tax induces substitution towards dirty coal, sands, and unsafe nuclear energy.
- Government picks winners & faces lobbies: solar, wind, ...
- Wind energy is expensive and is intermittent, so need backup energy which will not be used when wind is on at zero marginal cost. Offshore energy is even more expensive due to costs of repairs on sea.
- Solar costs are dropping dramatically: infant industry?

Europe …

- Europe's policies are a failure: carbon production is priced and has gone down but carbon consumption including imports from China etc is not and has gone up.
- Europe has grandfathered emission rights and has given exceptions to steel and greenhouse industry.
- Europe has focused instead on renewables: wind and even more expensive solar energy.
- Still, subsidies for fossil fuel are much, much bigger than subsidies for renewable energy.

Do not use emissions pricing to redistribute incomes

- Fossil fuel subsidies are now a staggering $5.3 trillion a year (6.5% of world GDP) versus renewable subsidies of only $120 billion/year.
- $2.3tn in China, $700bn US, $355bn Russia, $227bn India.
- Get rid of energy subsidies (explicit or implicit) for coal with high carbon content, consumed more by the poor.
- Replace the subsidies with general tax deductions for the poor, which is a cheaper way to achieve same distributional goals. Do not direct pollution taxes at income distribution, even if poor spend a disproportionate amount on polluting goods.
- Cutting pre-existing, environmentally blunt energy taxes (e.g., on electricity use or car ownership rather than use) can help to compensate low income groups and energy-intensive firms in trade-sensitive sectors for higher energy prices and enhance feasibility.

Simple first-best rule for the Social Cost of Carbon (SCC)

$$SCC = \left(\left[\frac{0.2}{r} + \frac{0.32}{r + 0.0023} \right] \times 0.0238 \times GDP \right) \times \left(\frac{1}{1 + r \times 40} \right),$$

- where the appropriate rate of discount to discount damages follows from the Keynes-Ramsey rule: $r = \rho + (IIA - 1) \times g.$
- Hence, a lower weight to welfare of future generations (higher ρ), a bigger aversion to intergenerational inequality aversion (higher IIA), and richer future generations (higher g) curb desire to make sacrifices to curb future global warming and lead to higher carbon price.
- Since climate damages are proportional to world GDP, the global carbon tax is proportional to world GDP too.

Back on the envelope estimates for SCC

- Let g = 2%, *IIA* = 2 and ρ = 0. World GDP was in 2014 equal to 76 trillion $. Hence, *SCC* is in 2014 55 $/tC or 15 $/tCO2 or 13 cents per gallon petrol. *SCC* subsequently rises in line with GDP at 2%/year.
- Discounting welfare of future generations at ρ = 2% pushes down the *SCC* to 20 $/tC or 5.5 $/tCO2.
- Doubling the *IIA* to 4 gives *SCC* of 10 $/tC.
- Pessimistically halving trend growth to g = 1% gives *SCC* of 132$/tC which then grows in line with global GDP at a mere 1% per year.
- Easy to extend to allow for damages of global warming to the trend growth rate, pushing up the *SCC* a lot. Curbs carbon budget to 452 GtC & max. temp to 2.3C.
- Simple rules performs extremely well in IAM.

Climate damages and learning by doing

- Fossil fuel extraction costs rise as left reserves are left, which gives rise to untapped fossil fuel.
- Price of fossil fuel consists of this cost, the scarcity rent and the social cost of carbon.
- Renewable energy becomes cheaper as more is used (DRTS). This gives rise to an intermediate phase where renewable and fossil fuel energy are used together.
- Price of renewable energy corresponds to this cost minus any learning-by-doing subsidy.
- IAM allows for temporary population boom and ongoing technical progress.
- Allow for additive and multiplicative global warming damages.
- Take simplified carbon cycle from Golosov et al. (2013).

Policy responses: first best and second best

- What is needed is an aggressive renewable subsidy to bring renewable energy quickly into use and a gradually rising carbon tax to price and depress fossil energy use during the transition.
- The second-best subsidy with commitment has been shown to reproduce the first best outcome in terms of transition time and peak warming closely.
- Without commitment, the second-best policy performs much worse, with a later transition and higher fossil fuel use before. Peak warming increses by more than 1°C.

