



POTSDAM INSTITUTE FOR  
CLIMATE IMPACT RESEARCH

## **The Role of Technological Flexibility for the Distributive Impacts of Climate Change Mitigation Policy**

Michael Lüken, Nico Bauer, Brigitte Knopf, Marian Leimbach,  
Gunnar Luderer, Ottmar Edenhofer

International Energy Workshop  
Venice, 17.06.2009

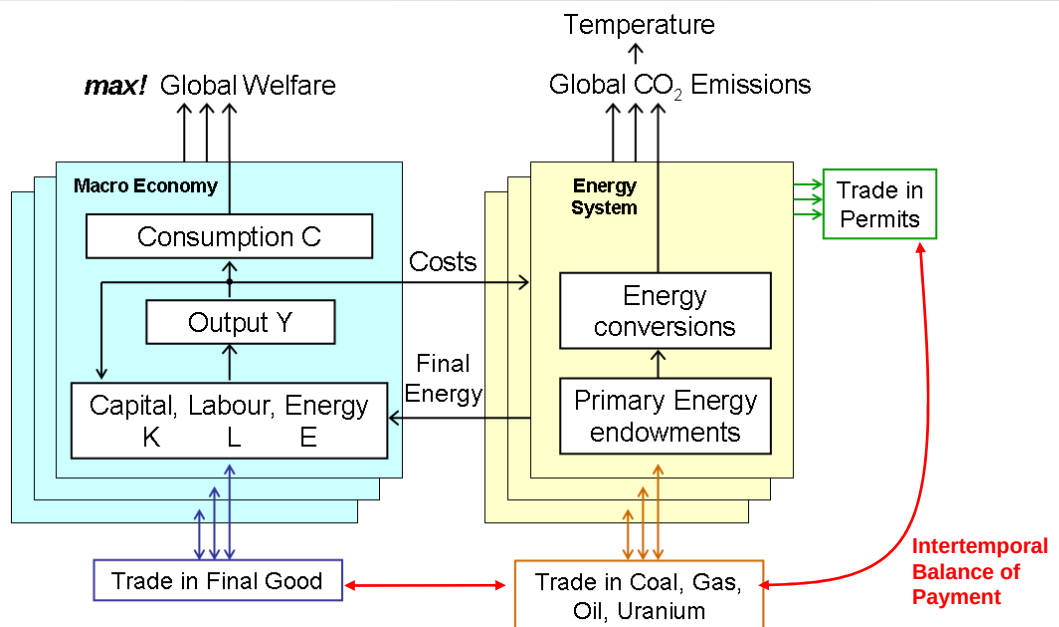
## Contents

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- Mitigation scenarios with a global multi-regional integrated assessment model
  - Understand and quantify  
domestic effects, energy trade effects, permit trade effects  
on regional mitigation costs by a new *economic decomposition* method
  - How are results influenced by assumptions on
    - the availability of low-carbon technologies and
    - the initial permit allocation
- We need a model with an appropriate representation of inter-regional interactions and high technological resolution.
- 



## The Model REMIND



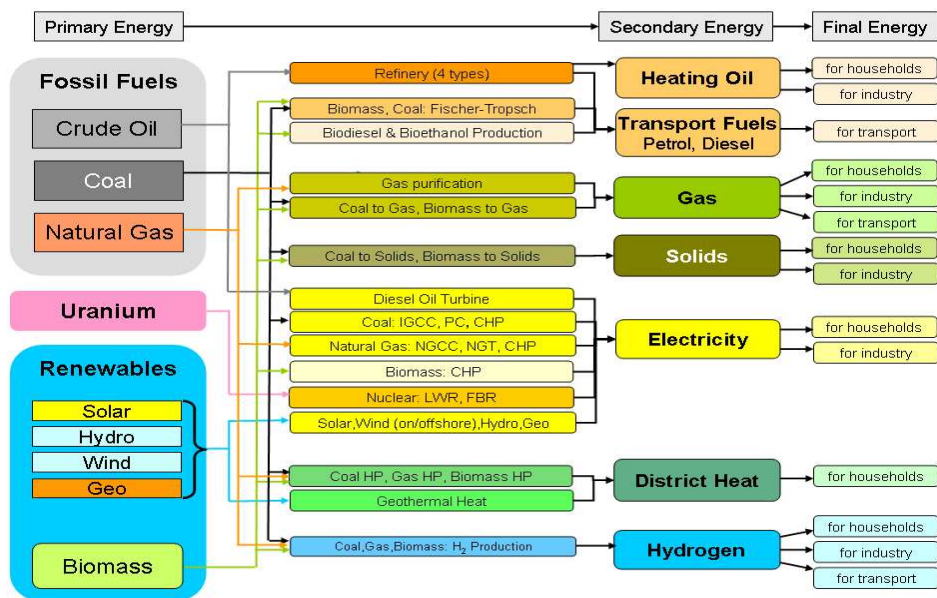
## Model Regions

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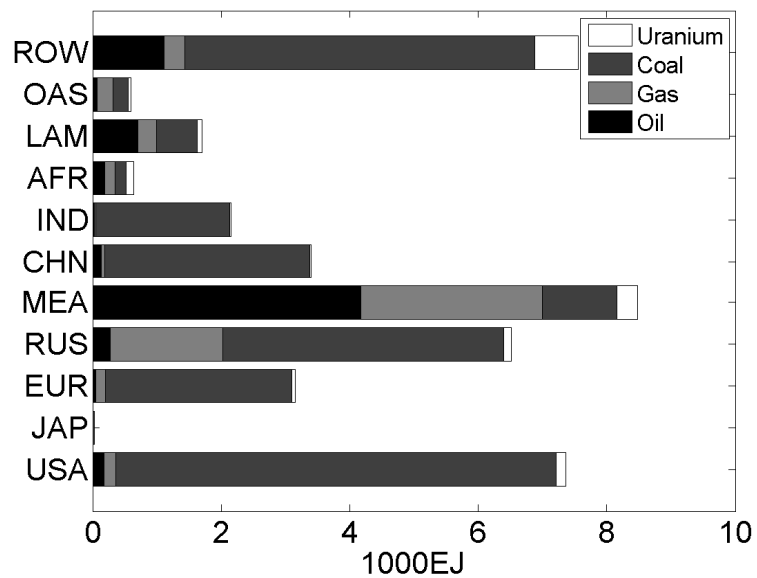
- Industrialized importers of fossil fuels
    - USA
    - EUR: Europe
    - JAP: Japan
  - Main exporters of fossil fuels
    - RUS: Russia
    - MEA: Middle East and Northern Africa
    - ROW (mainly Canada, Australia, South Africa, Eastern Europe)
  - Transition and developing economies
    - IND: India
    - CHN: China
    - LAM: Latin America
    - OAS: Other Asia
    - AFR: Africa
- 



