Potsdam Institute for
Climate Impact Research

The Green Paradox Revisited

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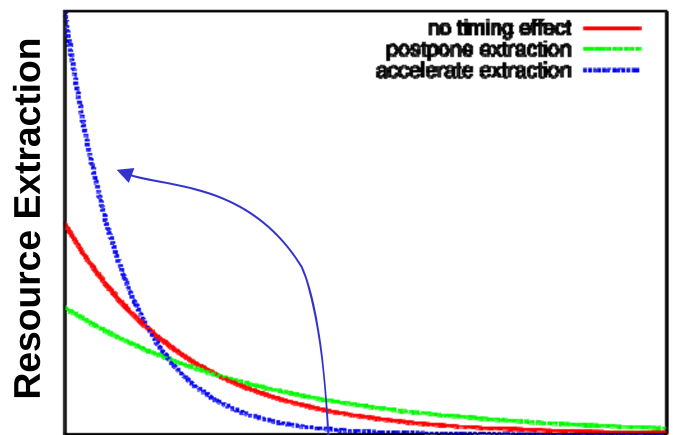
Outline

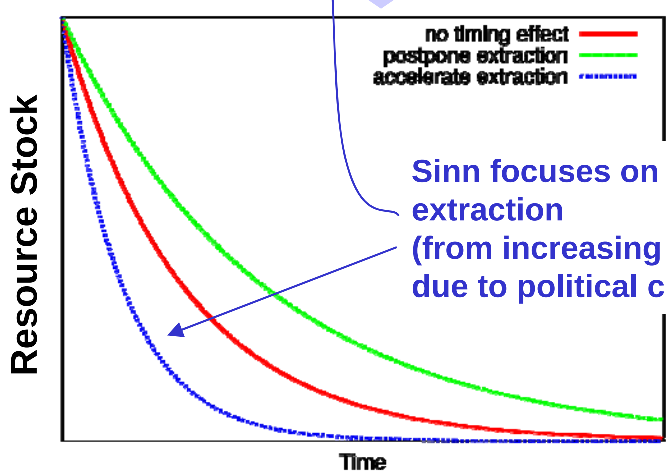
1. Timing vs. volume effect of increasing carbon taxes
2. Prices vs. quantities: informational requirements for optimal policy instruments
3. Implications of the green paradox within a 2nd-best policy setting

How Do Resource Taxes Influence Extraction?

Pure intertemporal re-allocation ("Timing effect")

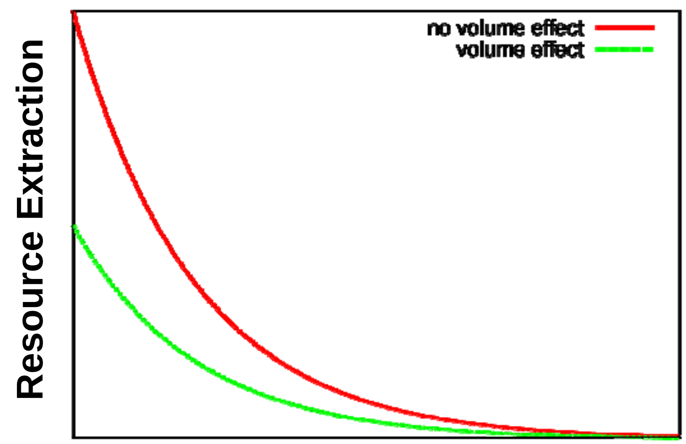


Different timing,
same cumulative extraction

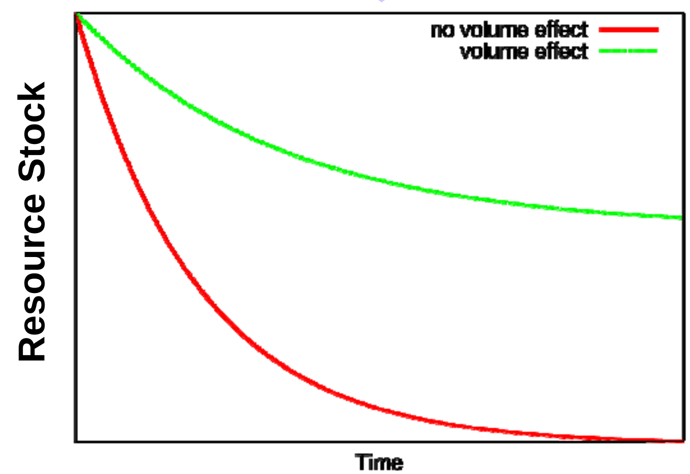


Sinn focuses on accelerated extraction
(from increasing profit taxes due to political constraints)

Lower cumulative extraction ("Volume effect")