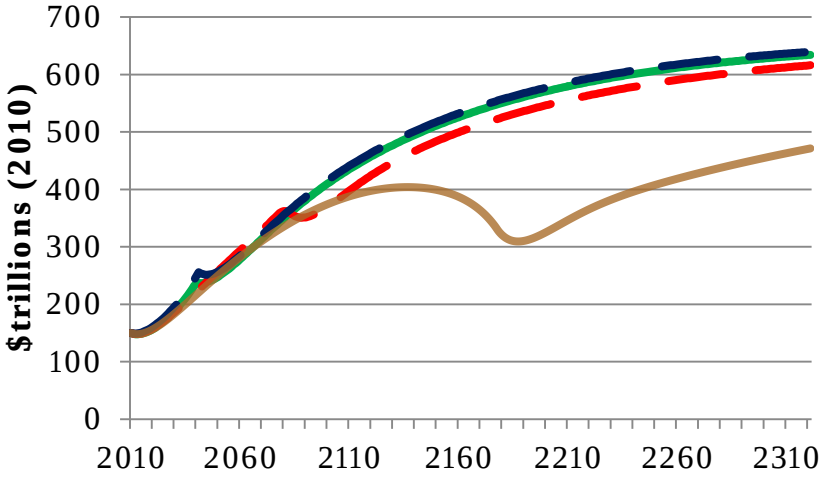
Second-best policy

- In a second-best setting, the government misses at least one instrument. In our case, the tax is not feasible ($\tau_t = 0$) and the government has to choose how to maximize welfare choosing a subsidy, while respecting the decentralized market conditions.
- Under pre-commitment, the government will increase the subsidy beyond the *SBL* in order to price fossil fuels out of the market.
- Under no-commitment (Markov Perfection), the government will set the subsidy to the *SBL* (i.e. it cannot use the subsidy to correct for the zero-tax.

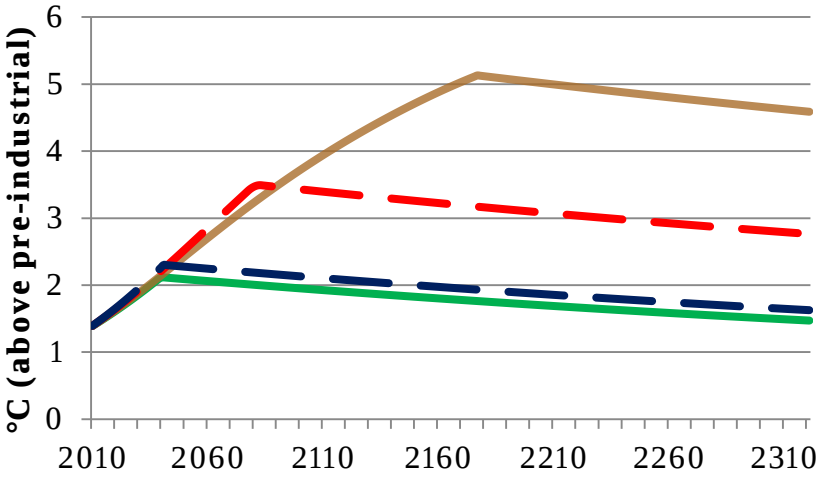
Policy simulations

- Solution decade by decade from 2010 to 2600: t = 1 is 2010-2020, .., t = 60 is 2600-2610.
- I. the first-best outcome where the carbon tax is set to the optimal SCC, and the renewable subsidy to the optimal SBL, (solid green lines);
- II. the second-best case: subsidy without commitment (dashed blue lines);
- III. the second-best case: subsidy with pre-commitment (dashed red lines);
- IV. business as usual (BAU) without any policy (solid brown lines).