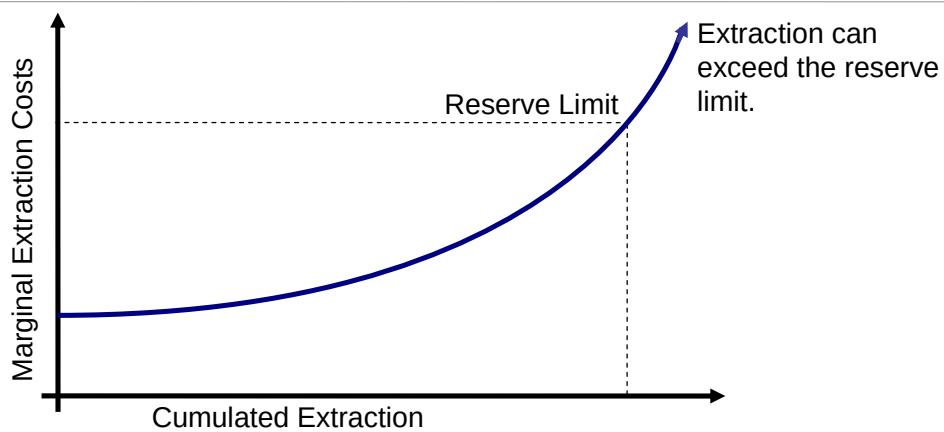
## The Energy System in REMIND



## Exhaustible energy endowments (reserves)

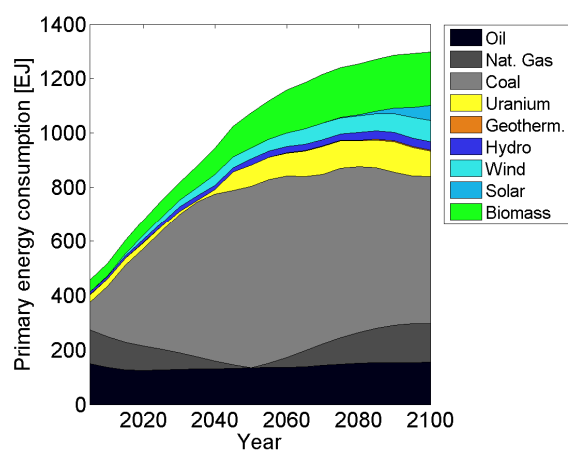


## Fossil energy endowments

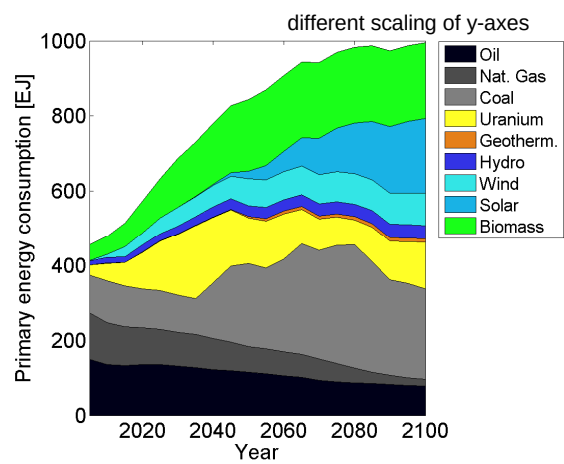


| Extraction costs [\$US per GJ] | COAL | OIL | NATURAL GAS | URANIUM    |
|--------------------------------|------|-----|-------------|------------|
| Initial costs                  | 2    | 8   | 5.5         | 30 \$US/Kg |
| Costs at reserve limit         | 4    | 10  | 8           | 80 \$US/kg |

## Primary energy demand (global)

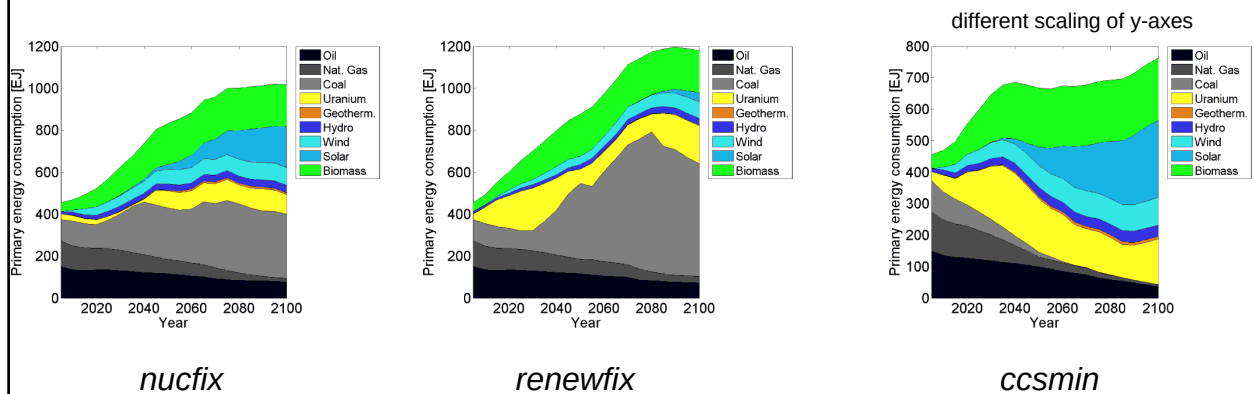


Reference Scenario  
(no policy target)



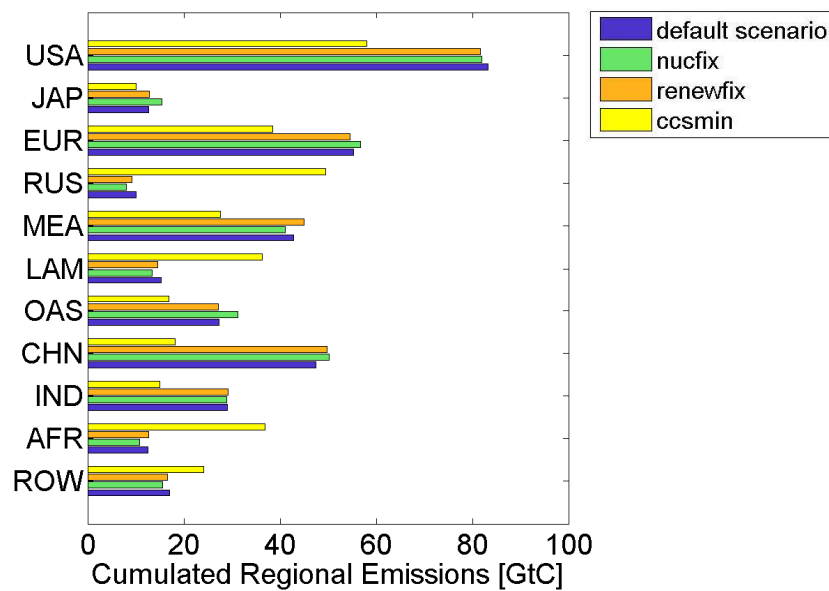
Default Scenario  
(2° target)

