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CAMBRIDGE | **Electricity Policy  
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# Oil shortages and climate change

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<http://www.eprg.group.cam.ac.uk>

# Outline

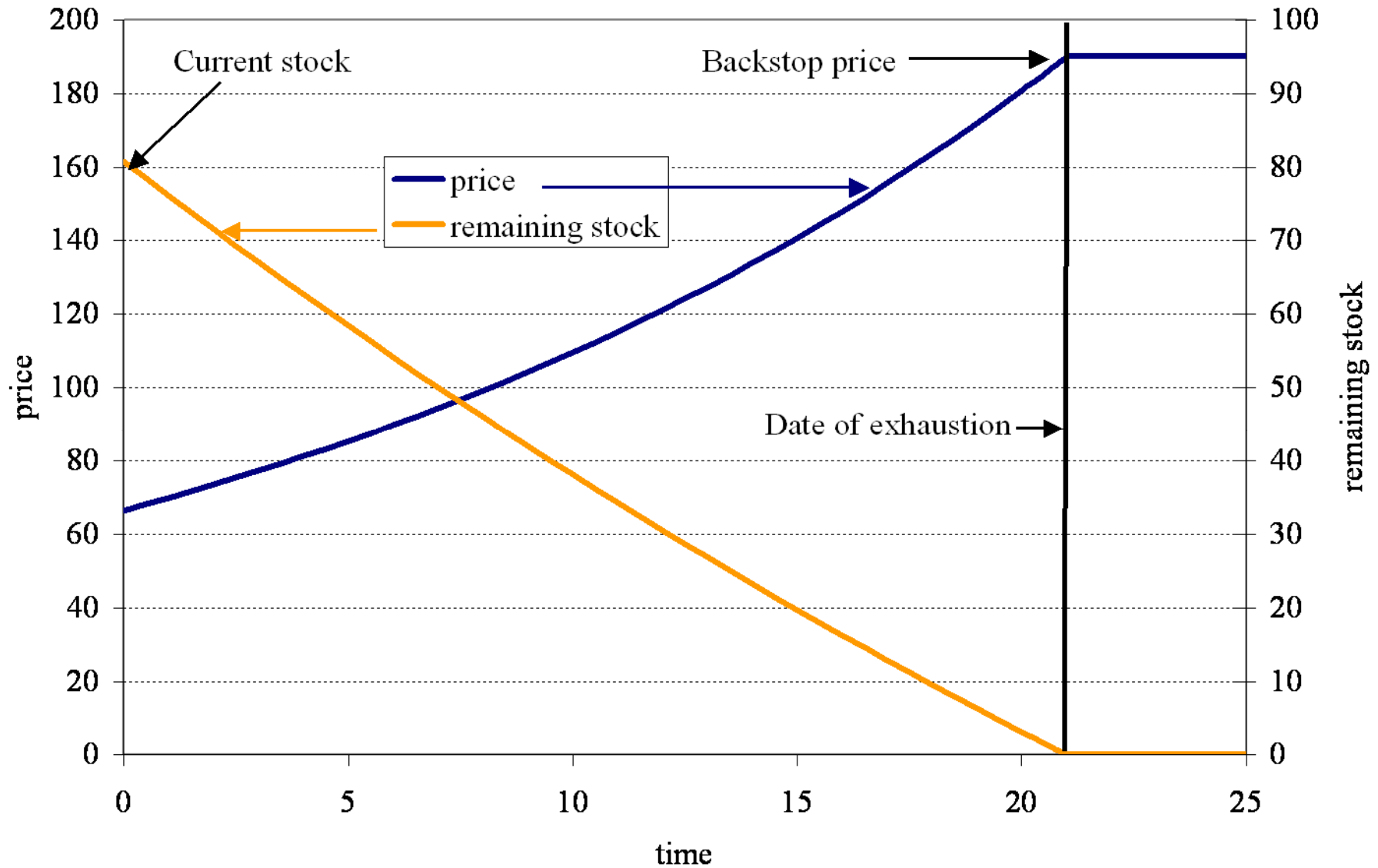
- Oil - exemplar of an exhaustible resource
  - pricing in theory and practice
- Mitigating Climate Change
  - The EU Emissions Trading System and its flaws
  - the case for a carbon tax/price
- Problems: prisoners' dilemmas
- Solutions - incentives for compliance
- Effect of carbon tax on climate change

# Exhaustible Resource Theory

## Competitive case, no externalities

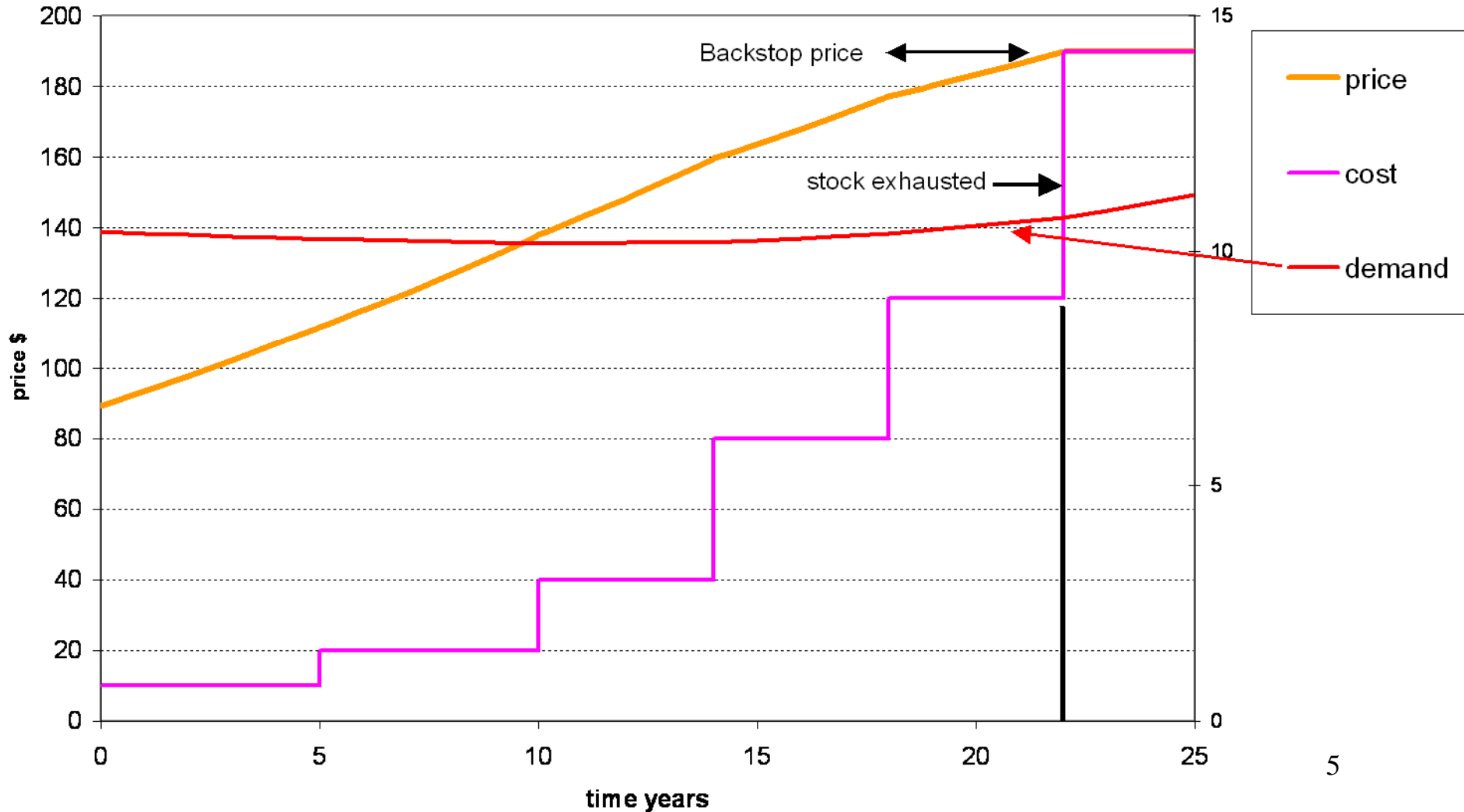
- current price depends on **expectations** about future
  - price  $p_t$  less marginal extraction cost = **rent**
  - rent rises at interest rate  $r$  during extraction
  - backstop price  $p^*$  set by substitutes or exhaustion
  - $p_0$  depends on stock
- Simple case: perfect certainty, zero cost oil  
=> given stock; **solve for exhaustion date and  $p_0$**