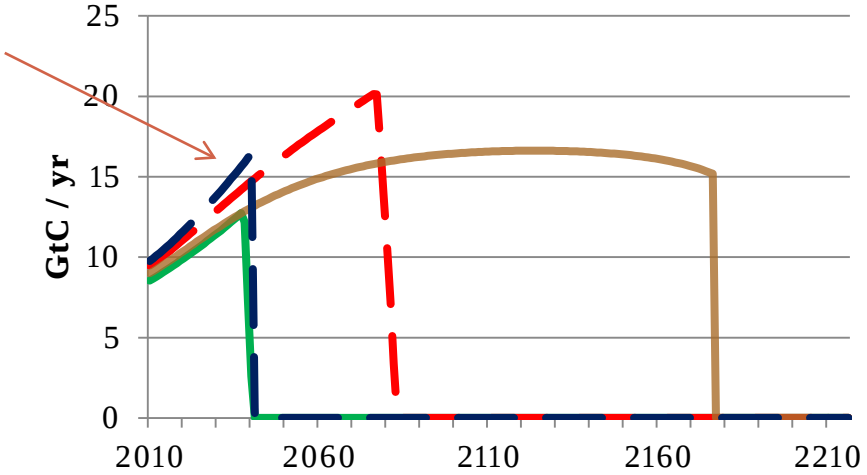
Capital Stock, K_t



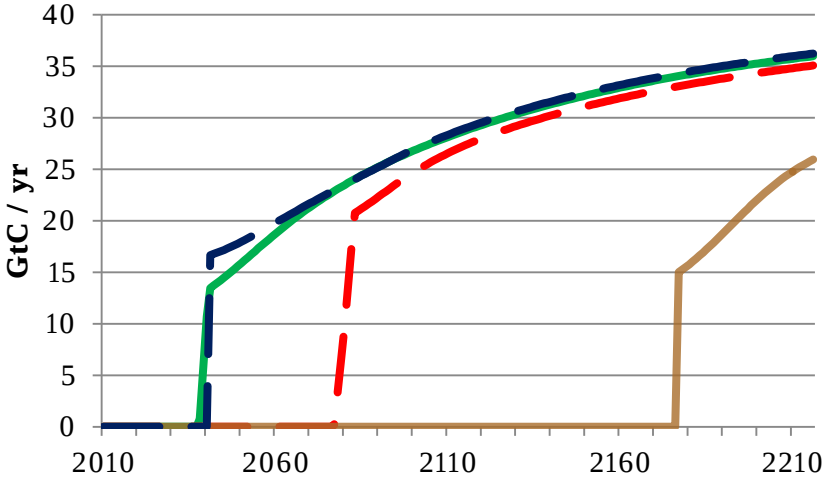
Mean Global Temperature, T_t



Fossil Fuel Use, F_t



Renewable Energy Use, R_t

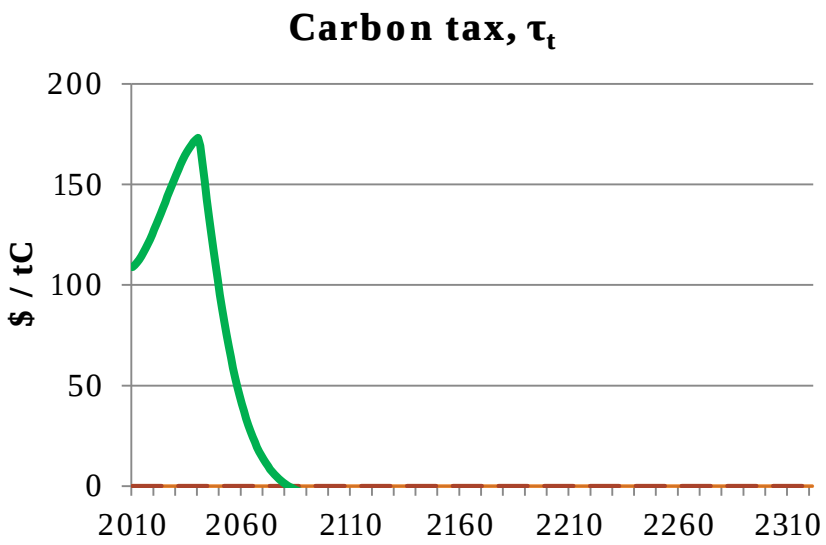


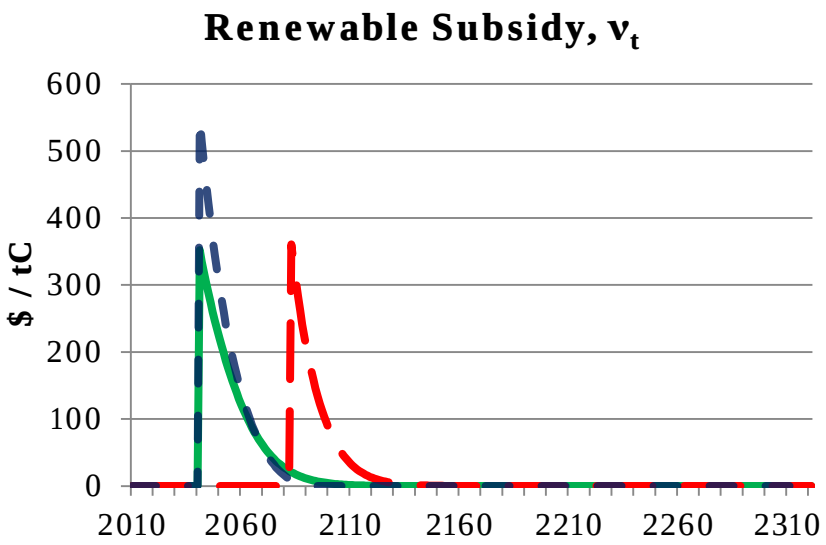
first-best

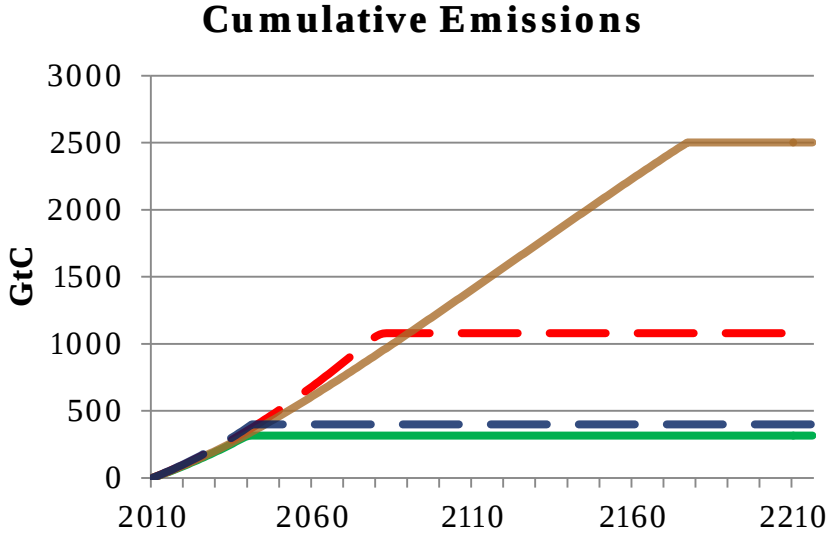
subsidy no commitment

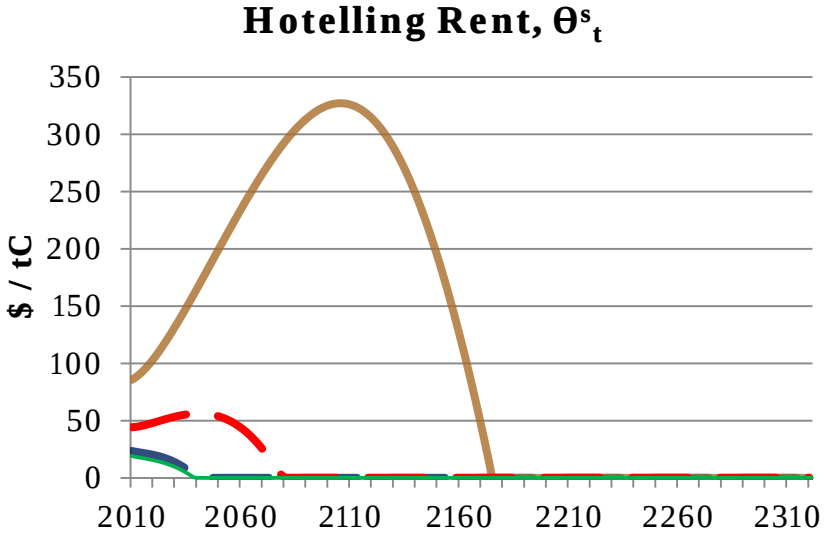
subsidy with commitment

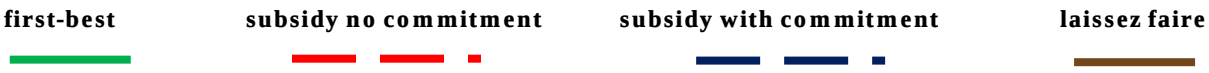
laissez faire


Carbon tax, τ_t
$ / tC
200
150
100
50
0
2010
2060
2110
2160
2210
2260
2310


Renewable Subsidy, ν_t
$ / tC
600
500
400
300
200
100
0
2010
2060
2110
2160
2210
2260
2310


Cumulative Emissions
GtC
3000
2500
2000
1500
1000
500
0
2010
2060
2110
2160
2210


Hotelling Rent, θ^s_t
$ / tC
350
300
250
200
150
100
50
0
2010
2060
2110
2160
2210
2260
2310


first-best
subsidy no commitment
subsidy with commitment
laissez faire

Interpretation

- The optimal policy mix combines a persistent carbon tax with an aggressive renewable subsidy and limits warming to 2.1°C.
- Under laissez-faire, global temperature rises to 5.1°C. Missing markets lead to a transitory capital over-accumulation, inducing severe climate damage and a fall in capital stock. Rising extraction costs drive transition.
- If the government can commit to a subsidy policy, the second-best subsidy can get close to the first-best outcome. There is a weak Green Paradox effect with small increase in temperature.
- If the government cannot commit to the policy, the subsidy is delayed considerably with large Green Paradox effects.

