PRIJS VAN HET KLIMAAT

LANDELIJKE VERENIGING VAN NATUURKUNDIGEN

UB UTRECHT, 9 JUNE 2017

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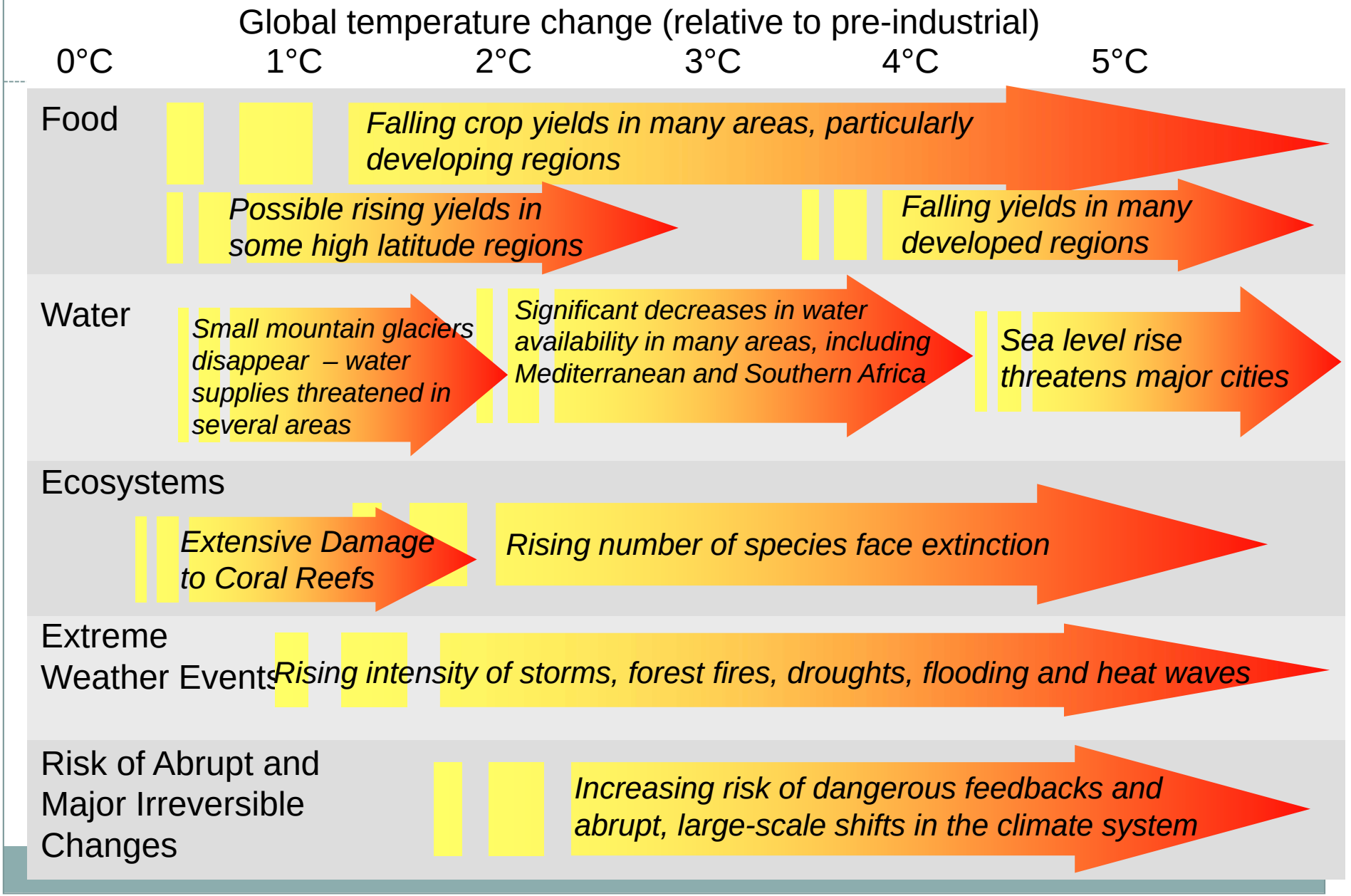
GLOBAL CLIMATE CRISIS

- Since 1750 both world population and production per person have risen tenfold. Hence, gigantic pressure on environment.
- World population will go from 6.6. to 9 billion in next forty years and all these new people need to eat, to be housed and to transported.
- No ‘peak oil’: lots of coal and .. shale gas
- During coming decades CO2 concentration in atmosphere may double: global warming.
- And it is anthropogenic – caused by human beings (Crutzen). Half of CO2 caused by vehicles, industry and especially coal-using energy companies. Rougly 20% caused by deforestation. Methane via cattle also important cause of greenhouse gas emissions.