Lower cumulative extraction



Carbon Taxes and the Volume Effect

Effect of an exponentially increasing resource tax $\tau = \tau_0 \, e^{\theta t}$

within a Hotelling model with

- discount rate *r*
- (constant) extraction costs *c*
- demand function *q(p)*

There exists a critical initial tax level τ_0^* **which provokes a *volume effect*:**

$$\int_0^\infty q(\tau_0^{*} e^{\theta t} + c)dt = S_0$$

- Tax starts at the level that equalizes cumulative demand with entire stock (if there were no further resource price component than the extraction costs)
- For each tax higher than τ_0^*, cumulative extraction over infinite time horizon is lowered – not all resources are extracted

When Do Increasing Carbon Taxes Provoke a Green Paradox?

Effect of an exponentially increasing resource tax $\tau = \tau_0 \, e^{\theta t}$

	Slowly increasing tax $\theta < r$		Tax increases at discount rate $\theta = r$		Fast increasing tax $\theta > r$	
	τ_0 small $\tau_0 \leq \tau_0^*$	τ_0 large $\tau_0 > \tau_0^*$	τ_0 small $\tau_0 \leq \tau_0^*$	τ_0 large $\tau_0 > \tau_0^*$	τ_0 small $\tau_0 \leq \tau_0^*$	τ_0 large $\tau_0 > \tau_0^*$
Timing effect	postpone extraction	postpone extraction	none	none	accelerate extraction	accelerate extraction
Volume effect	none	conservative	none	conservative	none	conservative
Green paradox	none	none	none	none	yes	ambiguous
Impact on damages compared to zero-tax case	- timing effect	-- timing and volume effect	none	- volume effect	++ timing effect	-/+ timing vs. volume effect

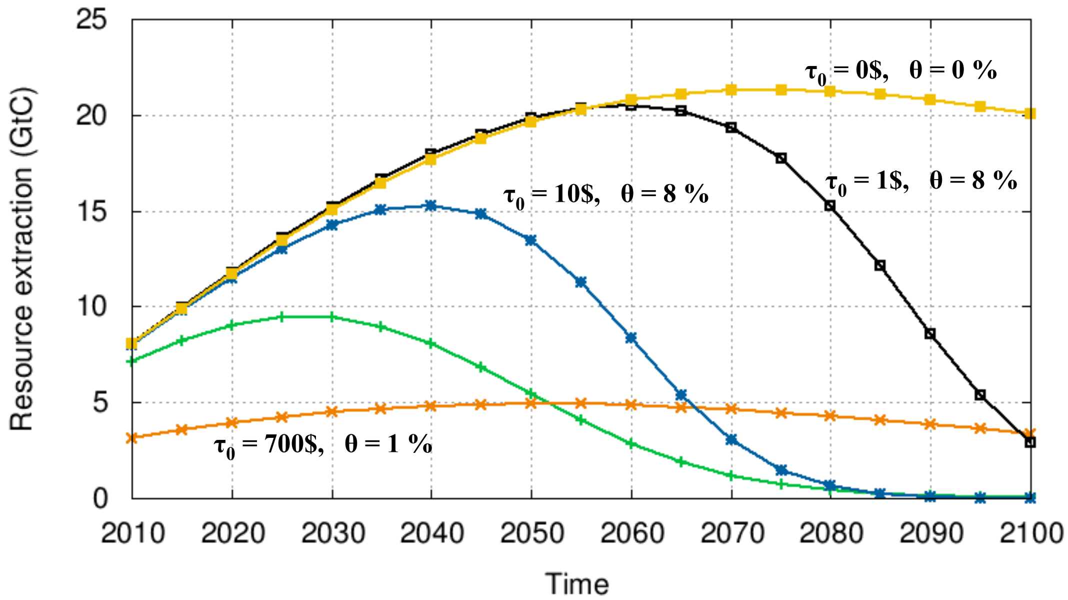
(Source: Edenhofer and Kalkuhl 2010)