# Simple Hotelling - no demand growth, zero cost oil



# Pricing oil: variable costs and income effects

## Price, cost and demand for an exhaustible resource





# Fuels, GHG and scarcity

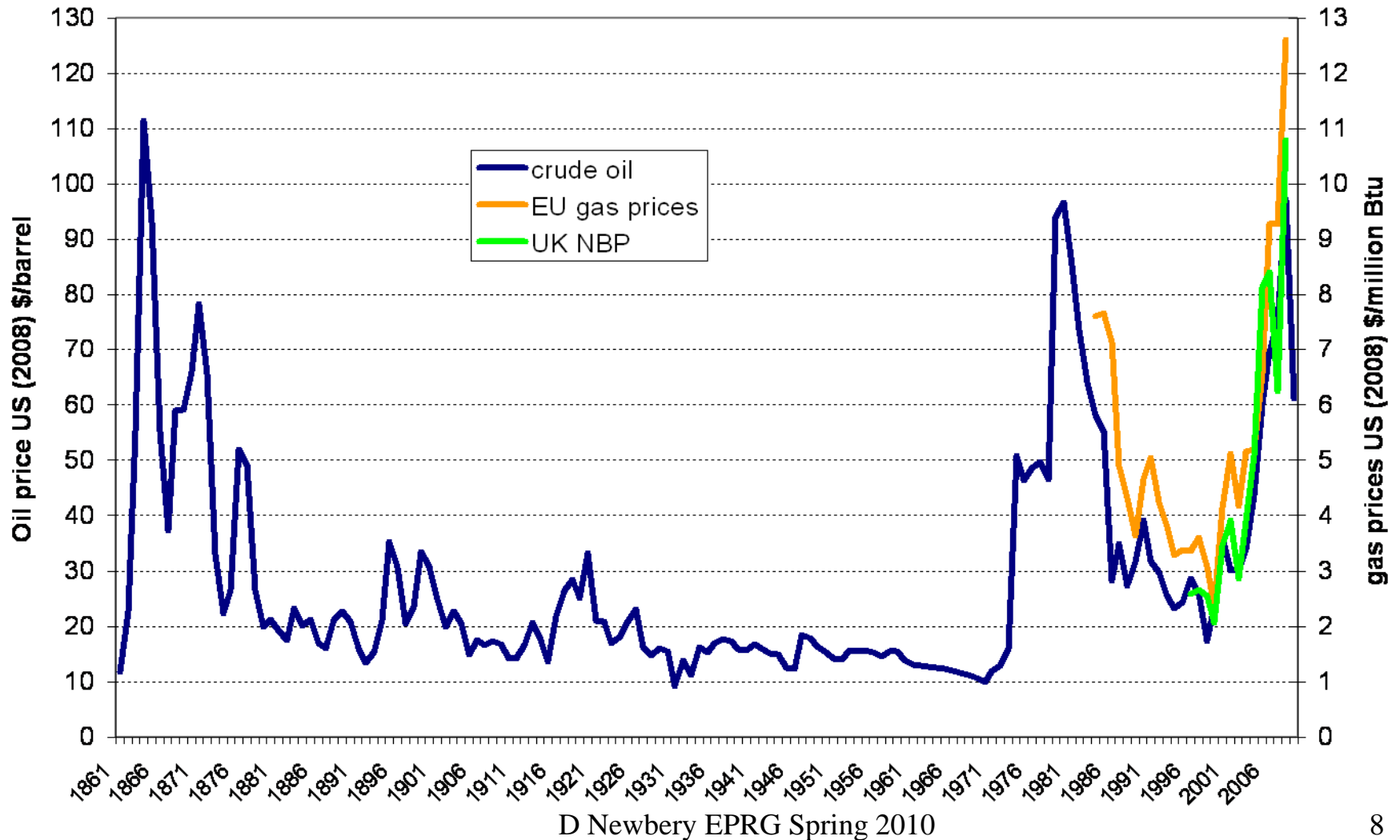
- Oil and gas are exhaustible resources
  - efficient price depends on future stocks, costs
  - **shortages**  $\leq$  markets not clearing - for political reasons?
- Shocks affect current price
  - new **discoveries**, **technical progress**, backstop  $p^*$ , changes in ownership affecting  $r$ , **supply constraints**
- competitive markets can price for scarcity
  - if “peak oil” is anticipated, prices should rise to clear market
  - but markets are not competitive
- fossil fuels are major source of GHG CO<sub>2</sub>