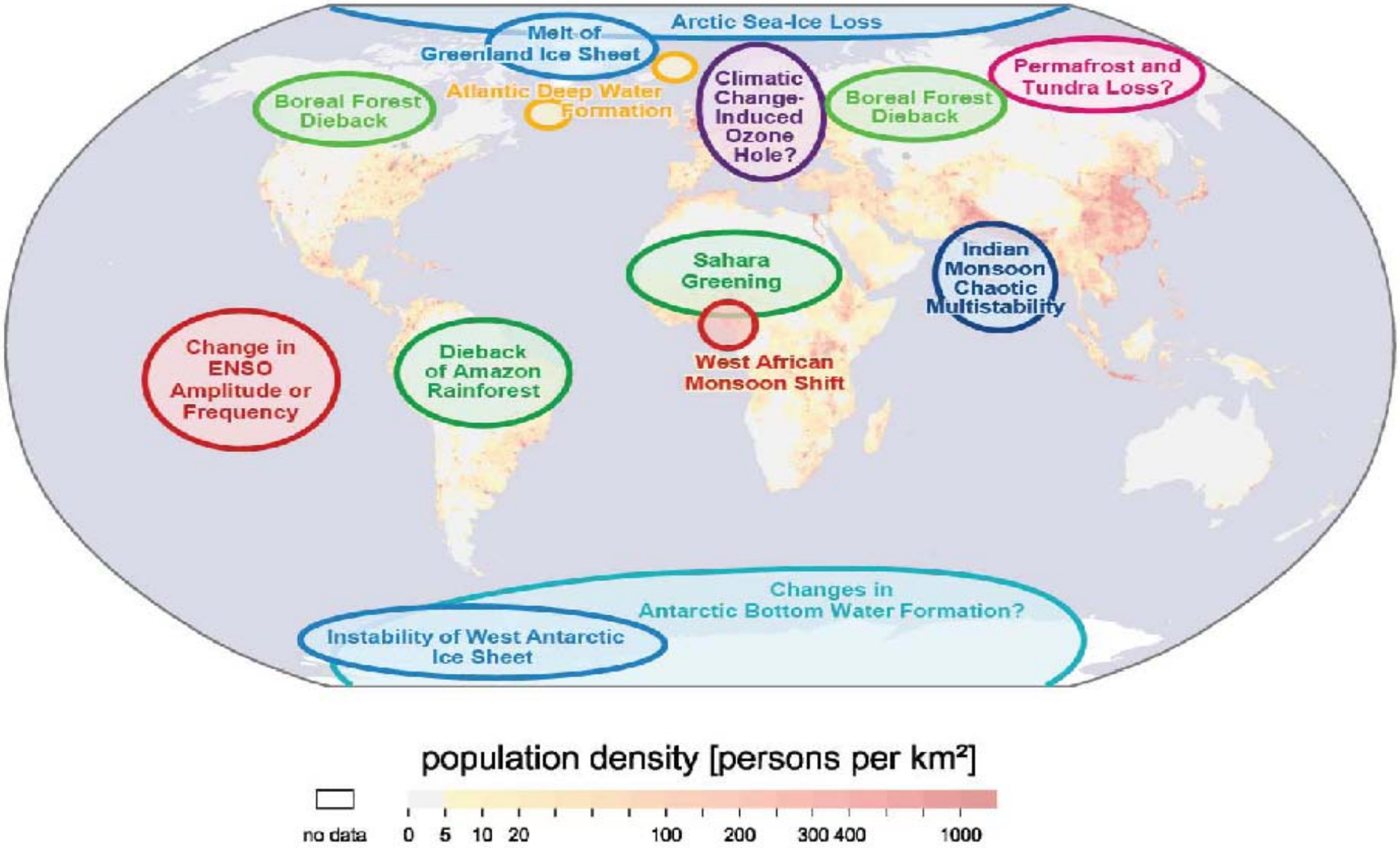
Risks of global warming

- Rising sea levels, more hurricanes, destruction of natural habitats, acidification of oceans leading to destruction of coral reefs and plankton, infectious diseases of hitherto unknown diseases, massive shortages of water (only 2.75% is fresh water and three quarters of that in icecaps etc.), desertification
- Much of burden falls on developing countries, who were not even responsible for global warming.
- Risk of tipping points and irreversible thresholds. Need not only mitigation, but also adaptation.

Disruptions from global warming



Tipping Points in the Earth System



Source: Lenton and Schnellnhuber (2007)

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.		

CARBON PRICING: GOLDEN POLICY

- Curbs demand for fossil fuel: less car trips, heating a degree less, etc.
- Induces substitution away from fossil fuel to renewables and brings forward the carbon-free era.
- Encourages learning by doing and R&D into clean fuel alternatives and energy-saving technology.
- Encourages to leave more fossil fuel in the crust of the earth.
- *Induces substitution from tar sands, coal, crude oil to less carbon-intensive gas.*
- *Encourages CCS and limits slash & burn of forests.*

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

- 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.

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.

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 subsidized, 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?