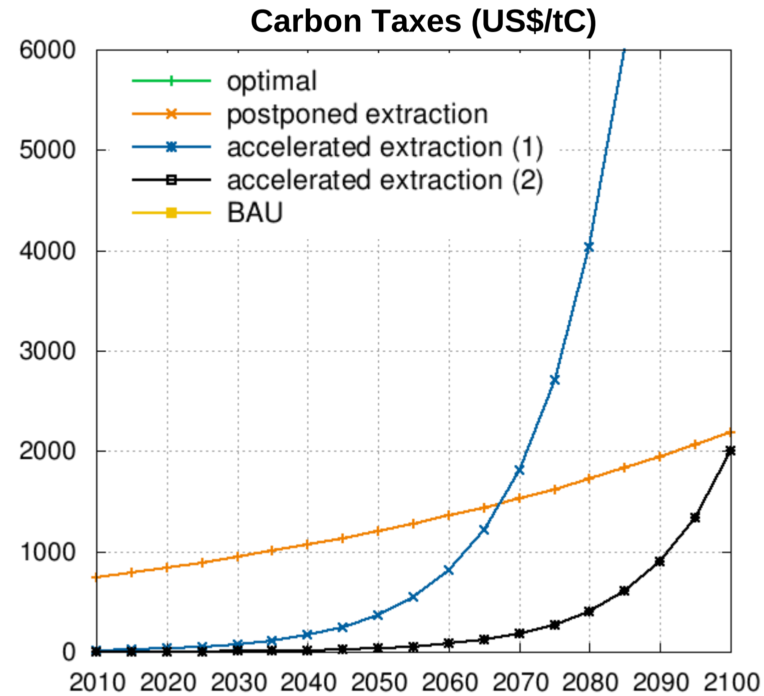
Critical initial tax level τ_0^*

$$\int_0^\infty q(\tau_0^* e^{\theta t} + c)dt = S_0$$

Green Paradox occurs only for a specific set of carbon taxes.

Are Carbon Taxes a Robust Instrument?

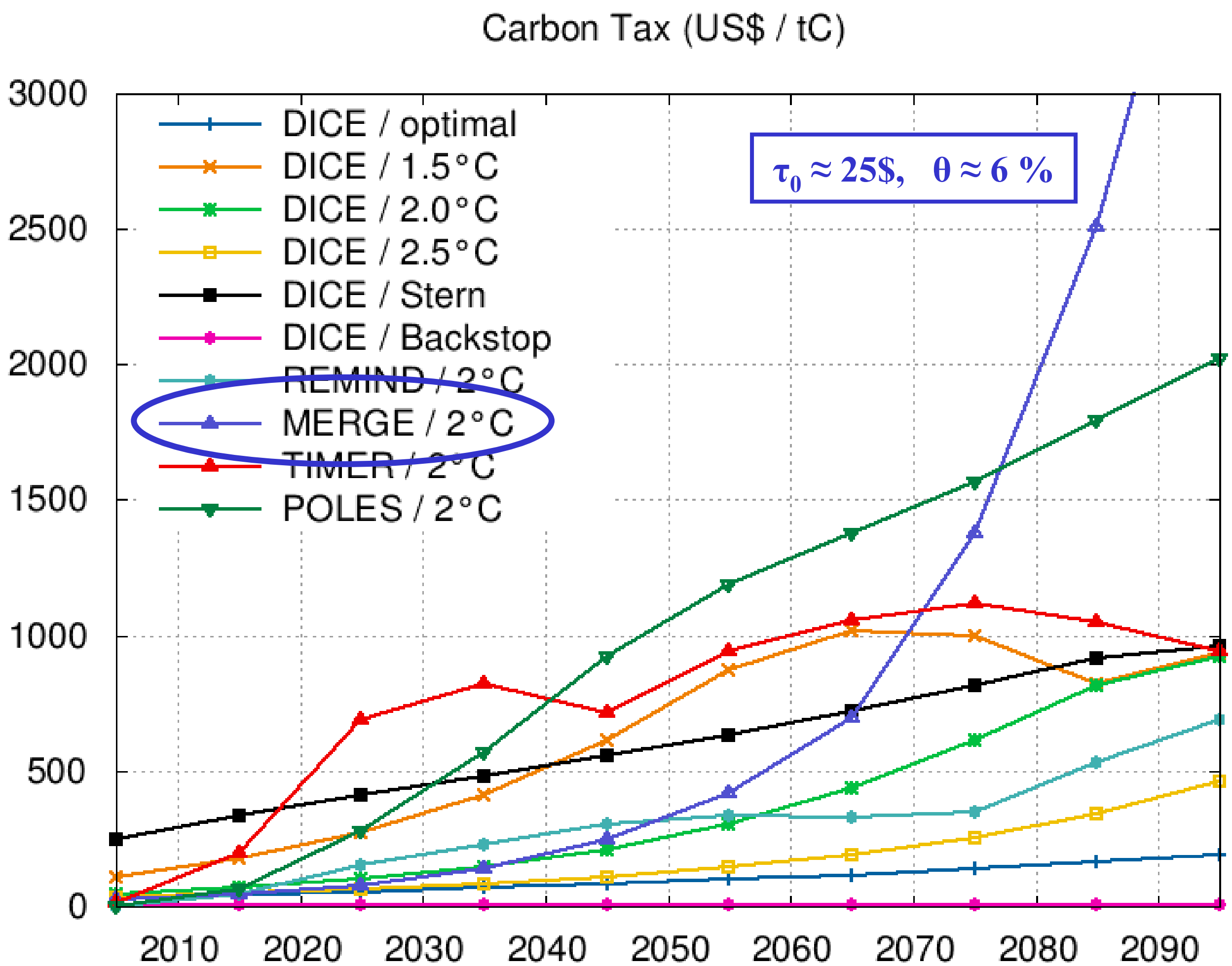




Resource extraction very sensitive to carbon tax

- Difficult to achieve optimal path
- Initially low and then fast increasing taxes lead to accelerated extraction (compared to optimum)