***GHG emissions are a global public bad***

***“greatest .. market failure ever seen” (Stern)***

# Pricing oil - practice

Real crude oil prices 1861-2009 and gas prices 1984-2008

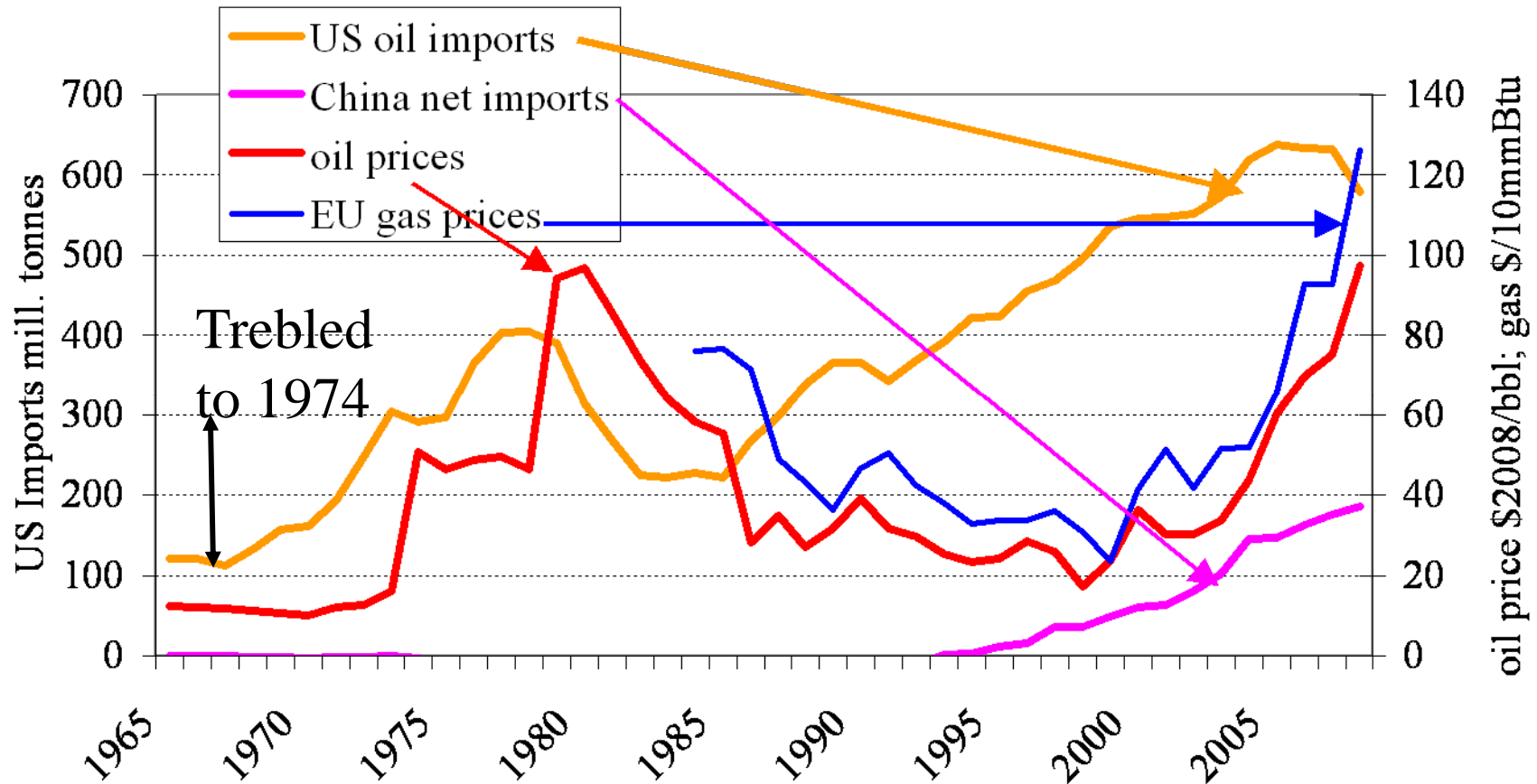


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# What caused the oil price shocks?

US and Chinese oil imports and oil and gas prices

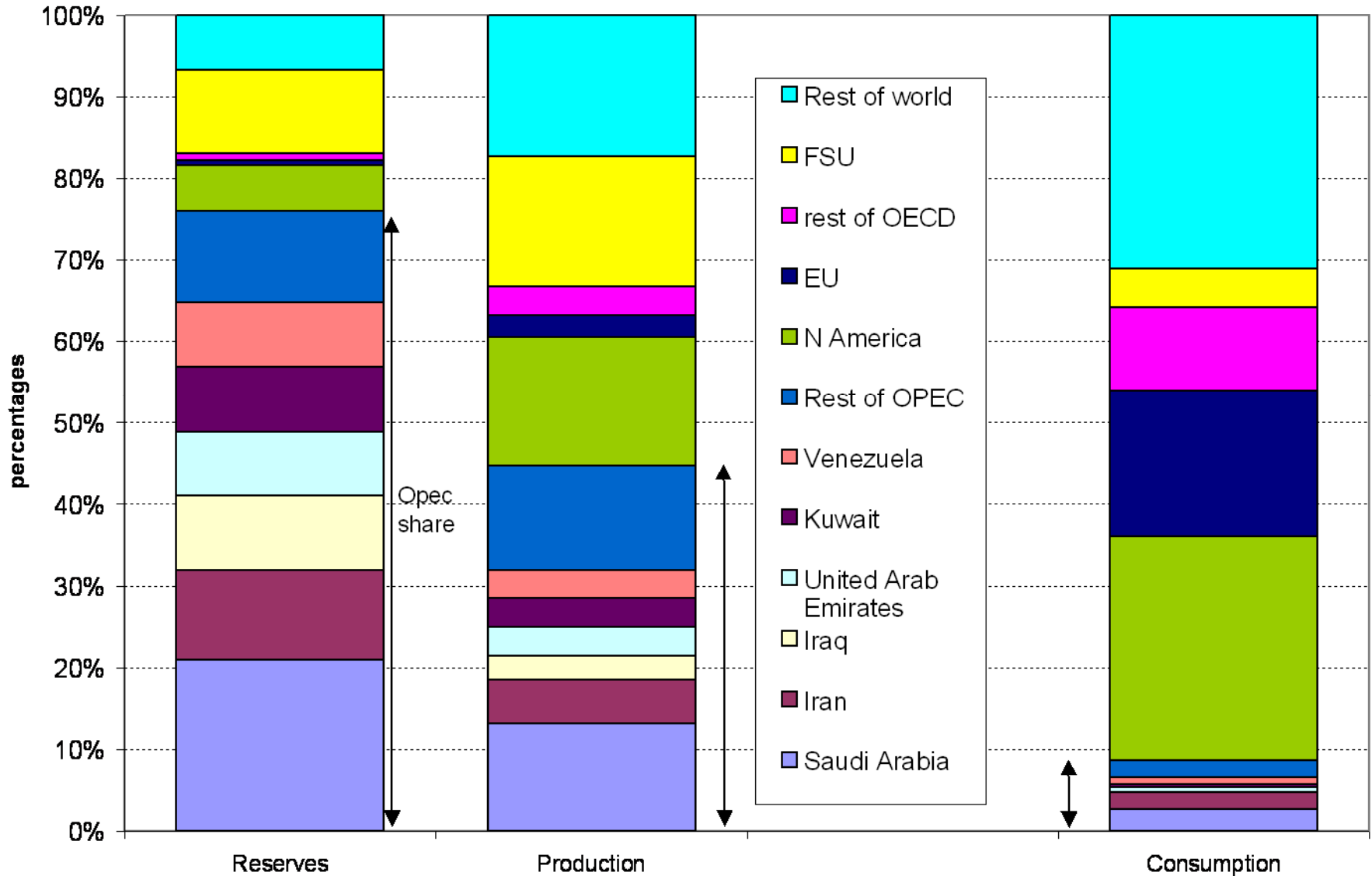


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# Market failures

- Oligopoly => prices higher than otherwise
- Imperfect property rights => overexploitation
  - or lowers interest rate on secure foreign assets => under-exploitation and higher prices?
- Import cartels - e.g. fuel import tariffs
  - raise domestic price => reduce demand => lower world price (*but how much?*)
  - not credible? Temptation to cheat in future
- Externalities in use - GHG emissions
  - => restrict use, lower demand and world price