Netherlands: CPB 2015

- 540 Euro fossil fuel subsidy per Dutch citizen.
- Companies are responsible for 80% of emissions but pay not even half of all emission taxes.
- Coal companies have again been exempted in 2016. The 189 million loss in revenues has to be coughed up by consumers.
- Biggest polluters pays the least. Energy transition is frustrated.
- Disastrous policies: need moratorium on coal and get rid of all fossil fuel subsidies first..

Problem 4: Equity

- 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.
- Replace subsidies with general tax deductions for the poor, which is a cheaper way to achieve same distributional goals.
- 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.

Problem 5: Intergenerational challenge

- Current generations must make sacrifices today to cut global warming decades or centuries in the future.
- So they are not going to be alive to enjoy their sacrifices. So why would they?
- Need climate-debt deals.
- Or even better climate-pension deals where pensions are PAYG financed (i.e., current young finance pensions of current old).
- So crucial role of pension funds and other institutional investors in making climate policy work.

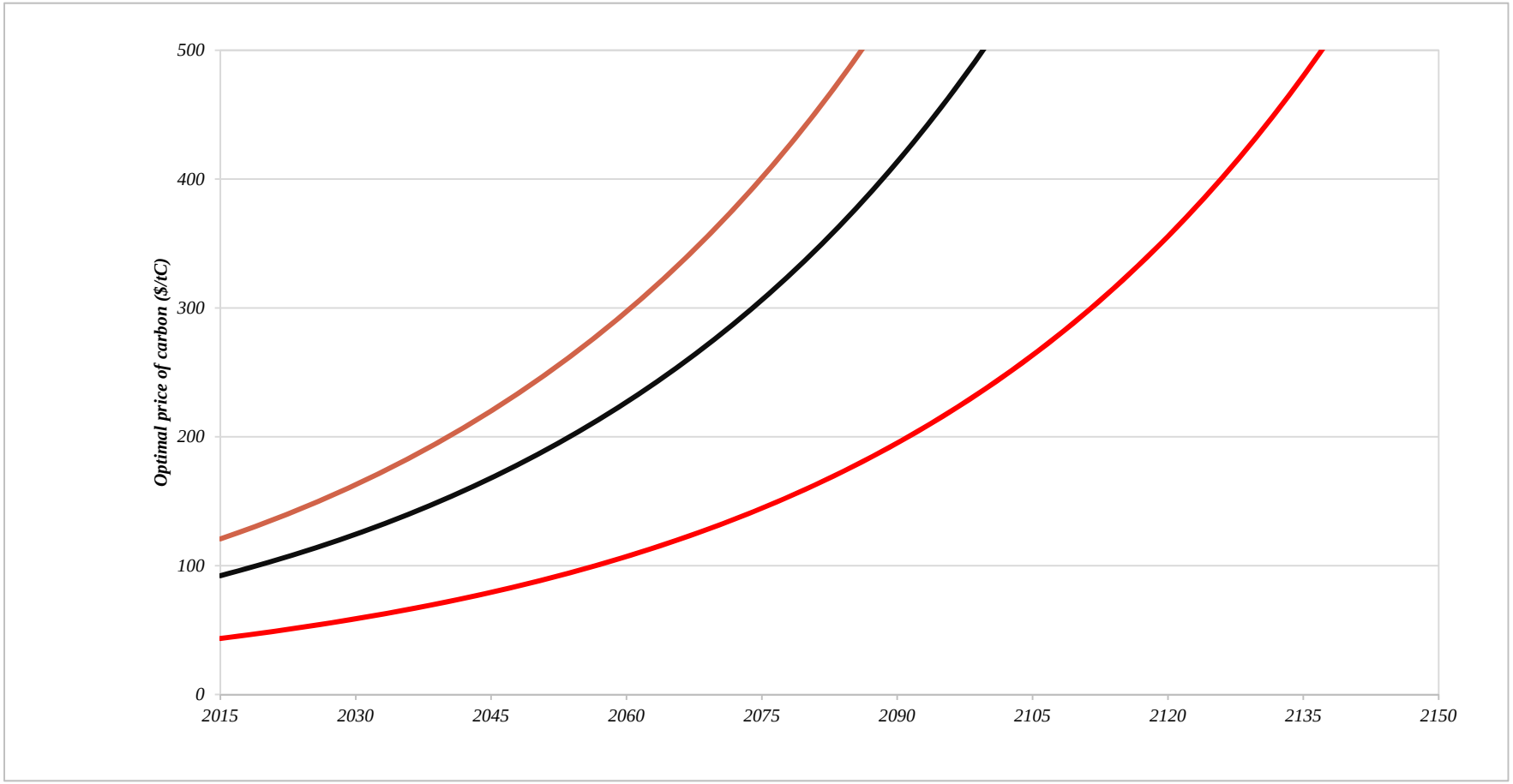
PEAK GLOBAL WARMING

- Peak global warming (PGW) driven by cumulative carbon emissions (CE).
- Time path of emissions reductions does not matter. What matters is the safe budget.
- PGW = 1.276 + TCRCE x CE, where TCRCE is the transient climate response to cumulative emissions.
- The mean value of the TCRCE is about 2 degrees Celsius per trillions tons of carbon with a 5-95% confidence range of 1.4-2.5 degrees Celsius.
- Ignoring uncertainty, the safe carbon budget is 362 GtC.
- With risk tolerance of 1/3, safe carbon budget is lower: 335 GtC.
- If the target is 1.5 degrees, it is only 104 GtC. Only ten years left.