Carbon Tax Proposals



- **Many proposed carbon taxes increase moderately**
- **Strongly increasing taxes might be dangerous**

Carbon taxes in 2005-US$ per ton of carbon and approximation by exponential carbon tax.

(Edenhofer & Kalkuhl 2010)

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1. **Timing vs. volume effect of increasing carbon taxes**

2. **Prices vs. quantities: informational requirements for optimal policy instruments**

3. **Implications of the green paradox within a 2nd-best policy setting**

CO_2 Tax: Regulator Determines Environmental Scarcity Prices

Optimal tax path: (Hoel & Kverndokk 1996)

$$\theta(t) = F_S(S^*(T))e^{-r(T-t)} - \int_t^T d_S^* e^{r(t-\xi)}\, d\xi$$

d(S)	damages (of stock S)
d_S*	marginal damages along socially optimal resource stock path
r	discount rate
$F_S(S^*(T))$	marginal scrap value of socially optimal resource stock at T

Optimal tax is incentive compatible within decentralized economy (Kalkuhl & Edenhofer 2010)

Optimal tax requires for the regulator to know *ex ante*:

- Environmental damages
- Economic development for the entire time horizon
    - Extraction costs
    - Economic growth, carbon demand, technological progress, development and costs of backstop technologies

Possible Solution: Progressive Carbon Tax

- "Progressive" (stock-dependent) carbon tax rule:
  (individual tax for each resource owner)

$$\tau^i(S^i) = \frac{-d_S(nS^i)}{r}$$

- Final-period payment rule (optimal transversality condition):

$$\varsigma^i(S^i(T)) = \frac{1}{n}\left(\frac{d(nS^i(T))}{r} - F(nS^i(T))\right)$$

- Progressive carbon tax works similar to increasing extraction costs: It slows down extraction

Pro: Regulator does not need to know optimal paths (only functional form of damages)
Contra: Strong (and unrealistic) commitment required; symmetric extraction costs assumed

Emissions Trading Scheme (ETS): Market Determines Environmental Scarcity Prices

Cost-benefit framework: Regulator issues permits

- For intertemporal efficiency, same informational requirements as in the carbon tax case
- Market determines scarcity prices – but regulator has to calculate *ex ante* the optimal permit path
- Optimal price path for permits: $\theta(t) = F_S(S^*(T))e^{-r(T-t)} - \int_t^T d_S^* e^{r(t-\xi)}\, d\xi$

With intertemporal flexibility:

- Free banking & borrowing leads to suboptimal emission path (Kling & Rubin 1997) because Hotelling price path does not consider intertemporal allocation of damages
- Introduce trading ratios:

$$r_b = \frac{-d_S^*}{F_S(S^*(T))e^{-r(T-t)} - \int_t^T d_S^* e^{r(t-\xi)} d\xi}$$

Initial permit stock:

$$b_0 = S_0 + \frac{\int_0^T e^{-r\xi} d_S^* S^*\, d\xi - S^*(T) F_S(S^*(T)) e^{-rT}}{-\int_0^T e^{-r\xi} d_S^*\, d\xi + F_S(S^*(T)) e^{-rT}}$$

Emissions Trading Scheme (ETS) and the Carbon Budget

Carbon budget does not require information about:

- Optimal future emission pathways
- Carbon cycles
- Climate sensitivity
- Socially optimal discounting

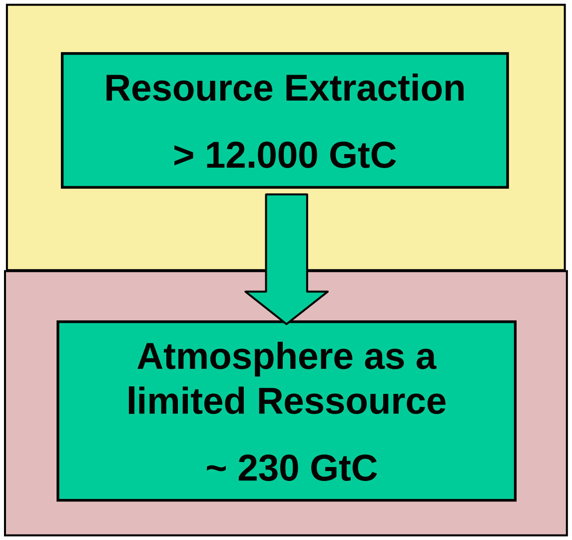
There is no intertemporal allocation of marginal damages!