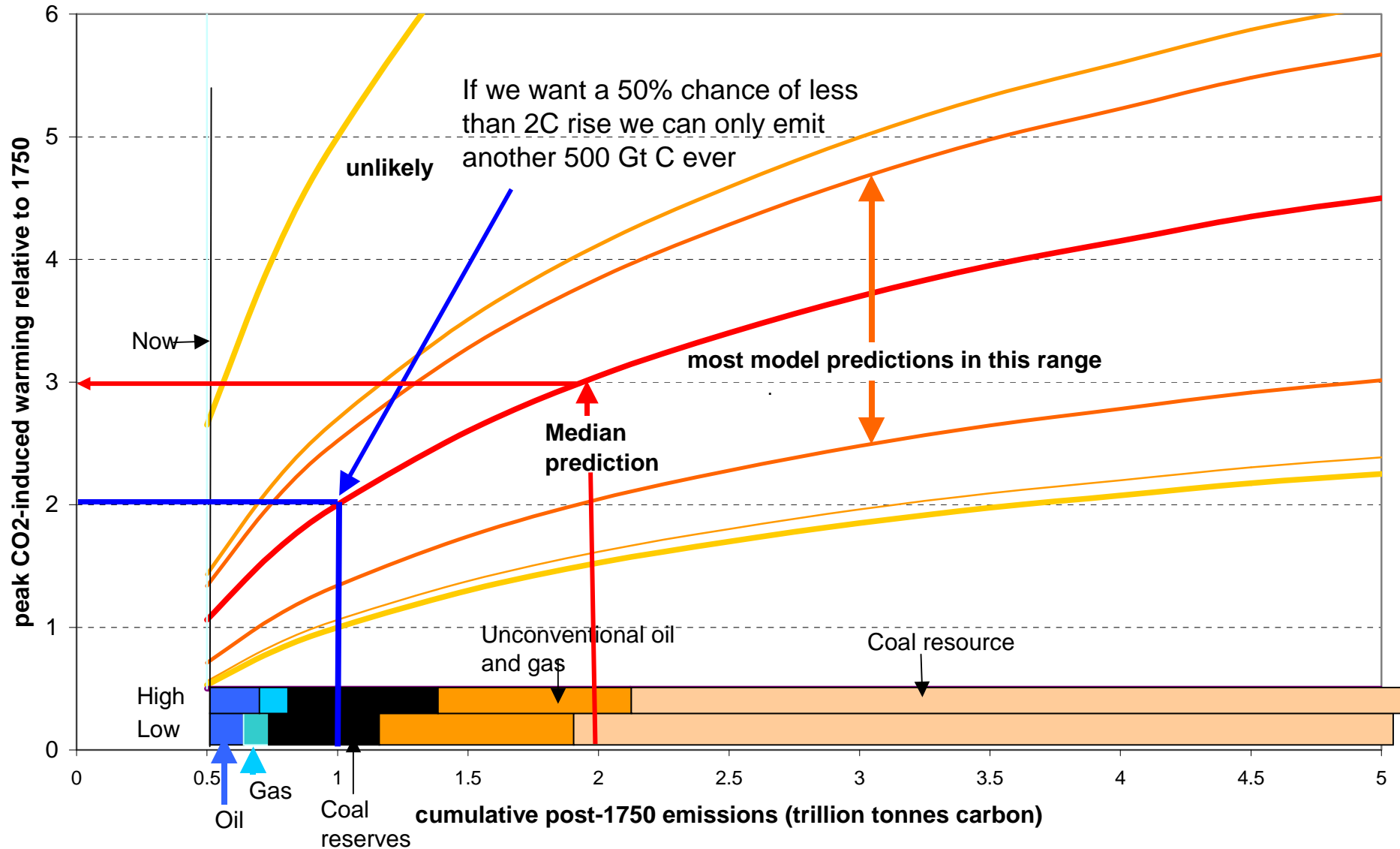
# Reserves, Production and Consumption shares 2008



# Policies for mitigating climate change

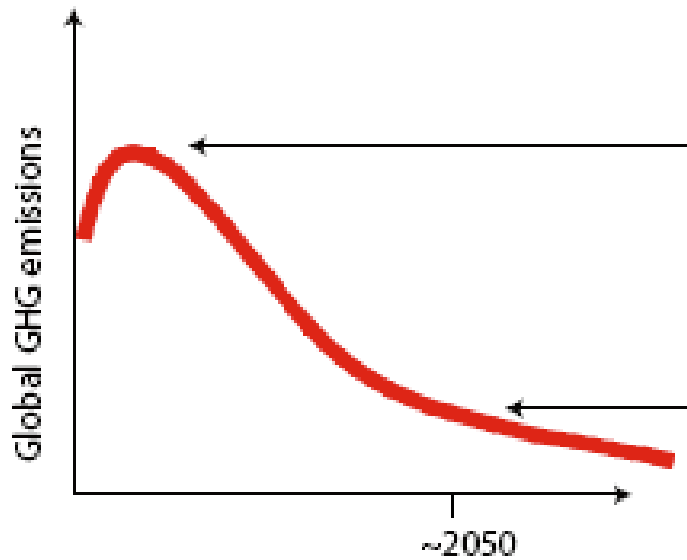
- GHG emissions are a **global stock public bad**
  - uncertain distant damage with uneven impacts
    - => **very hard to agree coordinated policies**
  - damage regardless of emissions location, persistent
    - => **damage moderately independent of date of emission**
  - much irreversible over historical time scales
- Solution: uniform charge for GHG emissions,
  - charge rises at discount rate
  - reset in light of new information

# Peak CO<sub>2</sub>-warming vs cumulative emissions 1750–2500



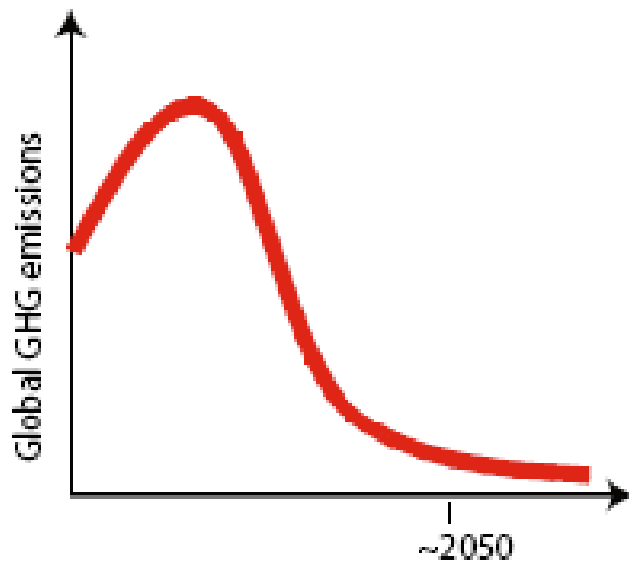
After MR Allen *et al.* *Nature* **458**, 1163-1166 (2009) doi:10.1038/nature08019