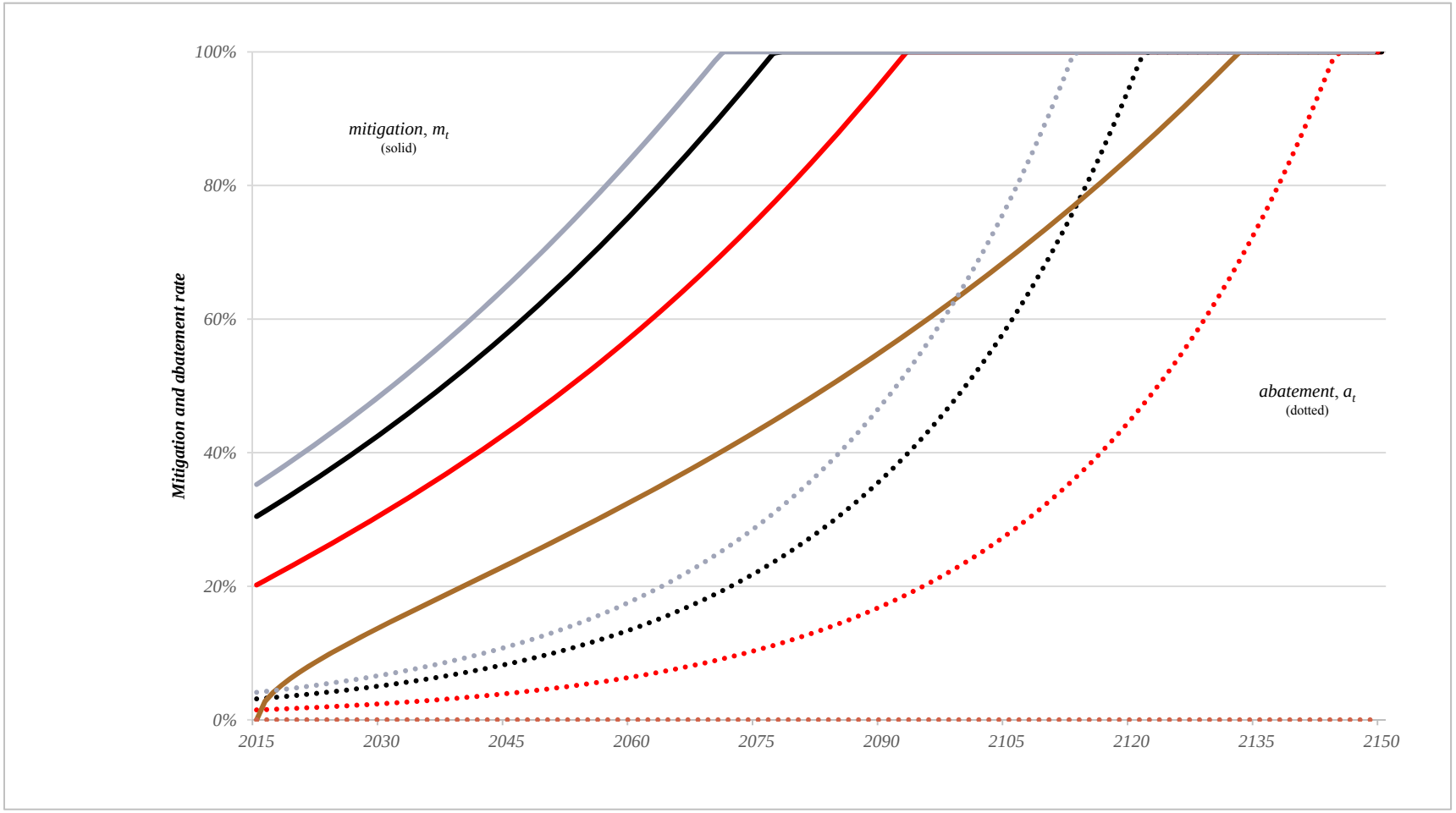
CONSTRAINED WELFARE OPTIMISATION

- Policy makers maximise welfare of current and future generations subject to the constraints of the economy, the dynamics of carbon and temperature, and the safe carbon budget constraint.
- This determines the time path of emissions.
- This depends on *ethics* (discounting, intergenerational inequality aversion); *geo-physics* (how much stays up how much returns to oceans, tipping, etc.); *global warming damages*; *costs of energy and technical progress*.