- It assumed that the carbon budget is an appropriate proxy for total damages
- Marginal damages can differ from total damages

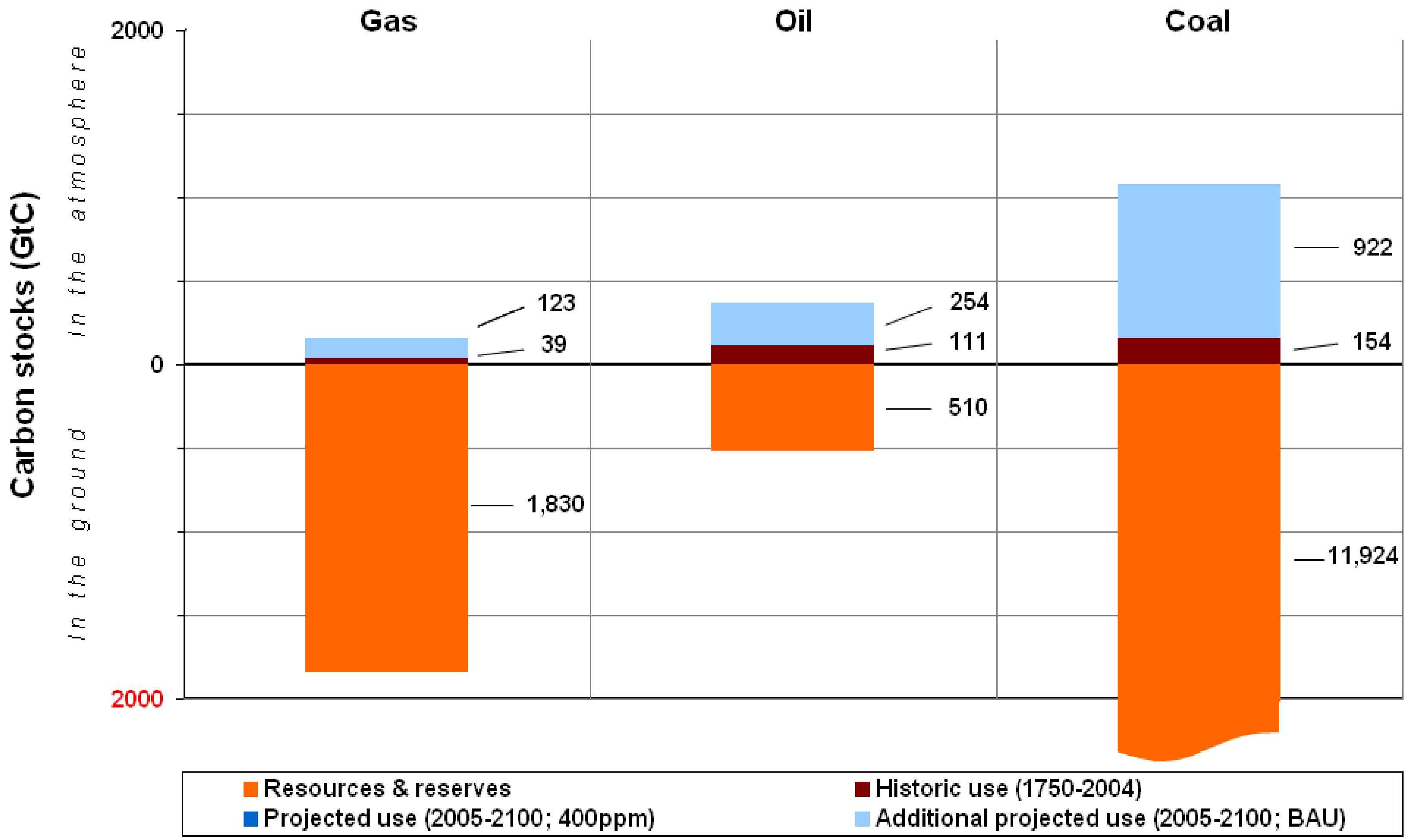
Carbon Budget Approach and Intertemporal ETS

Institutional Requirements:

- Assigning property rights according to the carbon budget
- Regulator needs no information about future economic development
- Banking and borrowing for intertemporal efficiency
- Scarcity rent can be distributed without efficiency losses (auctioning, grandfathering)
  - What-flexibility: Coal, oil, gas, conventional/unconventional
  - Respective market structures are required (futures markets)