# Total cumulative emissions determines global warming



Lower peak

Gradual reduction after peak



Higher / later peak

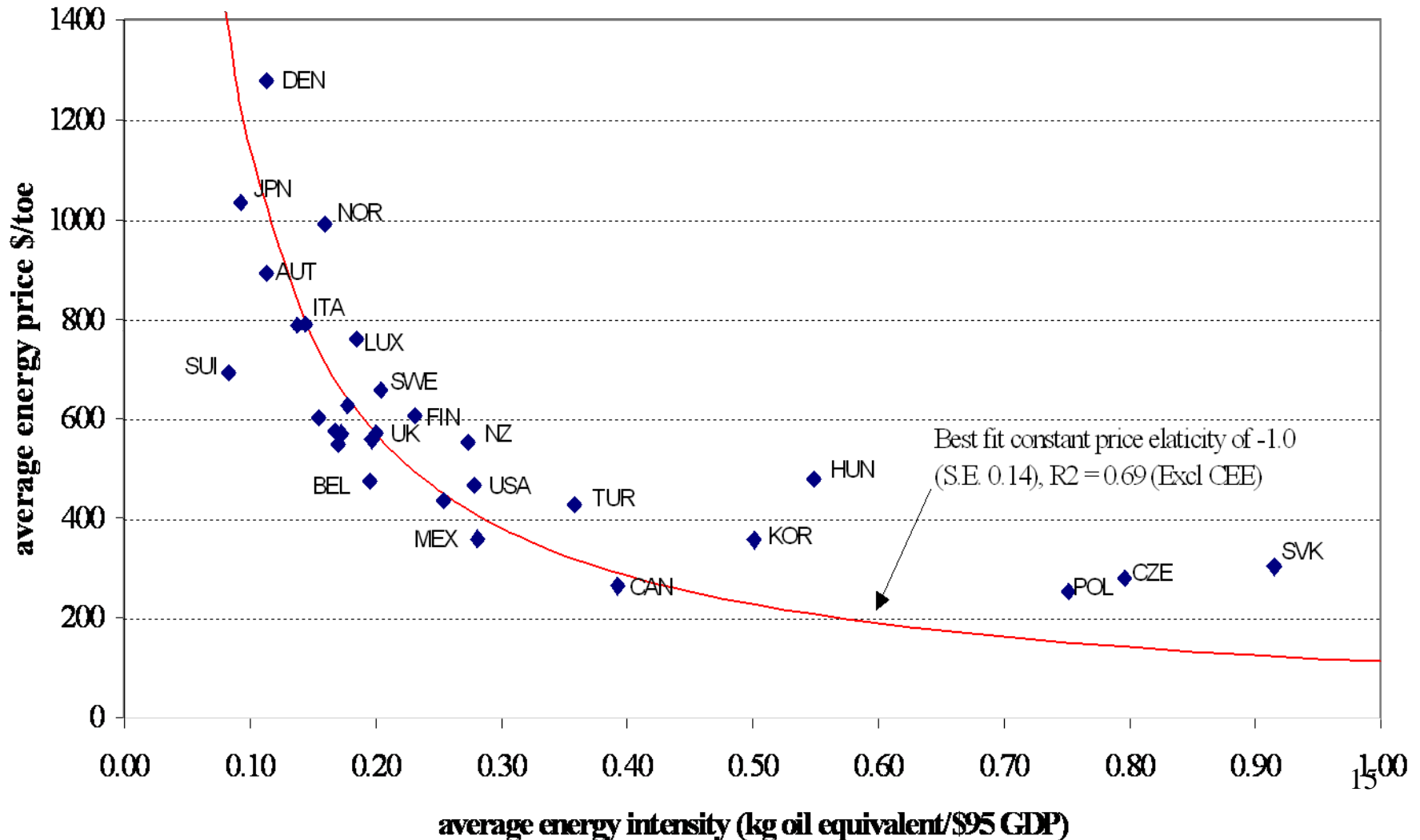
Faster reduction after peak

- Delaying peak requires a faster subsequent decline
- peak should be before 2020

Source: ENEP Emissions Gap Report 2010

# Prices matter for energy use!

Cross-section relation between average energy intensity and average energy price  
1993-99



# Controlling GHG emissions

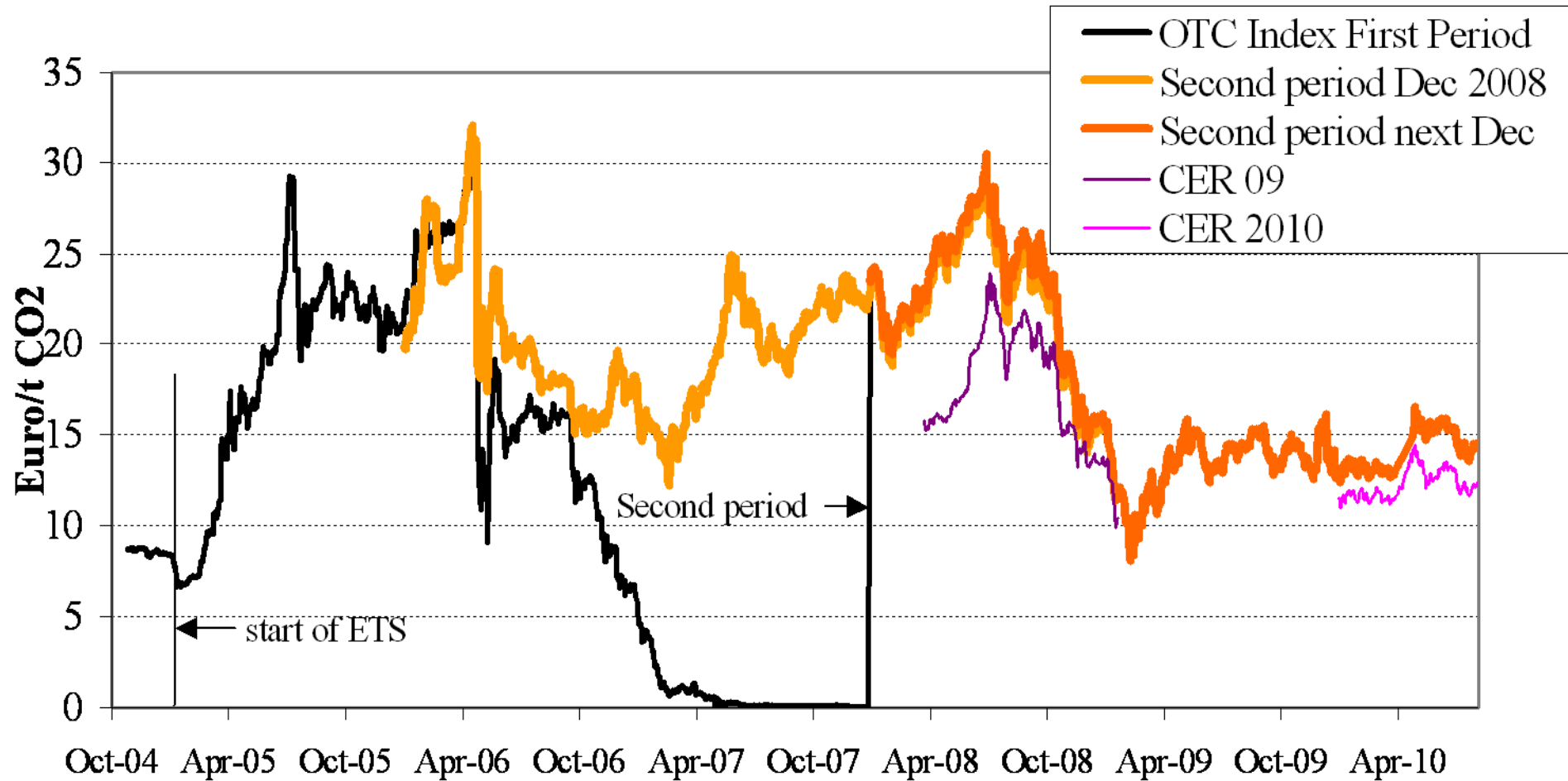
- Kyoto to agree targets for reduction by 2012
  - Annex 1 countries, CDM/JI to encourage others
  - But Copenhagen failed to extend adequately
- European Emission Trading System
- Fixes total quantities: cap and trade in EUAs

***But EUA prices volatile, collapse in 2009***



# CO<sub>2</sub> prices are volatile and now too low

## EUA price October 2004-December 2010



# Prisoner's dilemma

- Players: UK (or Annex 1) and rest of world (ROW)
  - UK: 2% of GHG; EU: 15%; OECD: 47%; Annex 1: 57%
- Actions: abate (A) or not abate (N)
  - Tax/price GHG or not; countries keep C-tax revenue
- Pay-offs (Rest of world=95%, India 5%):
  - (N,N) => no costs now but damaging climate change
  - (A,A) => costs now, future CC damage averted
  - (A,N) => India: **no costs, cheaper fossil fuel, AND most CC damage averted**