## Primary energy demand (global)

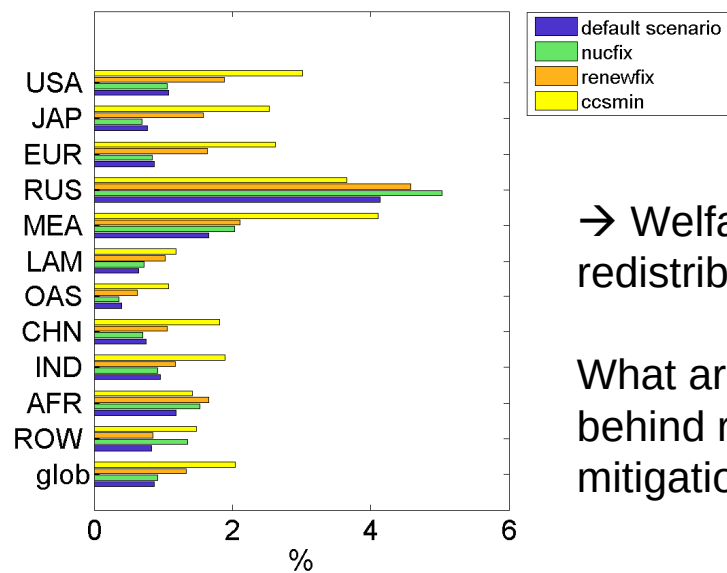


- *nucfix*: nuclear restricted to reference scenario level
- *renewfix*: renewables restricted to reference scenario level
- *ccsmin*: CCS restricted to 100 GtC cumulated

## Regional emissions (cumulative)



## Mitigation costs



→ Welfare redistributions

What are the effects behind regional mitigation costs?

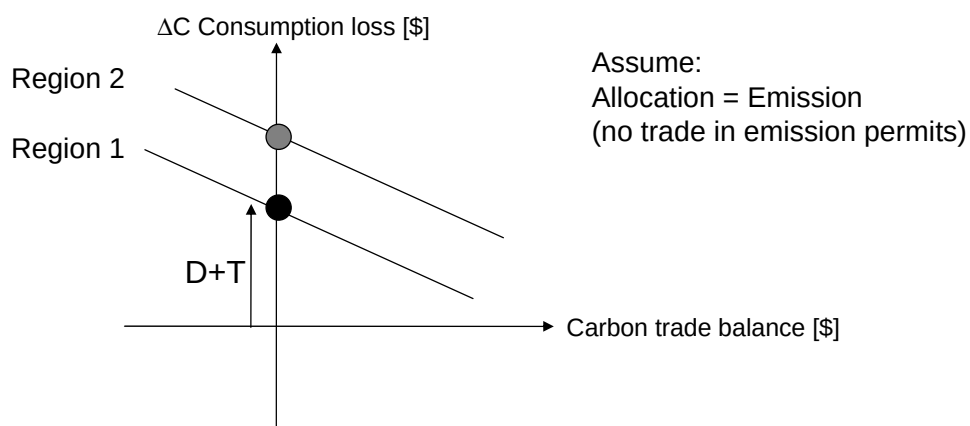
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  - the availability of low-carbon technologies and
  - the initial permit allocation



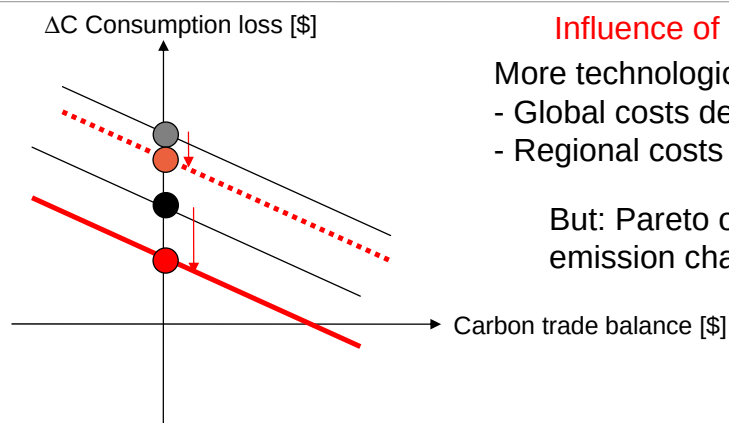
## Effects on regional mitigation costs



$$\Delta C = D + T + \int_{t_0}^T \exp(-\rho t) (A(t) - E(t)) p(t) dt$$

Allocation    Emissions    Carbon Prize  
 ↖                      ↗  
 Domestic Effect    Energy Trade Effect    Carbon trade balance = 0

## Effects on regional mitigation costs



### Influence of Technology:

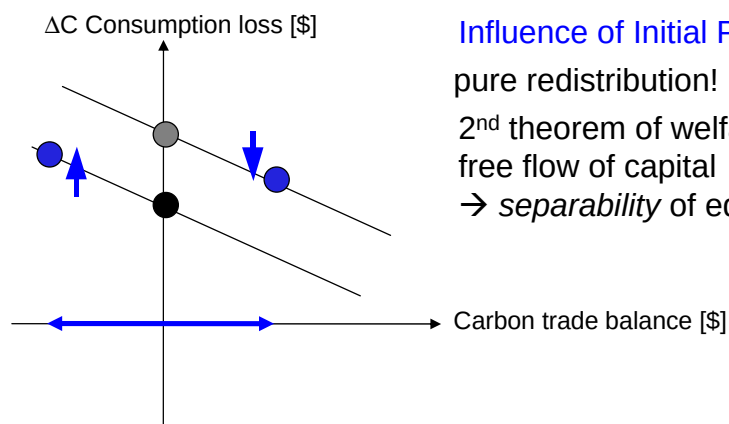
More technological flexibility →

- Global costs decrease
- Regional costs generally decrease

But: Pareto optimal sharing of emission changes!

$$\Delta C = D + T + \underbrace{\int_{t_0}^T \exp(-\rho t)(A(t) - E(t))p(t)dt}_{\text{Carbon trade balance} = 0}$$

## Effects on regional mitigation costs



Influence of Initial Permit Allocation:

pure redistribution!

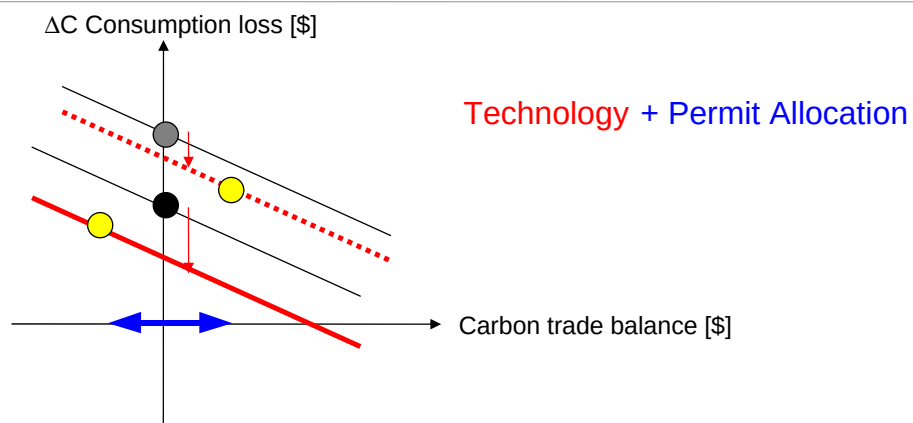
2<sup>nd</sup> theorem of welfare:

free flow of capital

→ *separability* of equity and efficiency

$$\Delta C = D + T + \underbrace{\int_{t_0}^T \exp(-\rho t)(A(t) - E(t))p(t)dt}_{\text{Carbon trade balance}}$$