Transition times and carbon budget

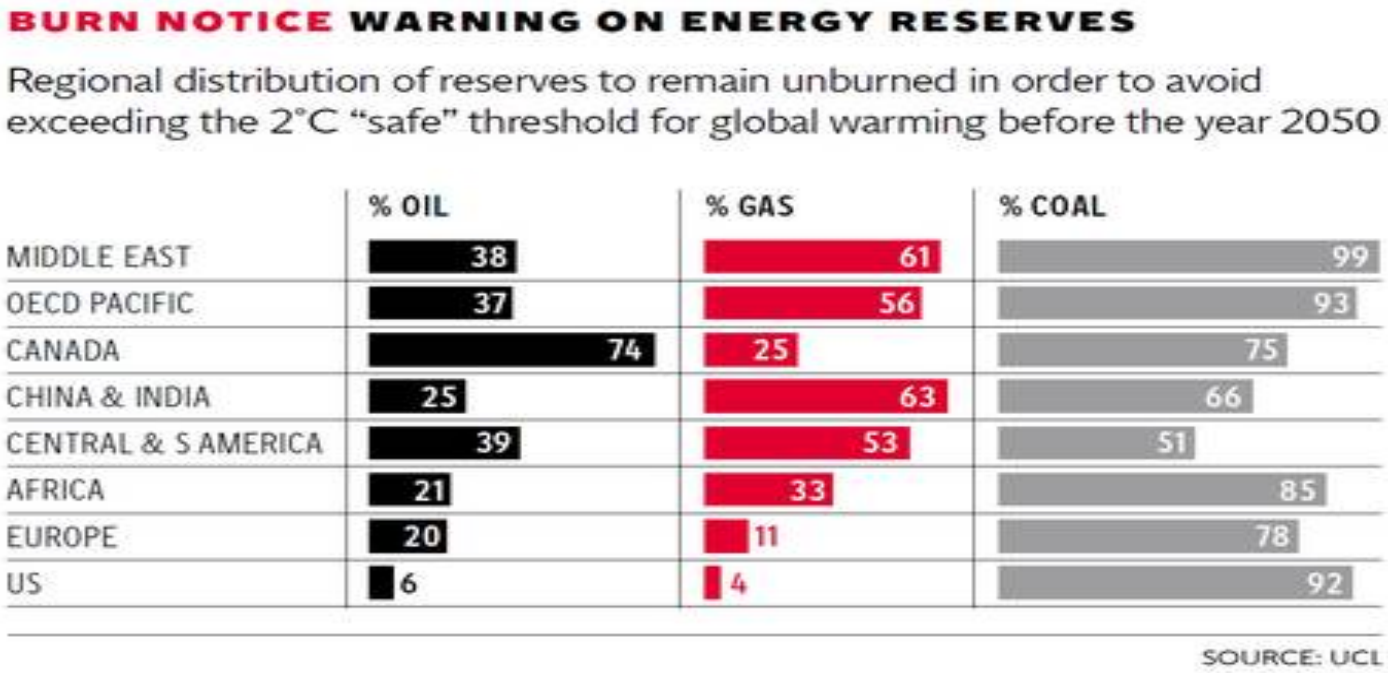
	Only fossil fuel	Simultaneous use	Renewable Only	Carbon used
Social optimum	2010-2038	2038-2040	2041 –	320 GtC
SB subsidy (w/o commitment)	2010-2076	2077-2082	2083 –	1080 GtC
SB subsidy (with commitment)	2010-2040	x	2041 –	400 GtC
No policy	2010-2175	x	2175 –	2500 GtC

Welfare losses, SCCs, renewable subsidies and global warming

	Welfare Loss (% of GDP)	Maximum carbon tax τ ($/tC)	Maximum renewable subsidy ($/tC)	max T (°C)
Social optimum	0%	175 $/GtC	350 $/GtC	2.1 °C
SB subsidy (w/o commitment)	-95%		360 $/GtC	3.5 °C
SB subsidy (with commitment)	- 7%		550 $/GtC	2.3 °C
No policy	-598%			5.1 °C

McGlade and Ekins (2015, *Nature*)

- Globally keep 1/3 of oil (Canada, Arctic), ½ of gas and 4/5 of coal (mainly China, Russia, US) reserves unburnt. Reserves are 3x and resources 10-11x the carbon budget. In Middle East 26o billion barrels of oil that should not be burnt.



Remarks

- Endogenous total factor and energy productivities allows for further substitution possibilities between energy and the (K,L)-aggregate in the longer run (see estimates of Hassler et al. (2011)). This justifies a more ambitious climate policy.
- US Interagency Working Group (2010) recommend SCC of 80$/tC rising to 165$/tC in 2050 based on discount rate of 3% per year. A discount rate of 2.5% would give 129 and 238$/tC in line with our estimates.
- Acemoglu et al. (2012) and Mattauch argue for an aggressive subsidy to kick-start green innovation; Nordhaus and Stern Review argue for a rising carbon tax. Our IAM argues for a combination of these policies.