***Incentive not to co-operate***

# Prisoners' Dilemma

		Player 2	
		A	N
Player 1	A	10, 10	-50, 110
	N	110, -50	5, 5

If P1 plays A, P2 plays N, P1 gets -50, P2 gets 110

If P1 plays N, P2 plays N, P1 gets 5

***(N,N) is a dominant strategy and Nash Equilibrium  
in one-shot game***

# Repeated game

- If the players repeatedly play they can sustain co-operation and enjoy (10,10) instead of (5,5)
  - temptation to deviate and gain 110 can be punished by refusing to co-operate ever again
- ⇒ gain 100 for one period, lose 5 for ever
- ⇒ worth co-operating if discount future at 5% or less

***Co-operation in PD requires penalties on deviants***

# Game theory and climate agreements

- Climate damage is not a static repeated game
  - Gradual increase, significant after 50-100 yrs
  - Once damage apparent it may be too late to act
- Strong mitigation now lowers energy prices
  - Increases incentive to cheat
- Unequal impacts around world
- Not two parties but large number
  - Coalitions like EU help, but China, India both large

***=> Increase benefits of cooperation, costs of deviation***

# Global carbon tax

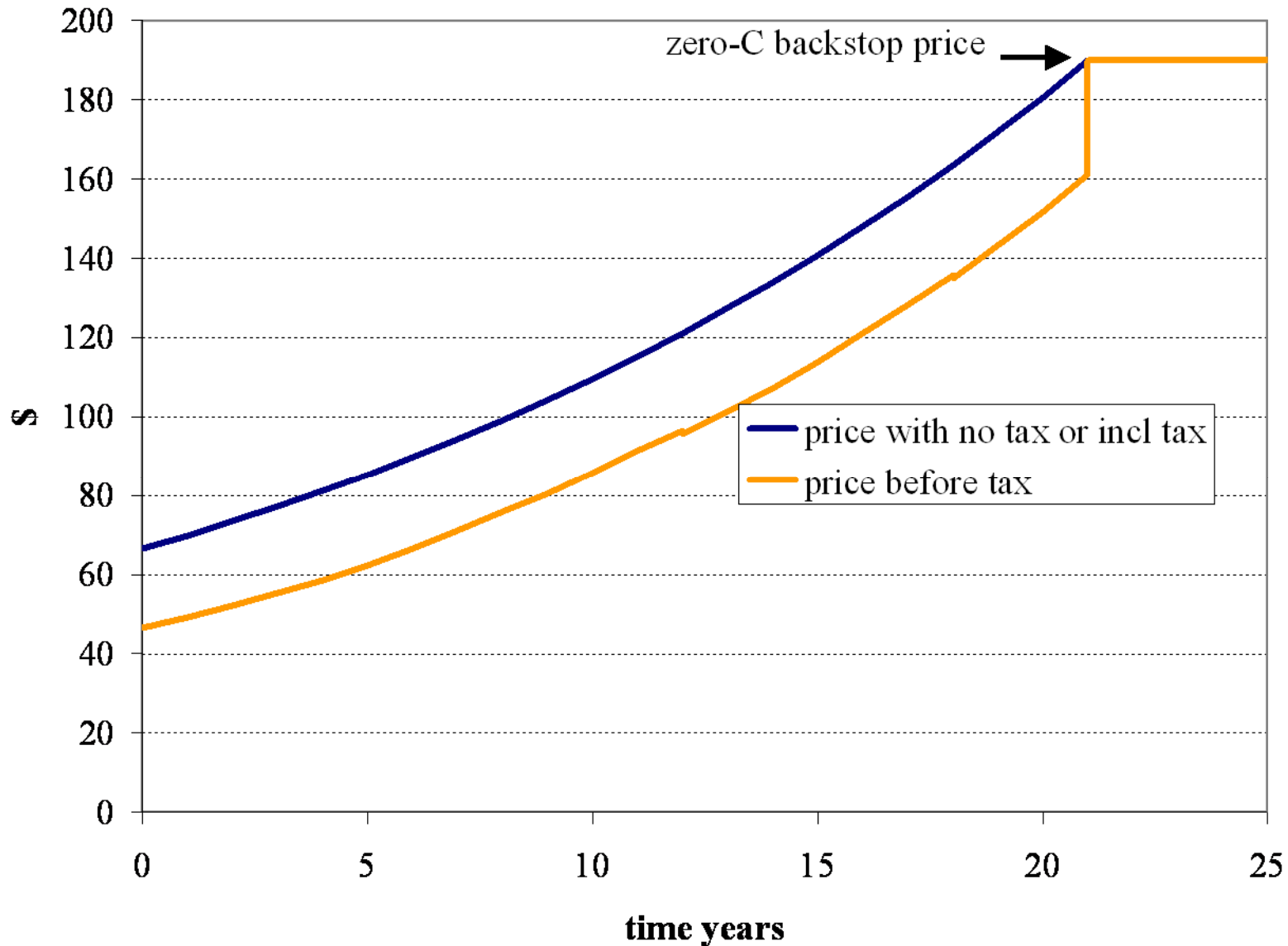
## Suppose

- we agree a global C tax on consumption
  - which should rise at the rate of interest
- backstop to oil is zero-C
  - fixes terminal price of oil independent of C-tax
- oil is competitive and zero cost
  - price rises at rate of interest to backstop price
- The tax inclusive price same as with no tax
  - but pre-tax price falls by C-tax => evasion