## Effects on regional mitigation costs



$$\Delta C = D + T + \underbrace{\int_{t_0}^T \exp(-\rho t)(A(t) - E(t))p(t)dt}_{\text{Carbon trade balance}}$$

## Decomposition of Cumulative Consumption Effects

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- Macro Economic Budget (cumulated over time):

$$(1) \quad \sum_t (Y + X_G) = \sum_t (C + I + G_{\text{ESM}}) \quad \text{for all regions}$$

- Intertemporal Trade Balance:

$$(2) \quad \sum_t (p_G X_G + p_E X_E + p_P X_P) = 0 \quad \text{for all regions}$$

- Combine (1) and (2), calculate aggregate differences of policy scenario and reference scenario for all regions:

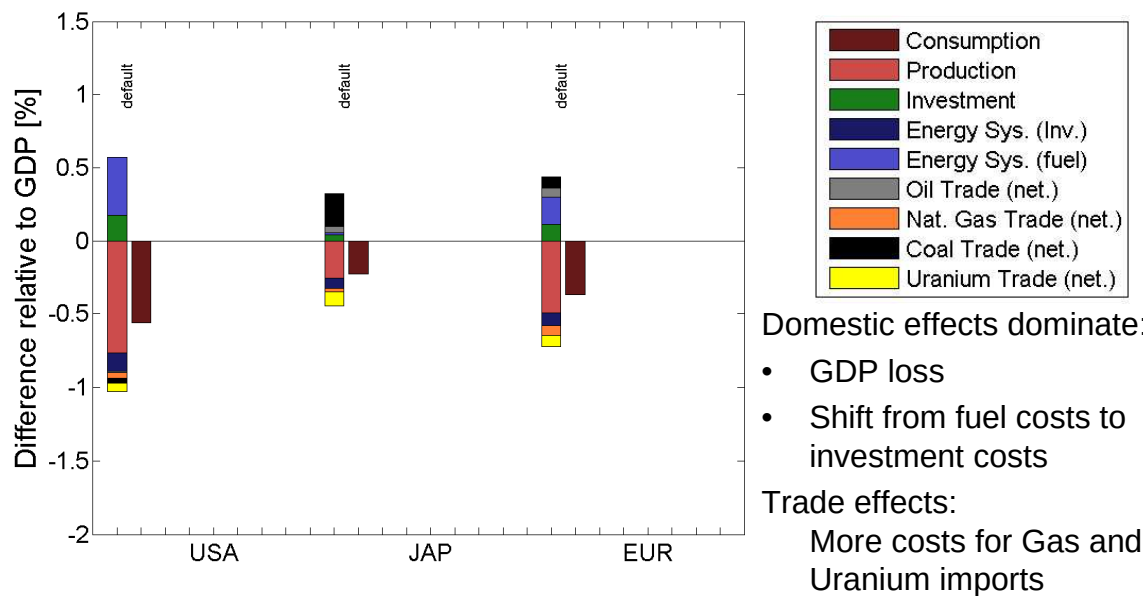
$$\Delta C = \underbrace{\Delta Y - \Delta I - \Delta G_{\text{ESM}}}_{\text{domestic effect}} + \underbrace{\Delta X_E}_{\text{energy trade effect}} + \underbrace{\Delta X_P}_{\text{permit trade effect}}$$

(subtract extraction costs from energy trade effect)

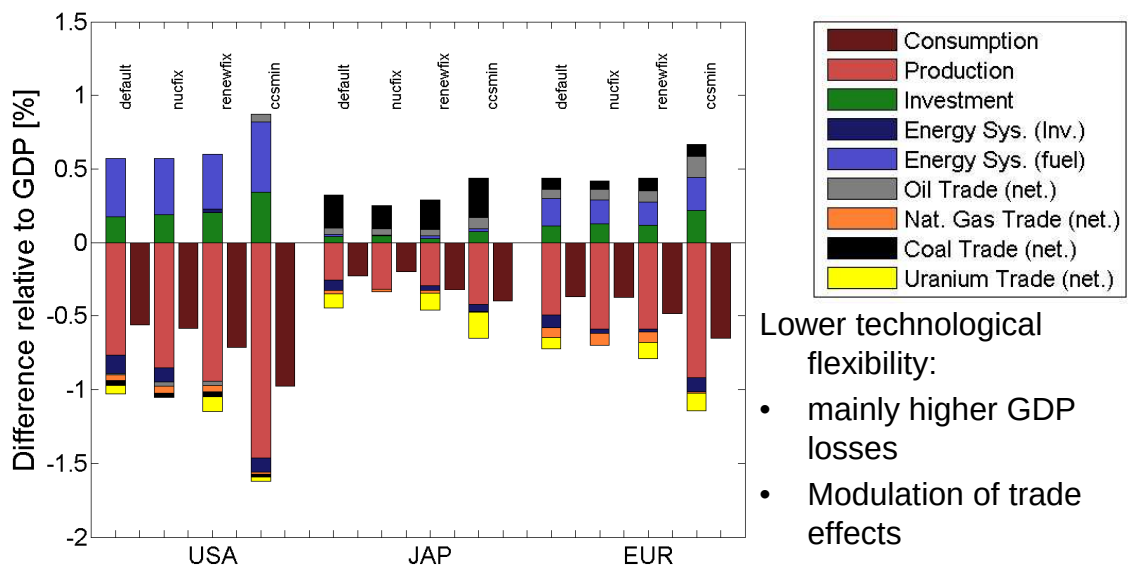
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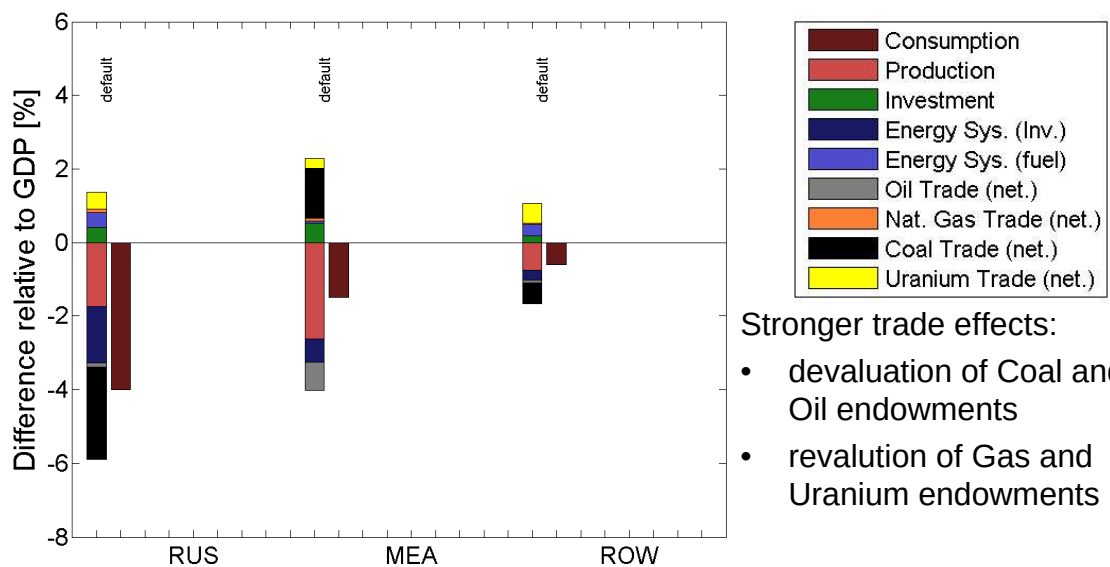
## Results: domestic and energy trade effect