How to model catastrophes?

- Chance that a discontinuous change in damages or carbon cycle takes place. This can be abrupt as with shifts in monsoonal systems. But loss of ice sheets resulting in higher sea levels have slow onsets and can take millennium or more to have its full effect (Greenland 7m and Western Antarctica 3m, say) and may already be occurring.
- 9 big catastrophes are imminent, not all at same time (Lenton and Ciscar, CC, Nature).
- Collapse of the Atlantic thermohaline circulation is fairly imminent and might occur at relatively low levels of global warming. This affects regions differently, but we capture this with a negative TFP shock.
- We look at TFP calamity and also at K, P and climate sensitivity calamities. Expected time of calamity falls with global warming.

Probabilities of Various Tipping Points from Expert Elicitation

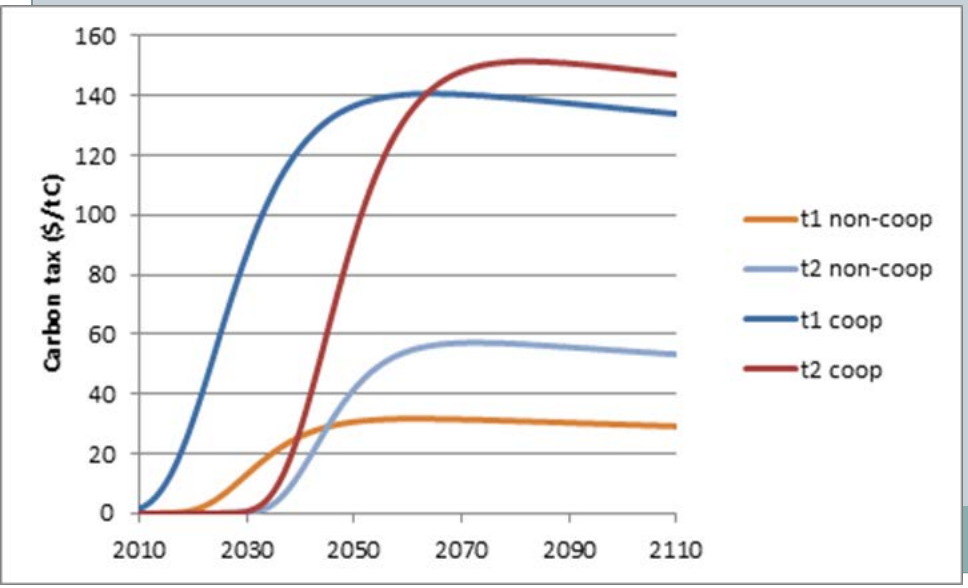
Possible Tipping Points	Duration before effect is fully realized (in years)	Additional Warming by 2100		
		0.5-1.5 C	1.5-3.0C	3-5 C
Reorganization of Atlantic Meridional Overturning Circulation	about 100	0-18%	6-39%	18-67%
Greenland Ice Sheet collapse	at least 300	8-39%	33-73%	67-96%
West Antarctic Ice Sheet collapse	at least 300	5-41%	10-63%	33-88%
Dieback of Amazon rainforest	about 50	2-46%	14-84%	41-94%
Strengthening of El Niño-Southern Oscillation	about 100	1-13%	6-32%	19-49%
Dieback of boreal forests	about 50	13-43%	20-81%	34-91%
Shift in Indian Summer Monsoon	about 1	Not formally assessed		
Release of methane from melting permafrost	Less than 100	Not formally assessed.		