*Average price falls, CO<sub>2</sub> rises at each date*

*Sinn's Green paradox*

# The “green paradox” - zero cost competitive oil and global carbon price rising at rate of interest



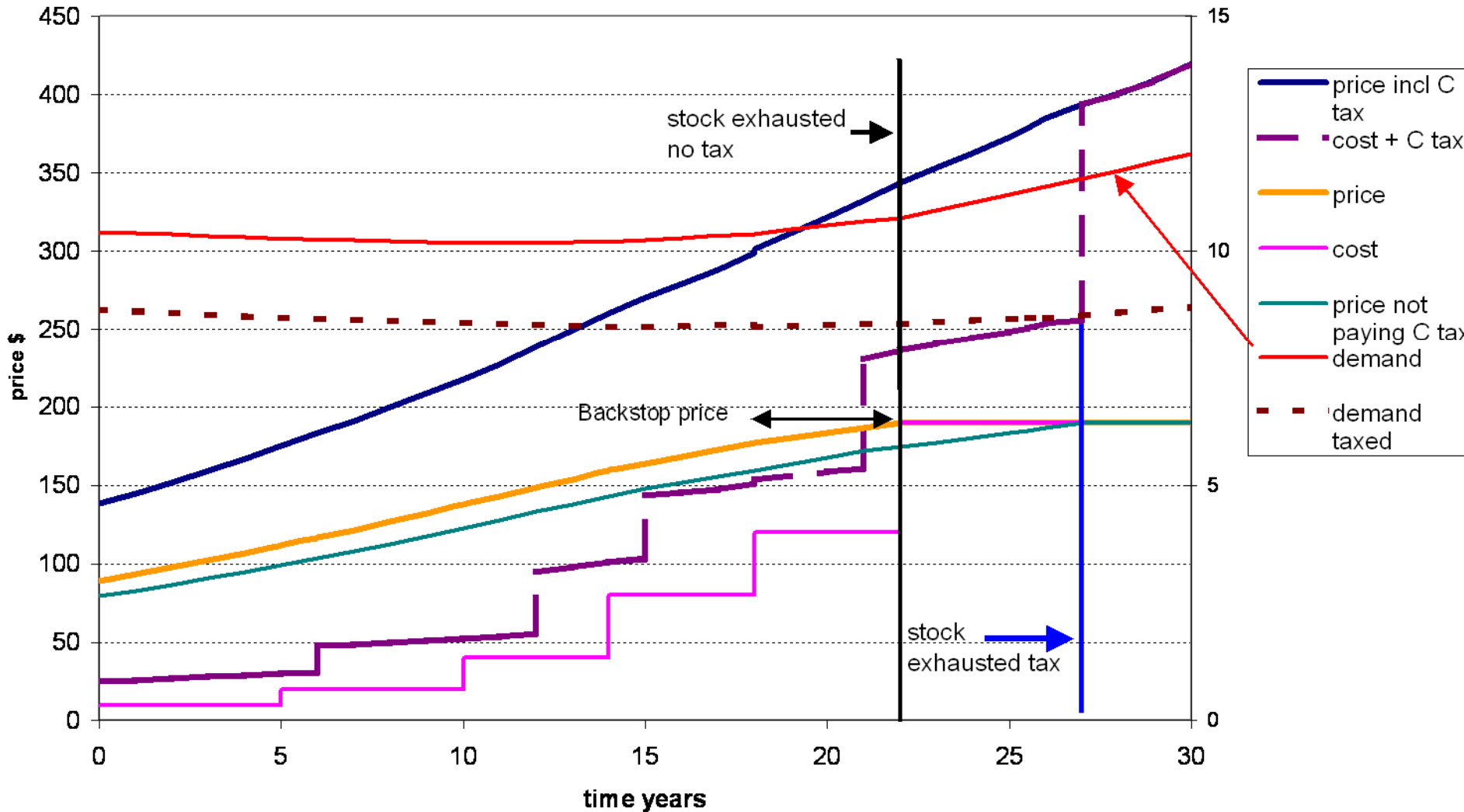
# Realism

- Most plausible backstops are carbon-intensive
  - Oil is increasingly expensive to extract
- => This greatly mitigates Green paradox
- => Forward shifting to consumer price high  
pre-tax price not much below no-tax price
- => oil demand falls, CO<sub>2</sub> falls, planet saved

*Question: how much forward shifting?*



# Price, cost and demand for an exhaustible resource

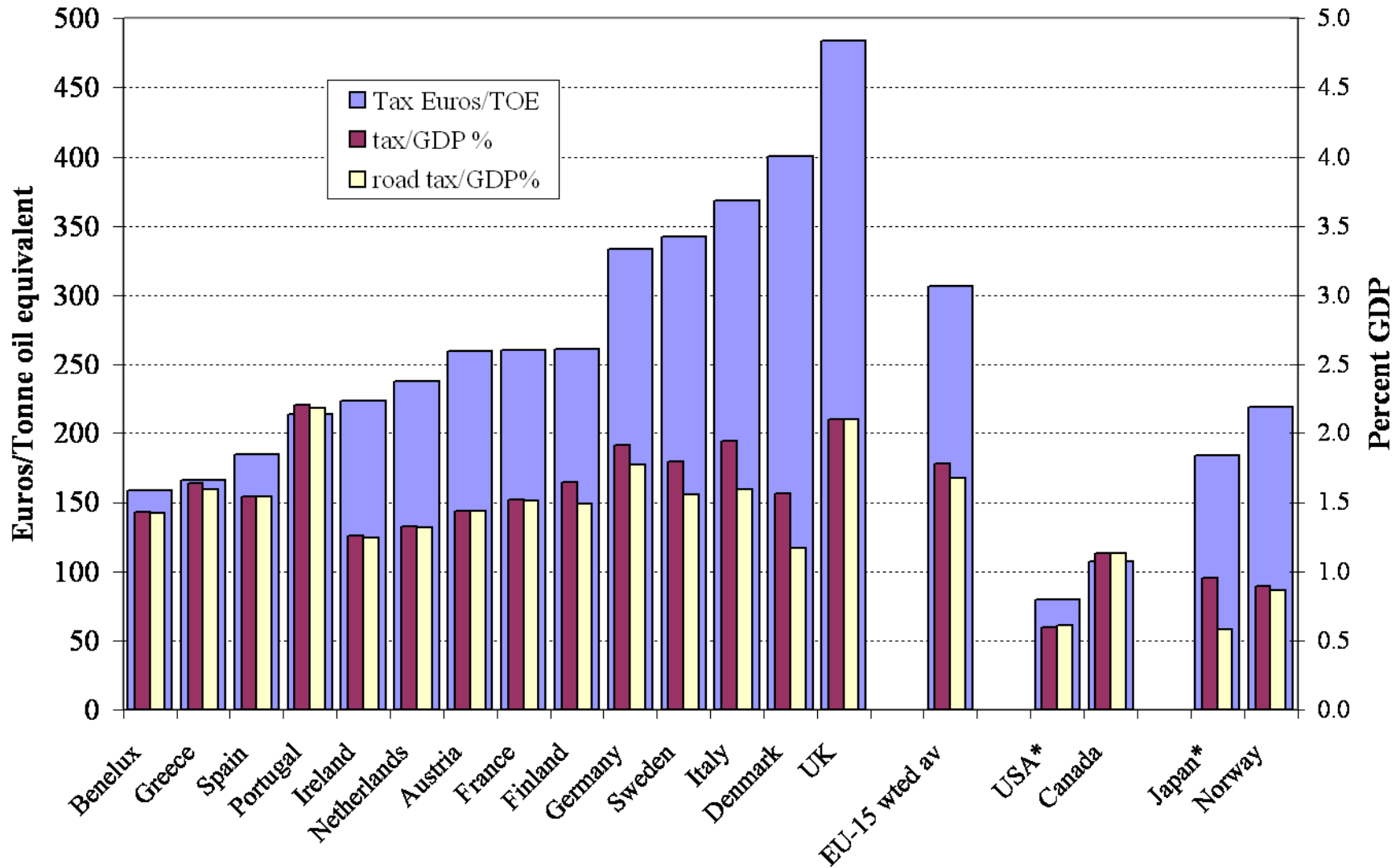


# Can we agree C-tax on oil?

- Oil is already heavily taxed
    - mainly for transport (but that is what oil is for)
  - A carbon tax would be partly a rent transfer to importers and an attractive revenue source
  - Transport is largely non-traded
- => raises few questions of leakage

*C-tax on oil may be feasible; but on coal??*

# Taxes on oil and products 2002



# Encouraging mitigation

- Charge GHG emissions everywhere to correct failure to properly price GHG
  - ⇒ C-tax on fossil fuel (rebates for ETS)
  - ⇒ countries replace other taxes with C-taxes
- Encourage compliance with border taxes
  - VAT on imputed carbon content
  - corrects for subsidy in non-taxing countries

# Conclusions

Economic theory helps understand issues

- Hotelling exhaustible resource theory
- externalities and public goods
- => corrective taxes/prices
- but Prisoners' dilemma requires incentives
- => penalties for non-compliance
- => border tax adjustments
- does a carbon tax increase emissions?