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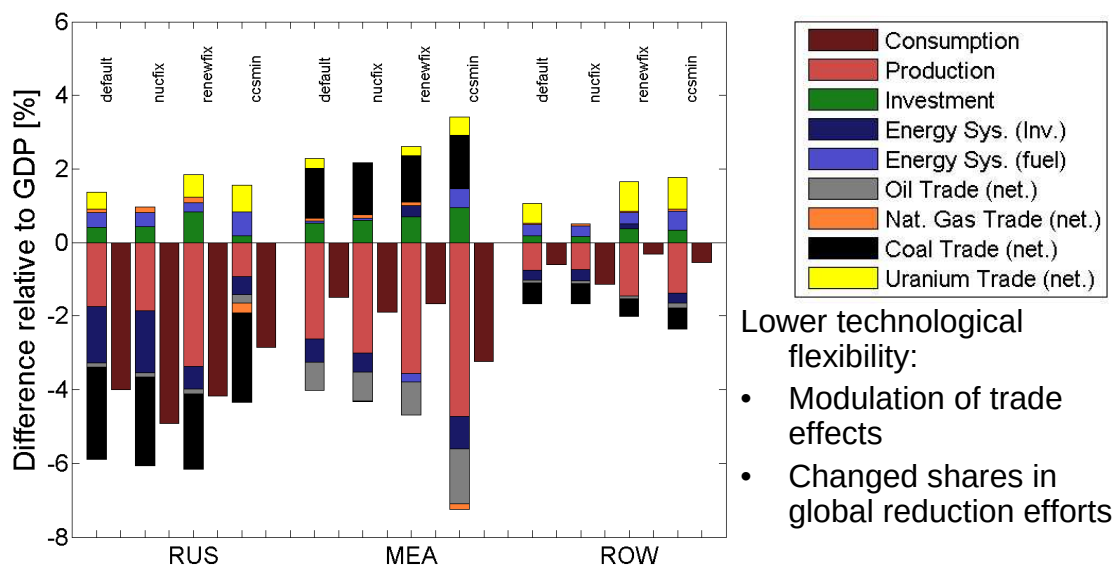
## Results: domestic and energy trade effect



Stronger trade effects:

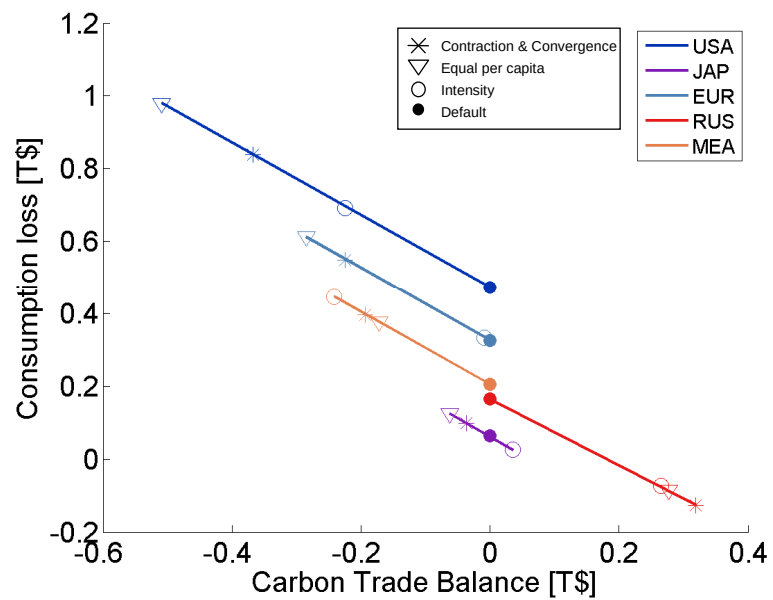
- devaluation of Coal and Oil endowments
- revaluation of Gas and Uranium endowments