The Supply-side of Global Warming



Cumulative historic carbon consumption (1750-2004), estimated carbon stocks in the ground, and estimated future consumption (2005-2100) for business-as-usual (BAU) scenario

Source: Kalkuhl, Edenhofer and Lessmann, 2009

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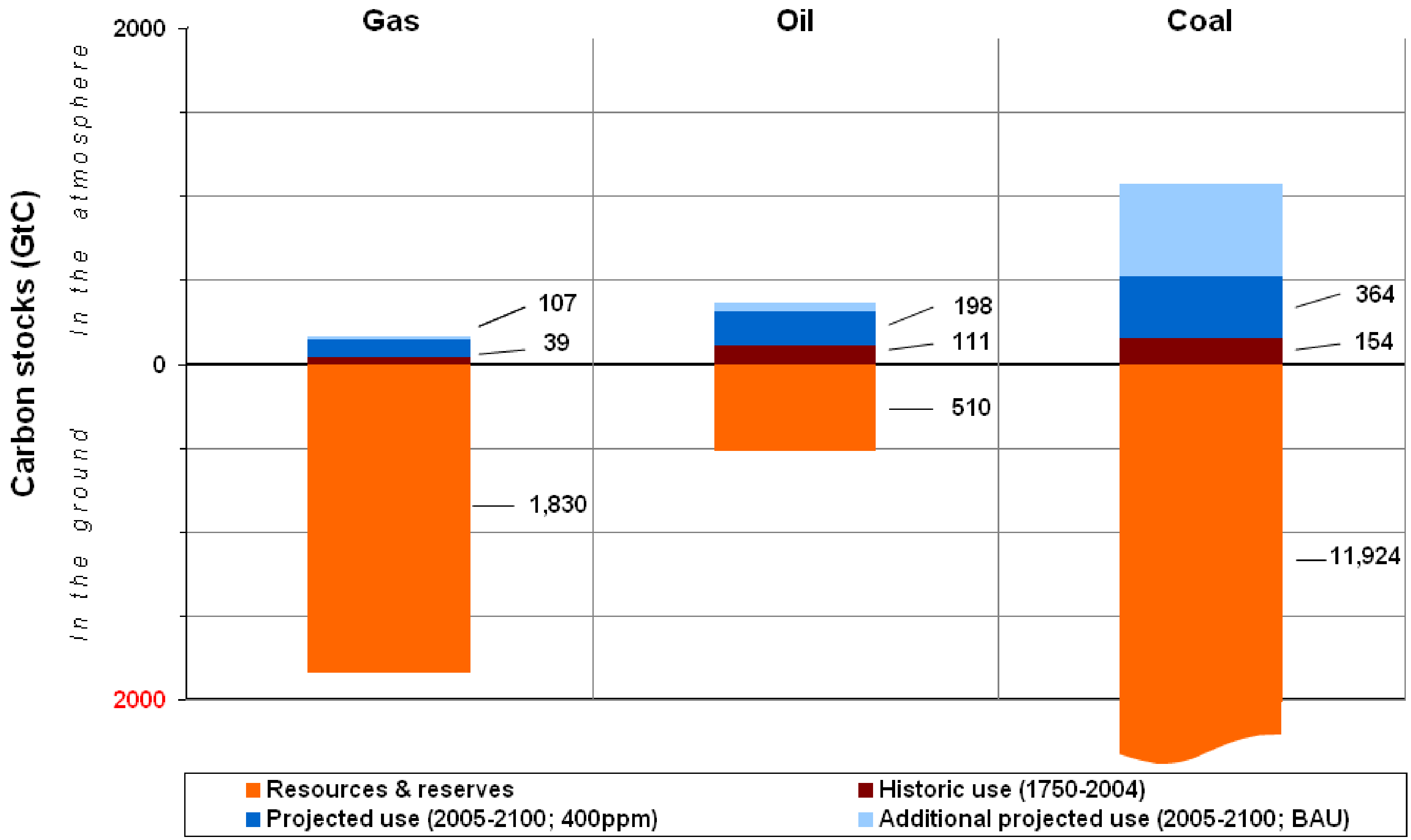

Cumulative historic carbon consumption (1750-2004), estimated carbon stocks in the ground, and estimated future consumption (2005-2100) for 400ppm stabilization and business-as-usual (BAU) scenario