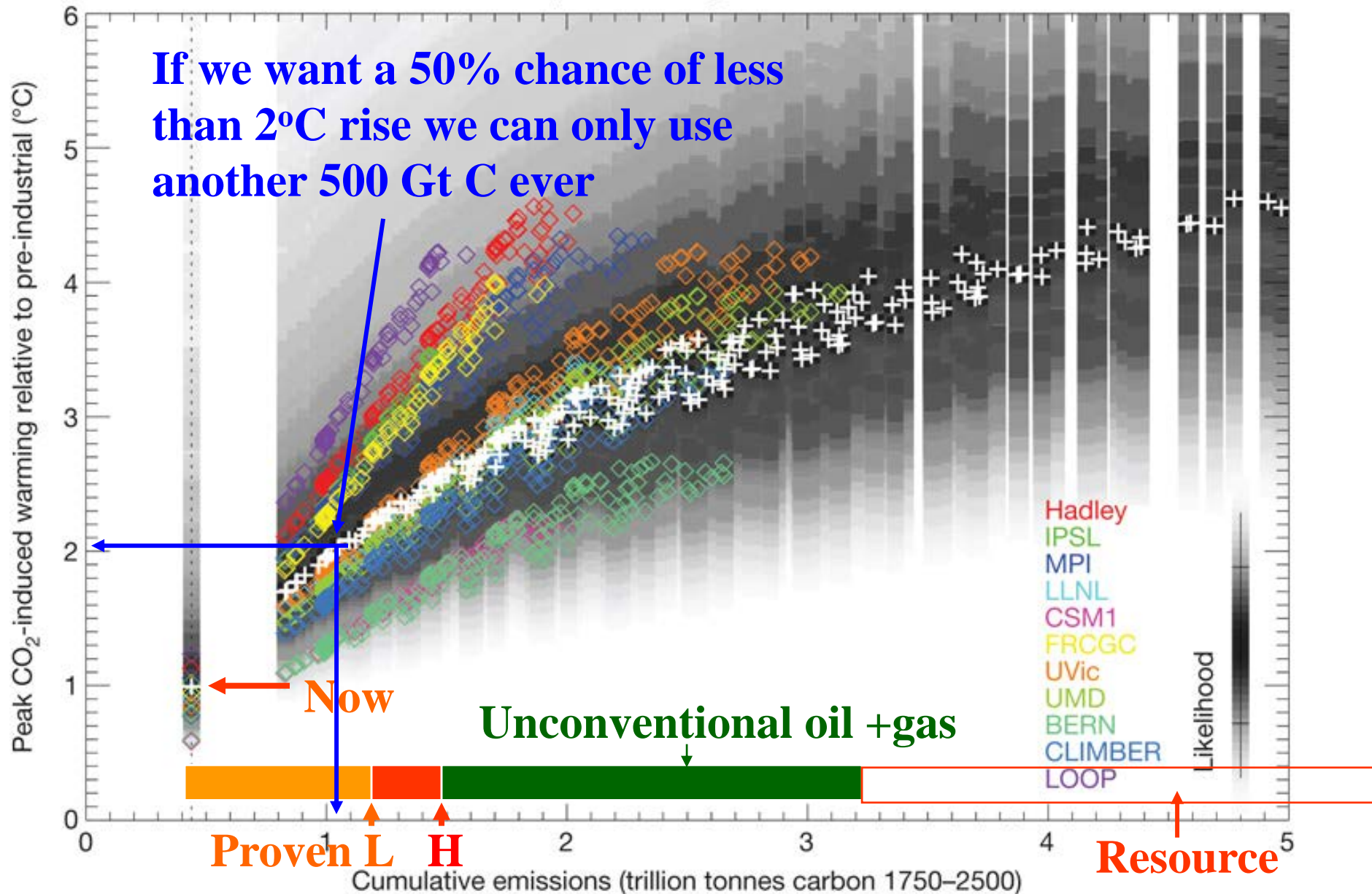
***Carbon taxes on oil lower consumption and CO<sub>2</sub>***

# Annex: background figures

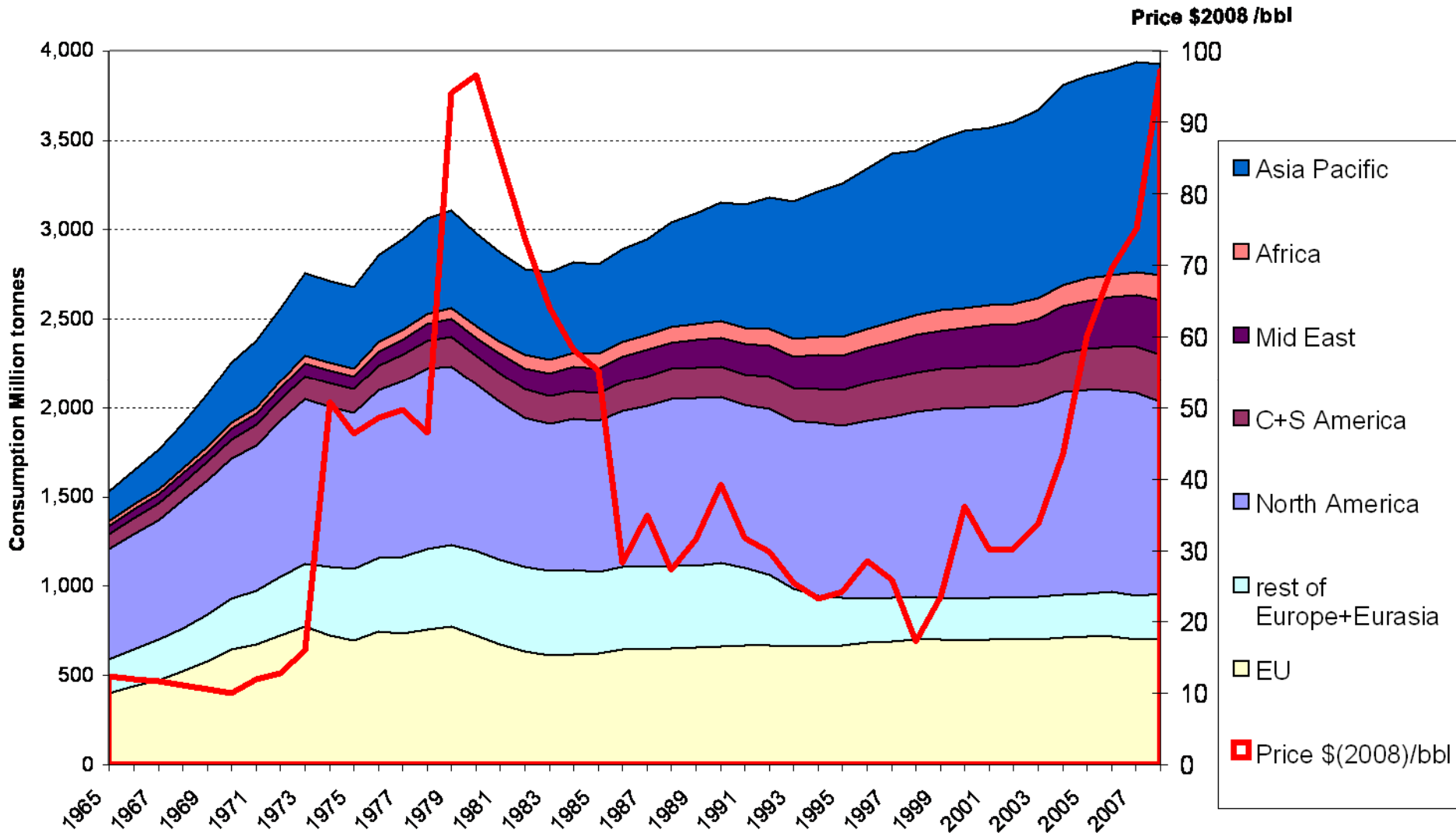
The original *Nature* diagram and a more detailed oil import figure follow (also from the BP *Statistical Review of World Energy*)

# Peak CO<sub>2</sub>-warming vs cumulative emissions 1750–2500

Relative likelihood of peak warming versus cumulative emissions



# Regional oil consumption 1965-2008





# Link to Paper

[Oil shortages, climate change and collective action](#)