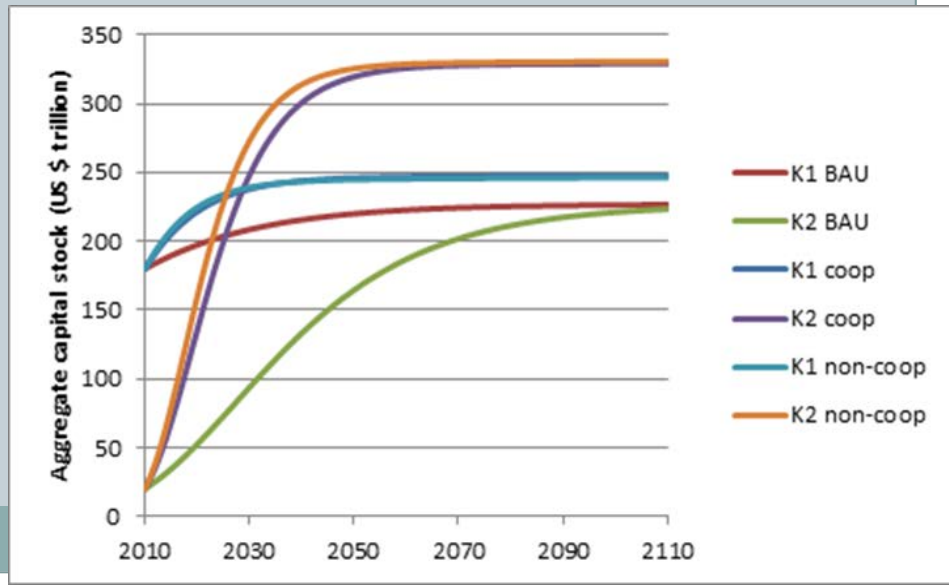
Messages and aims

- Small risks of climate disasters may lead to a much bigger *SCC* even with usual discount rates. Rationale is to avoid risk.
- Chance of catastrophe can lead to much higher *SCC* without a very low discount rate provided hazard rises sharply with temperature $\Rightarrow$ to avert risk.
- There is also a social benefit of capital (*SBC*) which gives a rationale for precautionary capital accumulation $\Rightarrow$ to be better prepared.
- Catastrophic changes in system dynamics unleashing positive feedback may be much more dangerous than *TFP* calamities.

Extension: North-South perspective

- Carbon taxes rise in line with GDP; lots of precaution.
- South is poor and is hit more by global warming than North ⇒ taxes carbon later and eventually more.
- Big non-cooperative bias in carbon tax, but not in precautionary return on capital.