Red = Nordhaus with 635 GtC; black = safe carbon budget with σ = 0 and 362 Gtc
Brown = safe carbon budget with σ = 0.6 and 280 GtC



SAFE CARBON BUDGET
Mitigation (solid) and abatement (dashed)



Hyperbolic discounting

- 74% choose fruit and 26% chocolate if they have it next week, but 30% and 70% if they have it now.
- People join gym for $75/month, but go only 4 times so effective cost is $19/visit. Whereas without joining they would only pay $10/visit on PAYG basis.
- Self wants to be patient and delay gratification, but our actions indicate we crave for instant gratification.
- Politicians are the same.
- Hyperbolic discounting explains procrastination in setting climate policy. So pricing carbon is put off.
- Can also use this to bridge high present & low future discount rates.

What if future is discounted less heavily in the distant future?

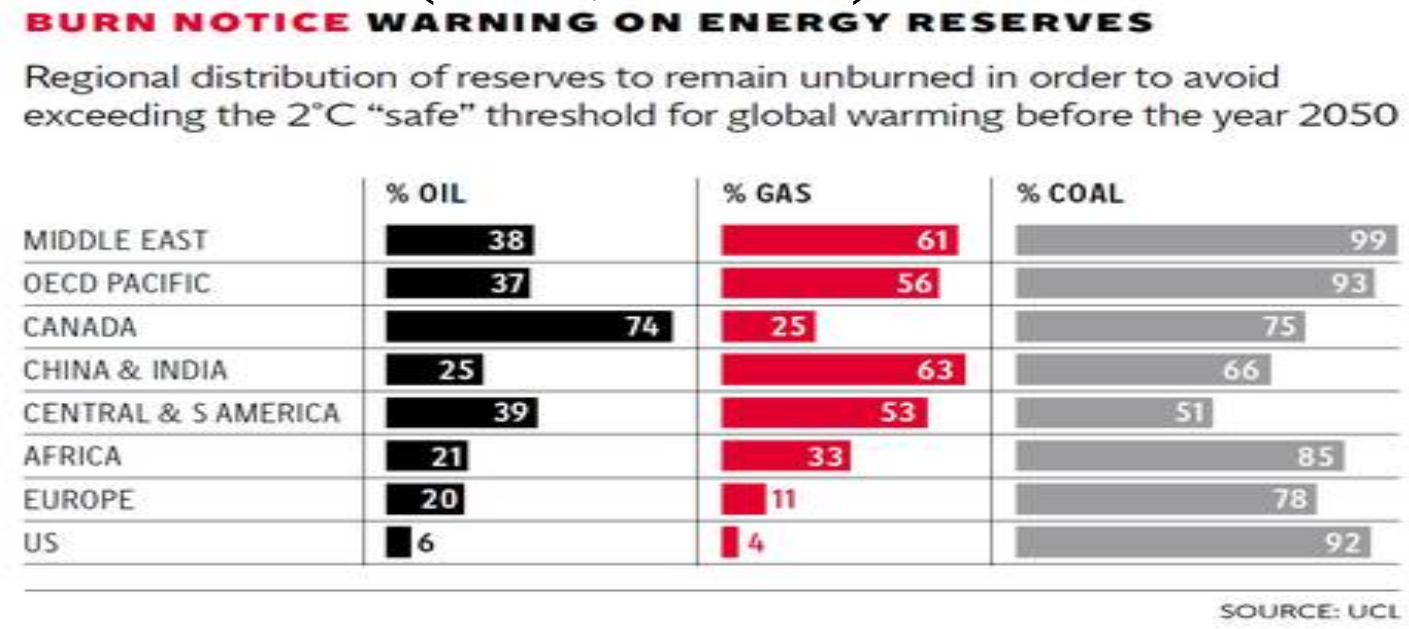
	Carbon price P_0	Abatement a_0	Mitigation m_0	Carbon budget B	End fossil era	Peak warming
Exponential discounting (DICE)	44 $/tC	1.5%	20%	635 GtC	78 yrs	2.6°C
Hyperbolic discounting (no commitment)	**92 $/tC**	**3.1%**	**30%**	**362 GtC**	**63 yrs**	**2.0°C**
Hyperbolic discounting (with commitment)	92 $/tC	3.1%	30%	320 GtC	59 yrs	1.9°C
Business as usual	0 $/tC	0%	0%	1,778 GtC	118 yrs	4.9°C
DICE	48 $/tC	–	17%	1,171 GtC	110 yrs	3.3°C

RISK OF STRANDED ASSETS

- To keep global warming below 2 degrees Celsius the world can only burn a couple of hundred GtC.
- Reserves of big oil and gas companies are much bigger and that is not counting reserves of state companies. And there is a lot of new investment in fossil fuel including shale gas.
- There is a serious risk of stranded fossil fuel assets. Short the oil and gas majors?
- What should for gas-exporting countries like Russia, Nigeria or Algeria do? Race to burn the last ton of carbon? (Limit pricing?)
- In any case, ongoing explosion of carbon discoveries and reserves cannot go on if planetary warming has to stay below 2 degrees Celsius. Need carbon pricing and climate club.