Source: Kalkuhl, Edenhofer and Lessmann, 2009

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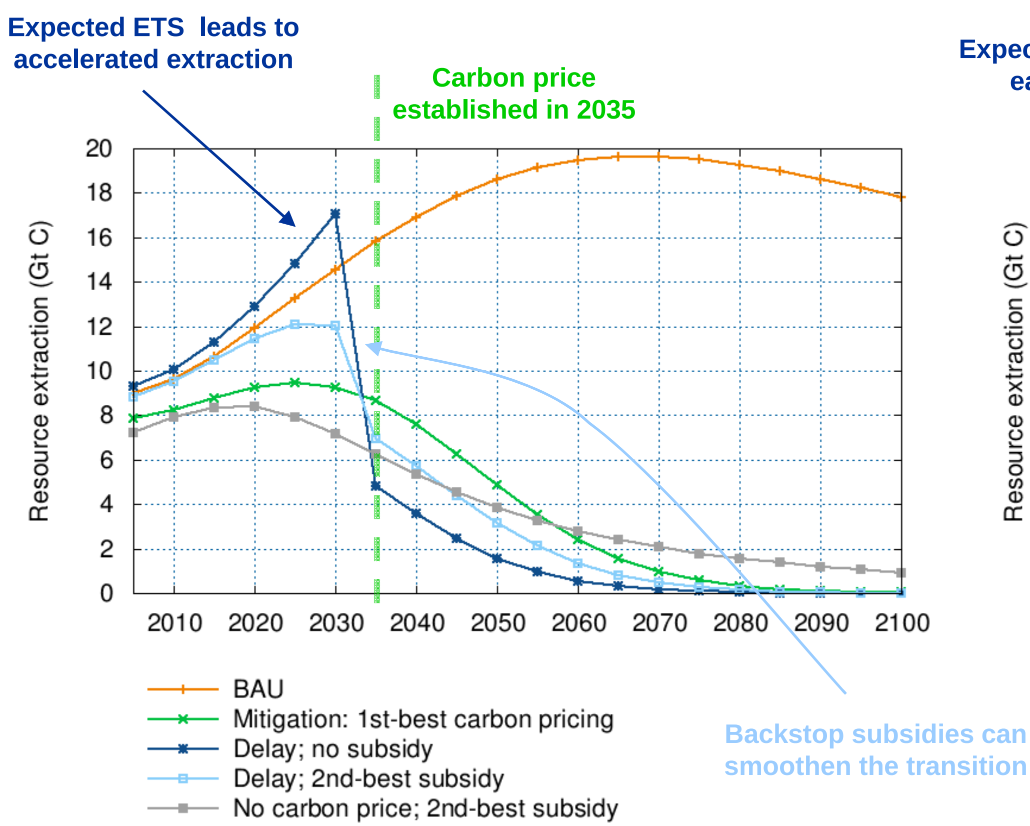
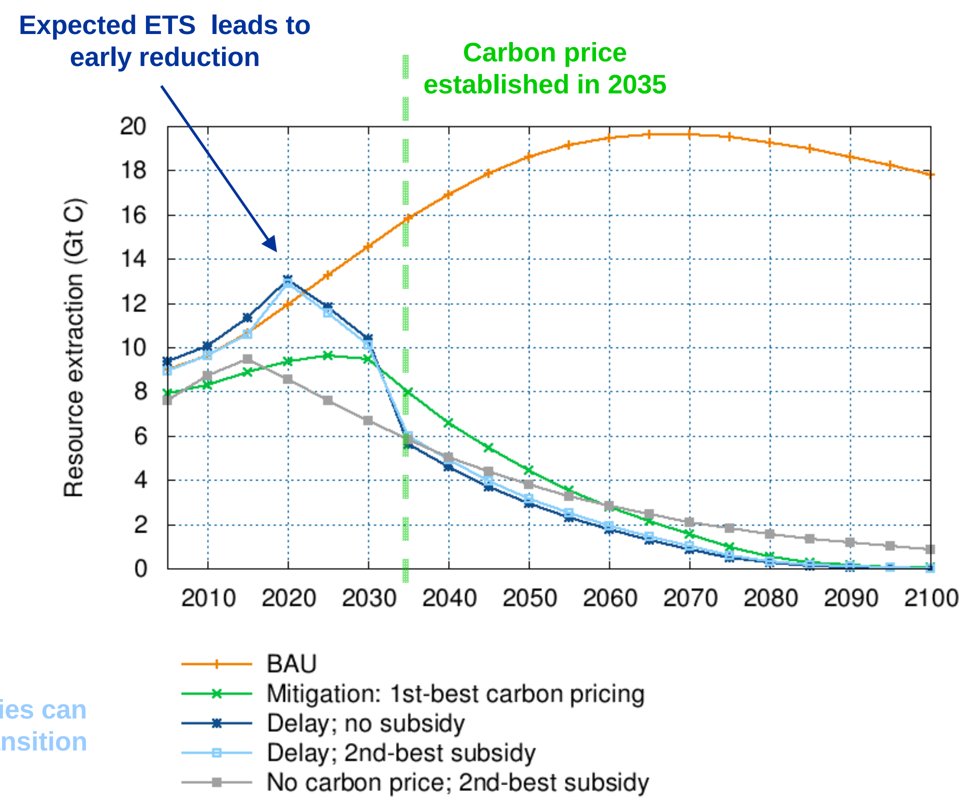
Example: The Impact of Delayed Carbon Pricing