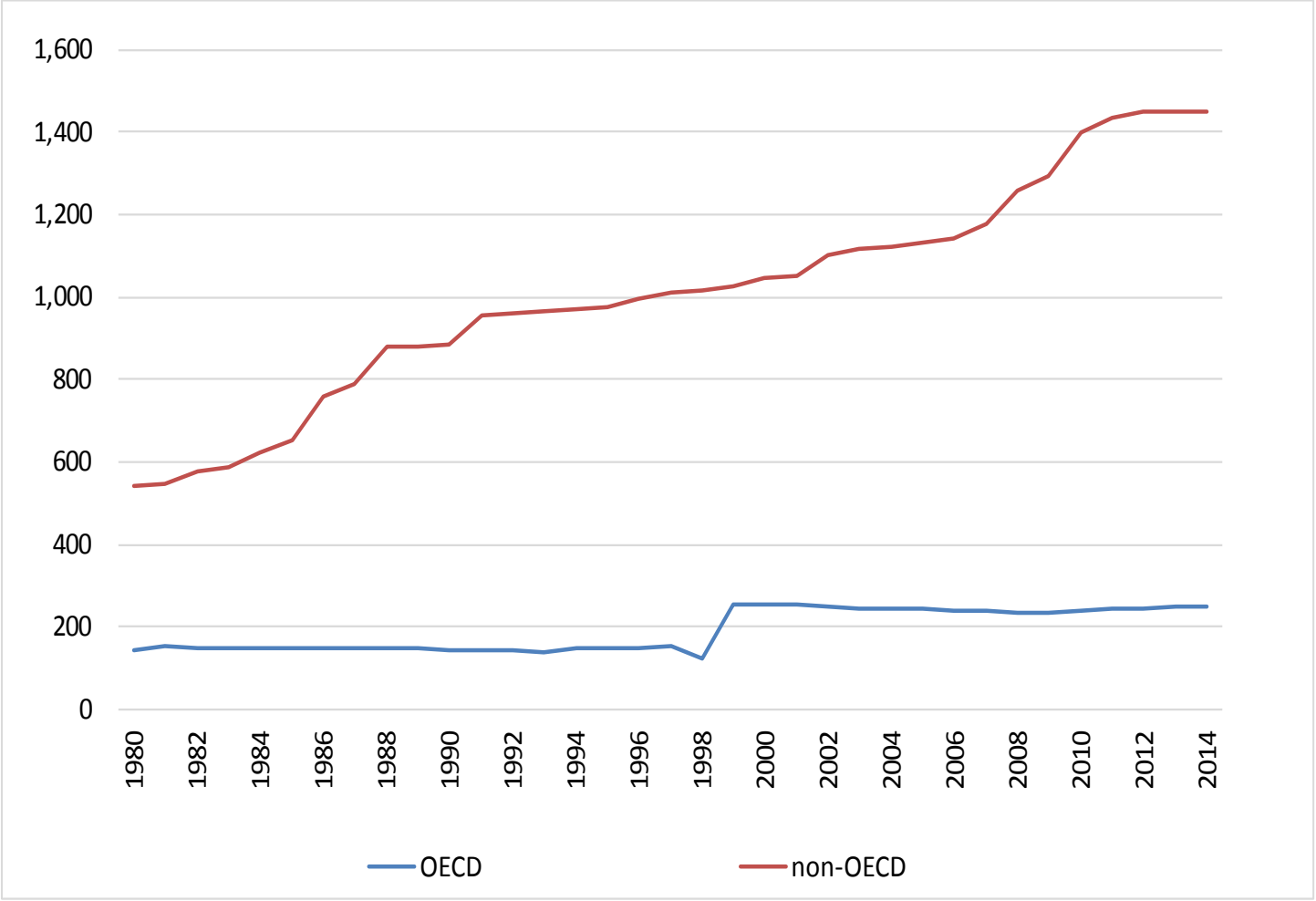
Other extensions

- Adaptation capital (sea walls, storm surge barriers) increases with global warming: trade-off with productive capital.
- Positive feedback in the carbon cycle changes carbon cycle dynamocs (e.g., Greenland or West Antarctica ice sheet collapse).
- Multiple tipping points with different hazard functions and impact lags (Cai, Judd, Lontzek). 'Strange' cost-benefit analysis (Pindyck).
- Learning about probabilities of tipping points, but also about whether they exist all (cf. 'email-problem'). How to respond to a tipping point which may never materialize?
- Exhaustibility of fossil fuel: so anticipation of tip $\Rightarrow$ Green Paradox.
- Second-best issues: Green Paradox can lead to 'runaway' global warming if system is tipped due to more rapid depletion of oil, gas and coal in face of a future tightening of climate policy (Winter, 2014).

SO FAR, MOSTLY TALK

- Paris has agreed to steer to below 2 degrees Celsius, but that was mostly to keep the island states on board. Not clear whether strong action will happen.
- In the mean time oil and gas discoveries have been rising steadily, and outstripping extraction, for decades (see graph on next slide).
- And fossil fuel subsidies are huge (6.5% of world GDP according to the FAD of the IMF).
- Even if emissions are frozen, temperature will continue to rise due to the long time lags.
- But oil price has fallen dramatically to under $30/barrel. This has led to a lot of reserves being mothballed.

Proven oil reserves in OECD and non OECD countries



Note: Data are from BP. Units are thousand million barrels.

Other threats to oil and gas producers

- Risk of stranded assets if global warming is to be limited to 2 or degrees (Allen et al., 2009; McGlade and Ekins, 2015; IPCC). Already IOCs can't burn all their reserves. Pricing carbon and subsidising renewables will put fossil fuel producers out of business.
- But also risk of oil and gas prices staying low for long time due to expansion of shale gas & unconventional oil.
- And arrival of new and cheap fossil fuel substitutes driven by technical progress (LNG, sub-surface platforms, sea bed extraction).
- Arrival of new game-changing carbon-free substitutes (e.g., fusion).
- Risks of new technology and tightening climate policy induces fossil fuel producers to pump more vigorously: Green Paradox.
- Might this incite fossil fuel importers to price carbon more quickly and vigorously (also to capture some of scarcity rents). Vicious circle?

What can oil- or gas-rich countries do in face of these risks?

- Diversify and become less specialised and dependent on export of fossil fuel. Work on a plan B!
- Make product and labour markets more flexible. Get rid of monopolies and make markets transparent and more competitive.
- Improve institutions and invest in state capacity (i.e., power to tax, support contract and infrastructure, establish peace and order, and spend on collectively valuable goods and services) before fossil fuel has run out or has become uncompetitive.
- Get rid of fossil fuel subsidies.
- Save the windfalls for as long as they last in a SWF. This does not only smooth consumption, but also helps to smooth the real exchange rate.
- Diversify investments in the SWF away from oil (correlated with the market). Divest from fossil fuel funds. Deleverage as fossil fuel runs out.
- Hedge by investing in decarbonised stock market index.

FUTURE RESEARCH

- Divesting fossil fuel or better dynamic and transparent hedging strategies against the risk of a dramatic and prolonged fall in oil prices, the “risk” that cumulative emissions will really be curbed, and the “risk” of finding really cheap carbon-free alternatives for oil and gas is a good start.
- Many oil-rich countries that do not have SWFs or a plan B and are in dire situation, and many have suffered from the curse of resources.
- But oil-rich countries with a SWF need to think of de-carbonisation strategies taking account of their large stocks of below-ground oil and gas reserves.