2 degrees Celsius target & stranded carbon assets

Keep 1/3 of oil (Canada, Arctic), 50% of gas & 80% of coal (mainly China, Russia, US) reserves unburnt. Reserves 3x and resources 10-11x the carbon budget. In Middle East 260 billion barrels of oil cannot be burnt. McGlade and Ekins (2015, Nature)



Irreversibility and stranded assets

- Yes, coal, oil and gas will have to be locked up in the crust of the earth.
- But that does not mean that big oil and gas companies such as Gazprom, BP or Shell will have to write off large chunks of assets on their balance sheet or even go bankrupt, especially if they can easily reverse their past exploration investments.
- However, much **irreversible** investments in say coal-fired electricity power stations will have to be written off. So many industries locked into carbon will be hit unless they become green.

TIME SCALE AND HEDGING CLIMATE RISK

- Climate risks are very, very far in the future.
- So need to use **very low** discount rates for discounting benefits say 100 years from now: Martin Weitzman.
- Cannot infer discount rates from market rates of return.
- A climate hedge is an investment project that yields a really big return in 100 or 200 years if global warming then turns out to be much hotter than expected. Problem: what are these projects apart from dykes, water defences, etcetera?
- Climate beta is close to one in most models. Realistic?
- Since the market is not anticipating tightening of climate policy, it is very cheap to hedge climate risk by investing in carbon-free tracker indices (e.g., those of MCCC).

COUNTRY RISKS

- Countries which export a lot of oil and gas like Russia, Algeria, Venezuela, Nigeria, Norway and Brazil have been hit a lot by the crash in world oil and gas prices.
- Norway has managed by dipping in its huge SWF and managed to mitigate their depreciation of their currency.
- Nigeria and others have had huge depreciations, high budget deficits, loss of foreign reserves and inflation. Russia did less bad, since it is did a big once and for all depreciation of the Ruble.
- Still, these countries will suffer if they commit to Paris COP-21 as they will have stranded carbon assets.
- Russian cannot burn 20% of oil and 60% of gas reserves in view of COP-21, so Russia's budgetary policies will be even more unsustainable and even more tightening of the fiscal stance is required. Need to tighten fiscal stance by a further 1 %-point of GDP. On top of what is required to deal with sustained lower oil prices.

CLIMATE SCIENCE AND ECONOMICS?

The Journal of Alternative Facts 01 (2017) 01–20

The Journal of Alternative Facts

We Have All the Best Climates, Really, They're Great

Iwas A. Scientistonce *

* and now I have all my research approved by a public relations office

Abstract

The research presented in this paper is really the best research that you will ever see. We have methods, the best methods, and we used them to study climate. As you may already know, the Earth, led by America, has all the best climates. In this paper we refute prior work by out-of-touch scientists who insist that the climate is changing – why would it change, when it's so great already? It is not getting warmer. In fact, our findings show that you were cold at least one day last year. Our (really fantastic) data also reveals that America has all the best CO2 levels, really great levels. In our discussion, we reveal that there is no reason to believe a bunch of scientists who spent all their time learning and studying "facts" instead of being out in the real world making jobs. Our alternative facts definitively prove that scientists are losers. Finally, we had peer reviews, by all the best people, our people, because politicians know the most about science, the very best things about science.

Keywords: climate, "data", "facts", #makeclimategreatagain, "science"

Pascal's Wager

Pay-offs	Believe in God	Do not believe in God
God exists with prob π	$+\infty$ (infinity)	$-\infty$ (minus infinity)
God does not exist with prob $1-\pi$	-1 (finite loss)	$+1$ (finite gain)

$\pi \times \infty + (1-\pi) \times (-1) = +\infty$ always exceeds $\pi \times (-\infty) + (1-\pi) \times (+1) = -\infty$

provided π is positive, however small.

Hence, agnonistics (doubters) should believe in God.

Only atheists have $\pi = 0$ and should not believe in God.

The Agnostic's Response to Climate Scepticism: Tax Carbon!

- Welfare as percentage on initial world GDP

Pay-offs	Tax carbon	Do nothing
IPCC with prob π	**56%**	0%
Trump with prob $1 - \pi$	137%	179%

- Worst possible outcome if tax carbon is 56%; worst possible outcome if do nothing is 0%. So do best in worst possible outcomes: tax carbon. Max-min policy.
- With expected utility only price carbon if $\pi > 0.43$.
- Min-max regret:

Regrets	Tax carbon	Do nothing
IPCC with prob π	0%	56%
Trump with prob $1 - \pi$	**42%**	0%

THE END
THANK YOU

REMAINING SLIDES GIVE SOME FURTHER TECHNICAL DETAILS

The globally optimal price of carbon

- Global price of carbon must rise at same rate as world GDP.
- It is high if growth-corrected social discount rate *SDR* is low: if society is relatively patient (low *RTI*), if future generations are richer than current ones ($g > 0$ if $IIA > 1$), and if *IIA* high. High growth in GDP implies high growth in damages and thus a lower SDR and higher price of carbon.
- Temperature lag depresses optimal price of carbon.