## Results: domestic and energy trade effect

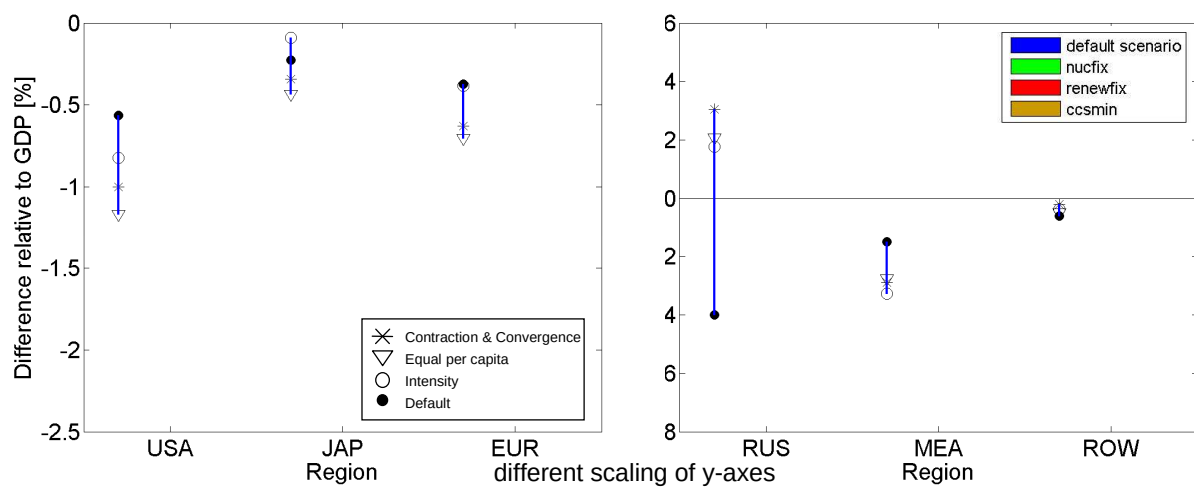


## Results: Permit trade effect

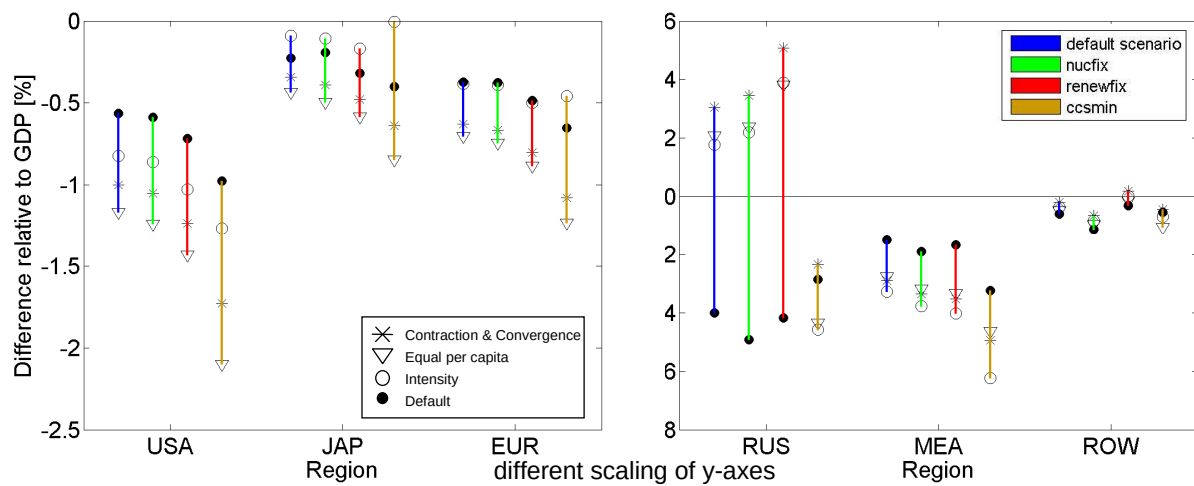
- linear relation
- huge (absolute) numbers
- Strong redistribution implied by common allocation schemes



## Results: Combined effects

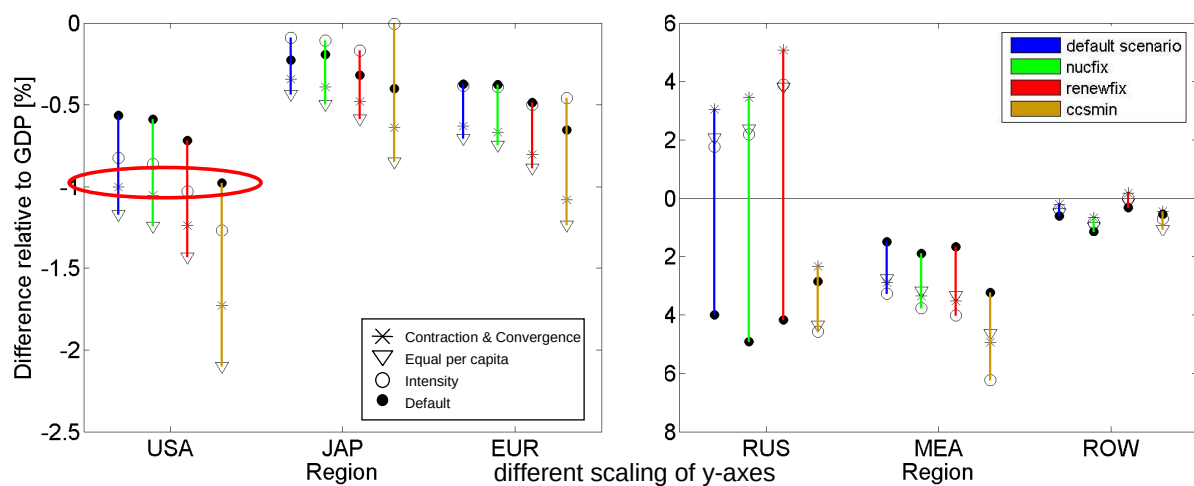


## Results: Combined effects



- Greater impact of allocation scheme, when technological flexibility is lower due to higher carbon price
- Exceptions (e.g., RUS, ccsmin): lower share in global reduction effort

## Results: Combined effects



- Incentive for industrialized regions to promote the availability of low-carbon technologies

## Conclusions

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- Consumption losses are lower than GDP losses for most regions
- Trade effects matter for the distributive effects of mitigation:
  - Costs of fossil energy exporters can largely be attributed to the devaluation of their endowments
  - Consumption losses of fossil exporters eventually exceed GDP losses
- Assumptions on the availability of low-carbon technologies have a significant impact
  - on regional shares in the global emission reduction effort
  - on revenues from energy trade due to a modified carbon price

## Conclusions: Policy implications

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- Higher technological flexibility
    - generally leads to lower redistributions
    - less conflicts about permit allocation scheme
  - Incentives for industrialized regions to promote the feasibility of low-carbon technologies, especially under allocation schemes that generate high redistributions
- A broad portfolio of low-carbon technologies facilitates international agreements on a permit allocation scheme, which is a cornerstone of a stringent global climate policy.



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## Scenarios

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- Reference scenario: no climate policy
- Policy scenarios with 2° temperature target:
  - default: full portfolio of low-carbon technologies
  - *nucfix*: nuclear restricted to reference scenario level
  - *renewfix*: renewables restricted to reference scenario level
  - *ccsmin*: CCS restricted to 100 GtC cumulated

Default permit allocation:

Allocation equals actual emissions for each region



Michael Lüken et al.

17.06.2009  
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## Fossil energy endowments

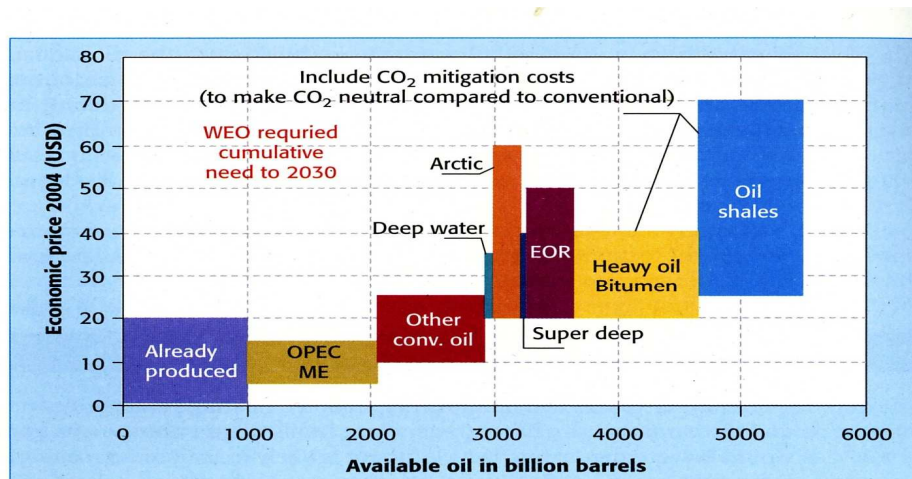
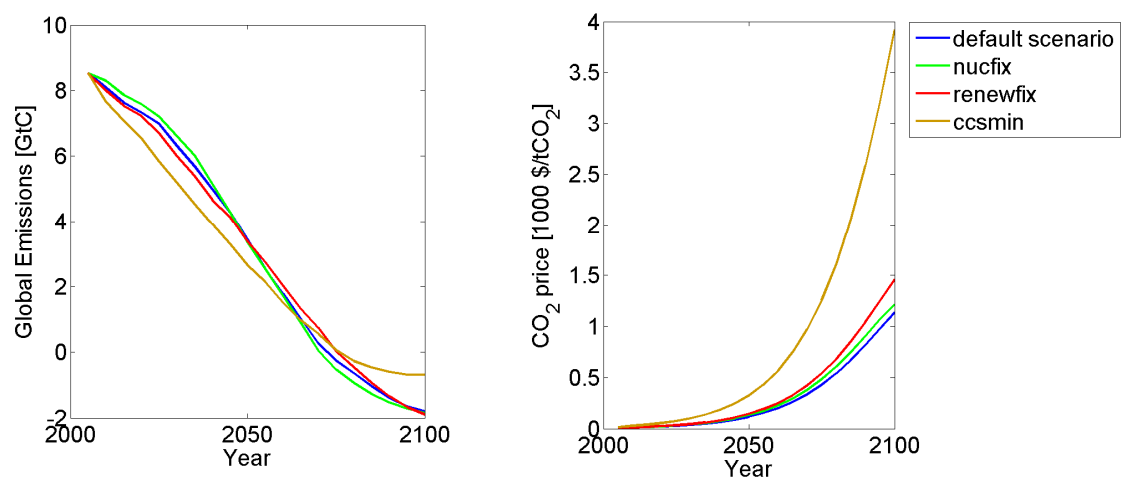