Investments in the fossil energy system are reversible

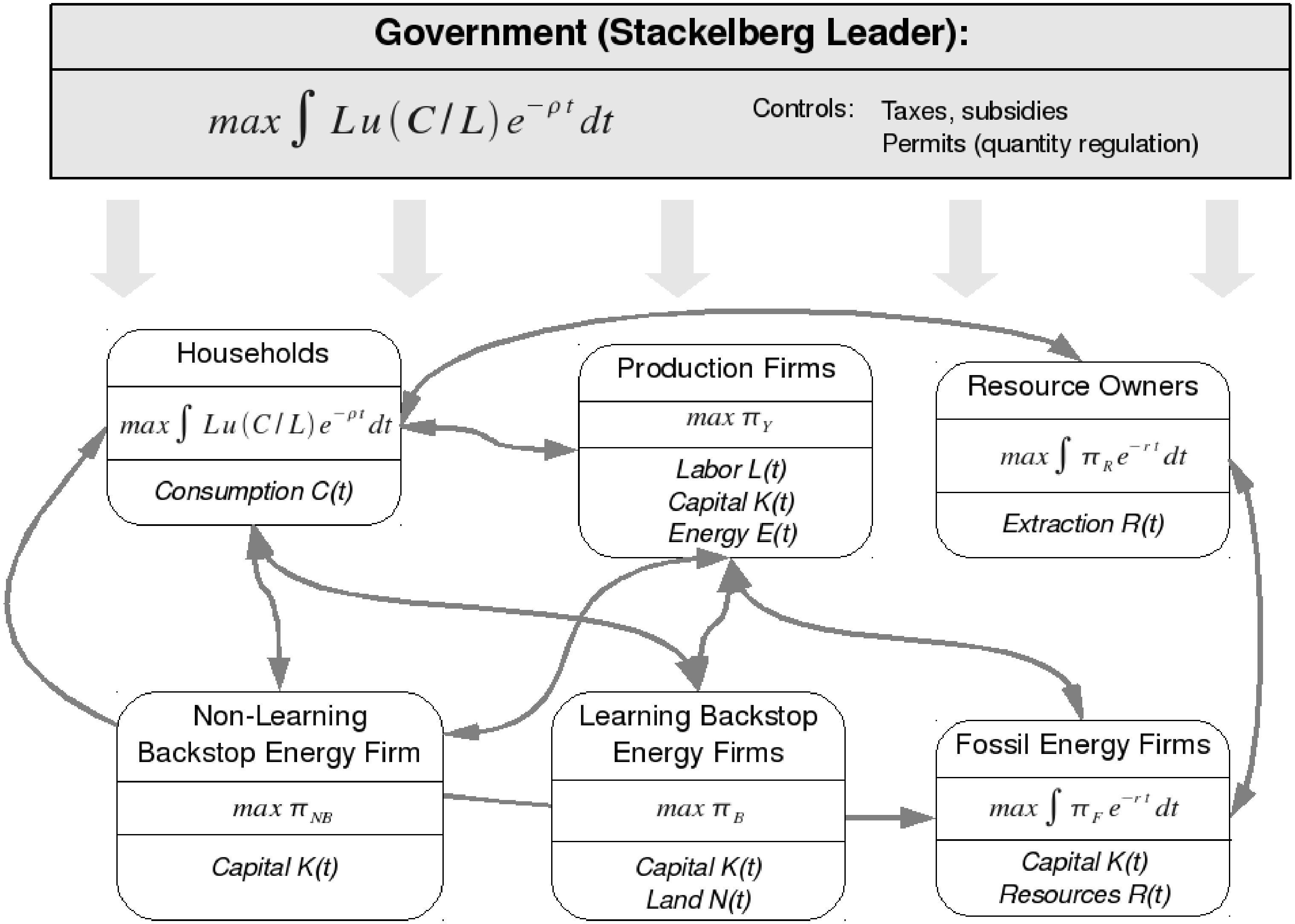
Investments in the fossil energy system are irreversible





Impact of expectations is ambiguous!

Integrated Policy Assessment Model



Thank You for Your Attention!

Further Reading:

- Kalkuhl & Edenhofer (2010): Prices vs. Quantities and the Intertemporal Dynamics of the Climate Rent. *CESifo Working Paper*
- Edenhofer & Kalkuhl (2010): When Do Increasing Carbon Taxes Accelerate Global Warming? A Note on the Green Paradox. Submitted to *Int Tax and Public Finance.*