$$P_t = \tau Y_0 e^{gt} \text{ with } \tau = \left(\frac{\beta_0}{SDR} + \frac{1-\beta_0}{SDR+\beta_1} \right) \left(\frac{1}{1+SDR \times Tlag} \right) d$$

and $SDR = RTI + (IIA - 1)g$,

Hyperbolic discounting: technically

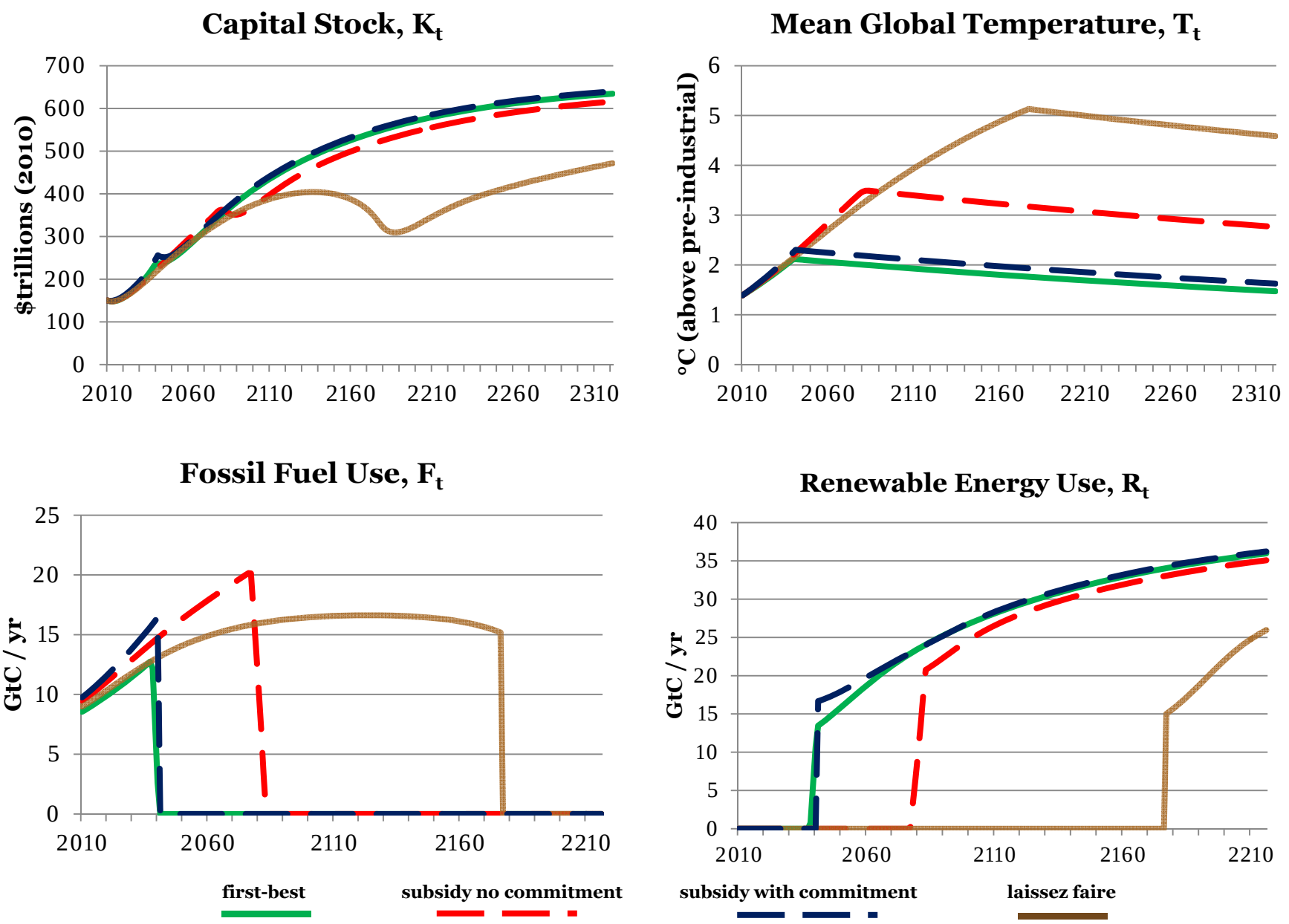
- Hyperbolic discounting has $D(t) = (1 + at)^{-\frac{\rho}{a}}$.
- Exponential discounting (as $a \to 0$) has $D(t) = e^{-\rho t}$.
- Instantaneous discount rate is $\delta_t \equiv -D'(t)/D(t) = \rho/(1+at)$.
- Calibrate *short-run* discount rate, ρ, to Nordhaus rate of 1.5% per year and *long-run* discount rate at t = 100 years to Stern rate of 0.1% per year, hence set a to 0.14% per year.
- Time inconsistency, so distinguish outcomes with and without commitment.