**Figure 7.6** Availability of oil by price<sup>48</sup>

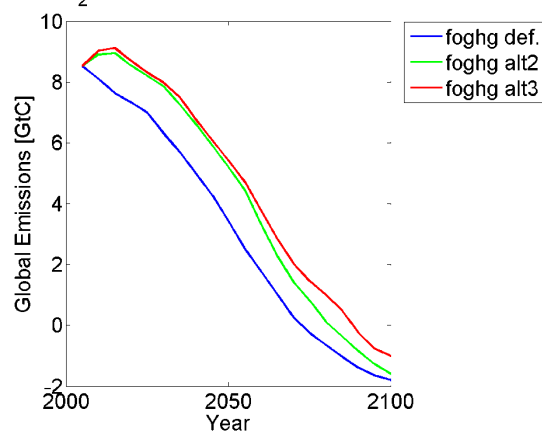
Source: International Energy Agency

## Emissions and Carbon Price

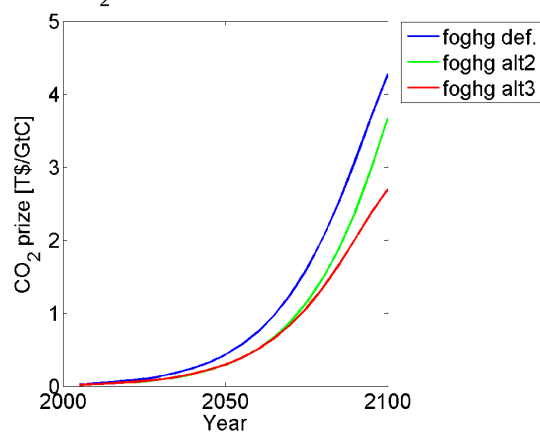


## Relevance of assumptions on OGHG emissions

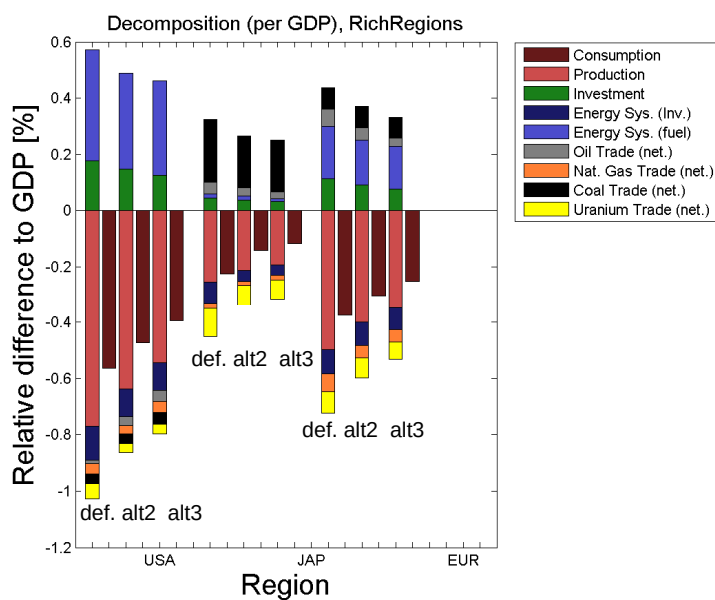
Global CO<sub>2</sub> emissions (check-foghg-emiop-alle)



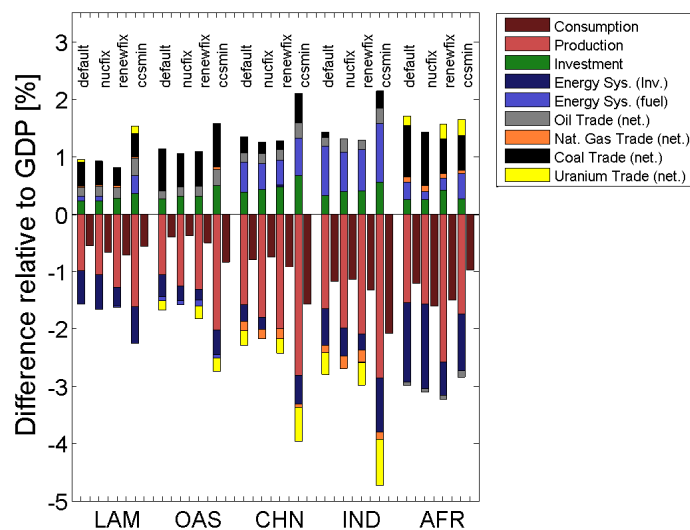
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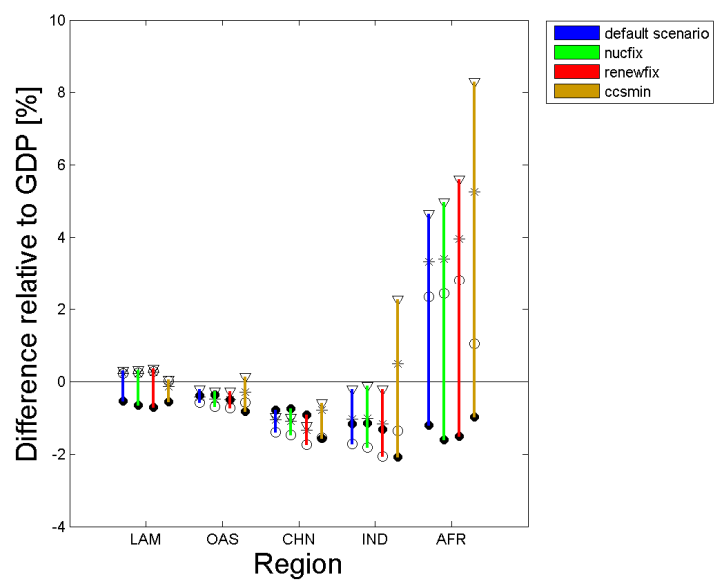
## Relevance of assumptions on OGHG emissions



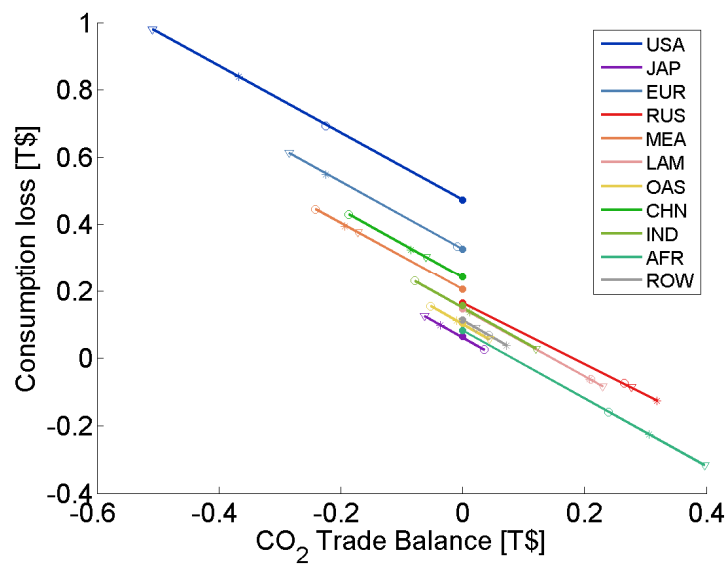
## Results: emerging and transition economies



## Results: emerging and transition economies



## Permit trade effect, all regions

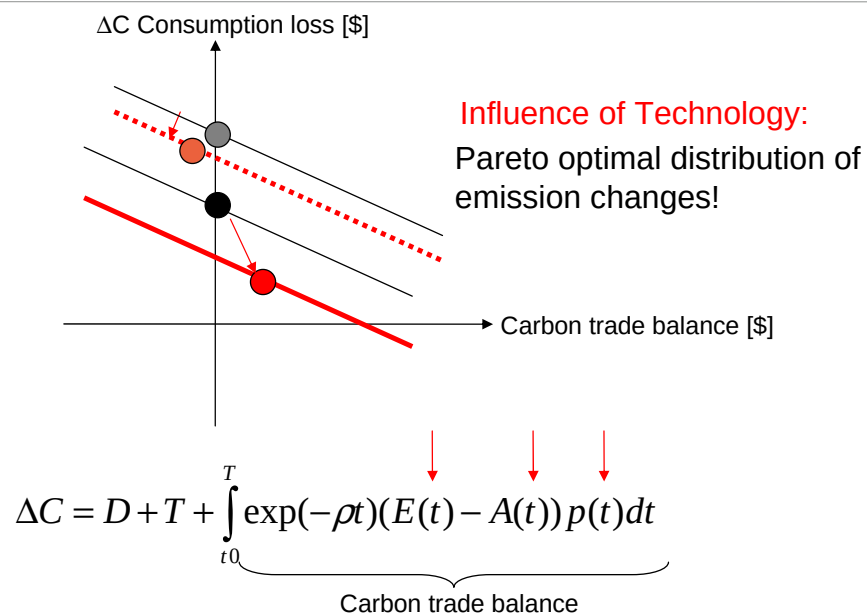


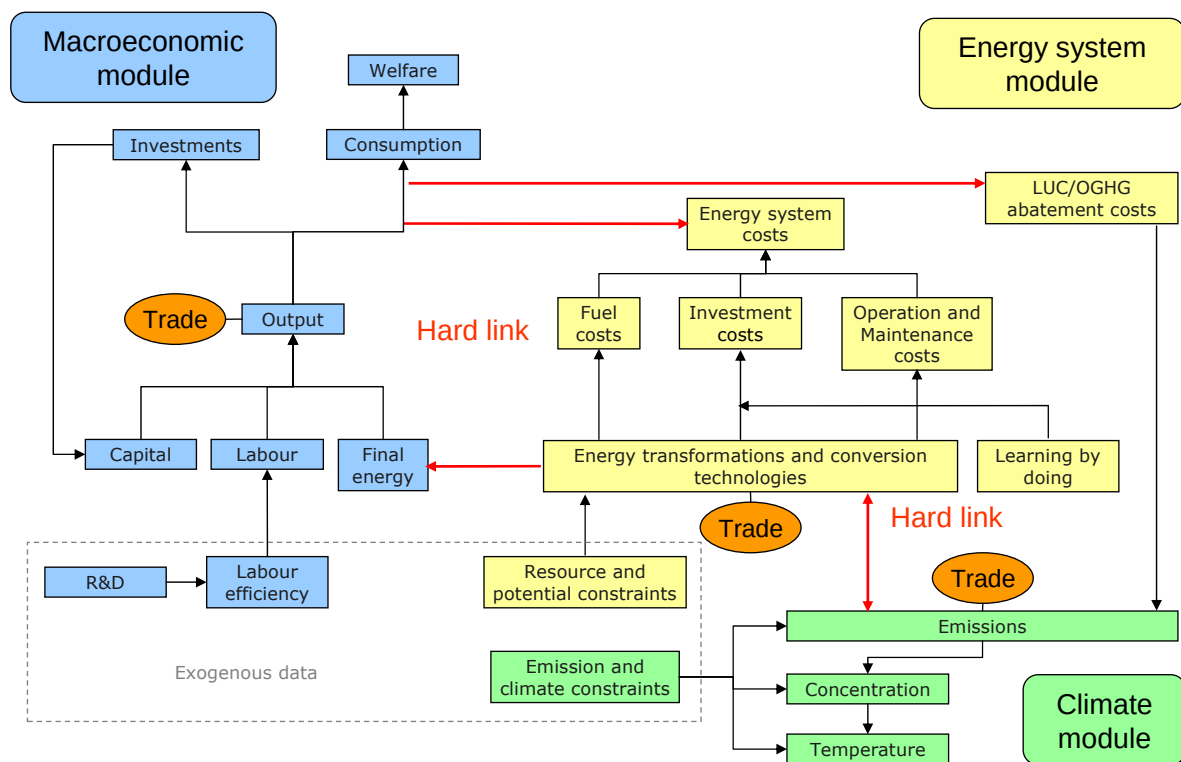
## 2<sup>nd</sup> Theorem of Welfare

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- In our model setting, the **2<sup>nd</sup> theorem of welfare** holds due to model assumptions, especially:
  - The externality of climate change is fully **internalized** by the policy target.
  - **Free flow of capital and permits** among regions.
- The theorem states that after a redistribution of endowments a market solution can always be attained.
- If the second theorem of welfare holds:  
„**Separability** of equity and efficiency“

## Introduction: Effects on regional mitigation costs





## Trade in REMIND

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- Tradable Goods:
  - Coal, Gas, Oil, Uranium
  - Aggregate Macroeconomic Output Good
  - Emission Permits

tradable Primary Energy carriers are *endowments* of the exporting regions

- subject to an Intertemporal Trade Balance:

$$\sum_t (p_G X_G + p_E X_E + p_P X_P) = 0 \quad \text{for all regions}$$