Second-best policy: 2 market failures

- 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 decentralised market conditions.
- Under pre-commitment, the government increases 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.

Second-best 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 red lines);
- III. the second-best case: subsidy with pre-commitment (dashed blue lines);
- IV. business as usual (BAU) without any policy (solid brown lines).


Capital Stock, K_t
$trillions (2010)
700
600
500
400
300
200
100
0
2010
2060
2110
2160
2210
2260
2310
Mean Global Temperature, T_t
°C (above pre-industrial)
6
5
4
3
2
1
0
2010
2060
2110
2160
2210
2260
2310
Fossil Fuel Use, F_t
GtC / yr
25
20
15
10
5
0
2010
2060
2110
2160
2210
Renewable Energy Use, R_t
GtC / yr
40
35
30
25
20
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10
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2010
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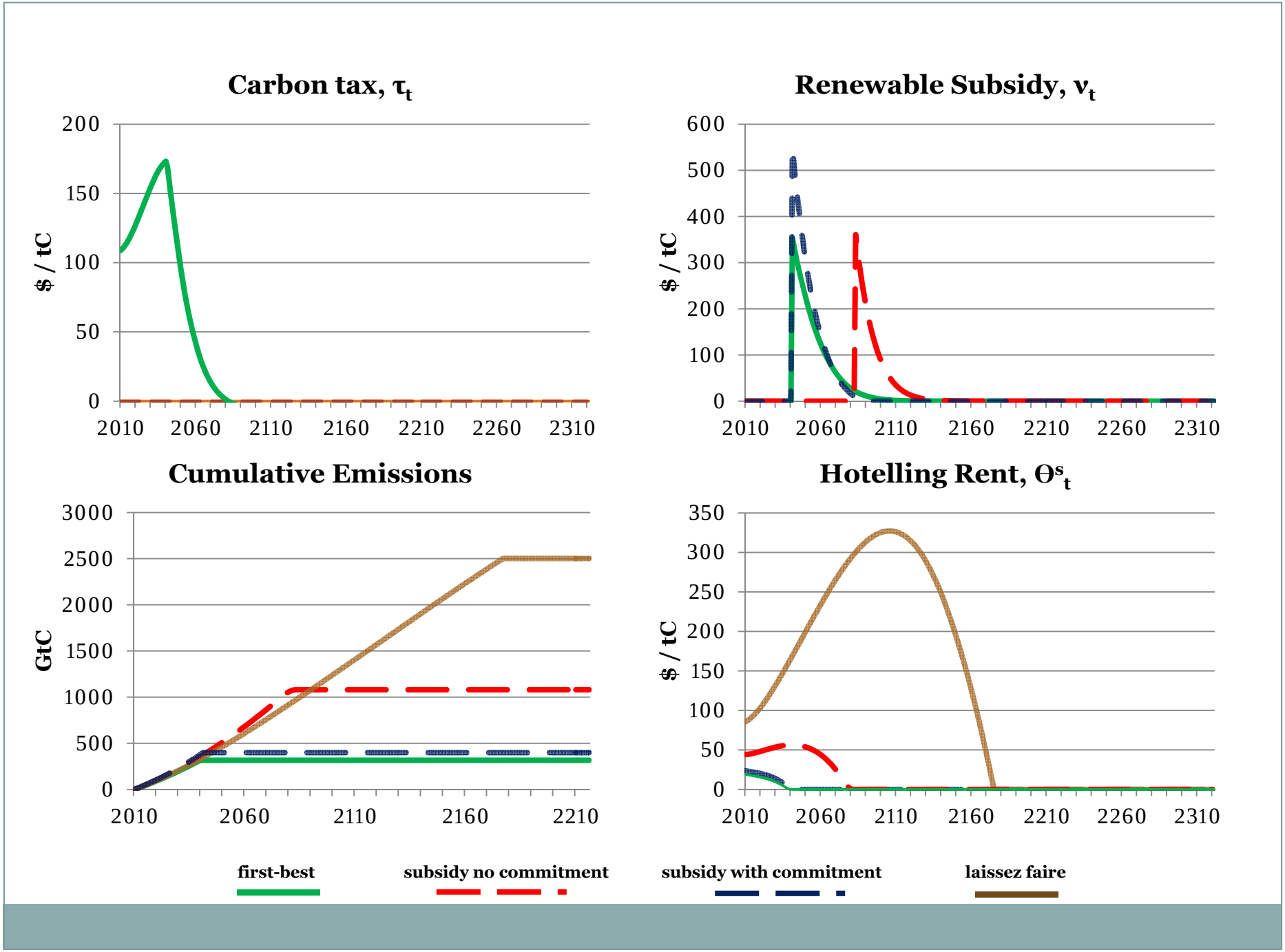
2160
2210
first-best
subsidy no commitment
subsidy with commitment
laissez faire


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
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2010
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first-best
subsidy no commitment
subsidy with commitment
laissez faire

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