18. Österreichischer Klimatag

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The economy-wide effects of large-scale renewable electricity expansion in Europe: the role of integration costs

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Outline

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- Methodology
  - CGE Model
- Data and scenarios
  - Wind expansion
  - PV expansion
- Results
- Conclusions

Motivation

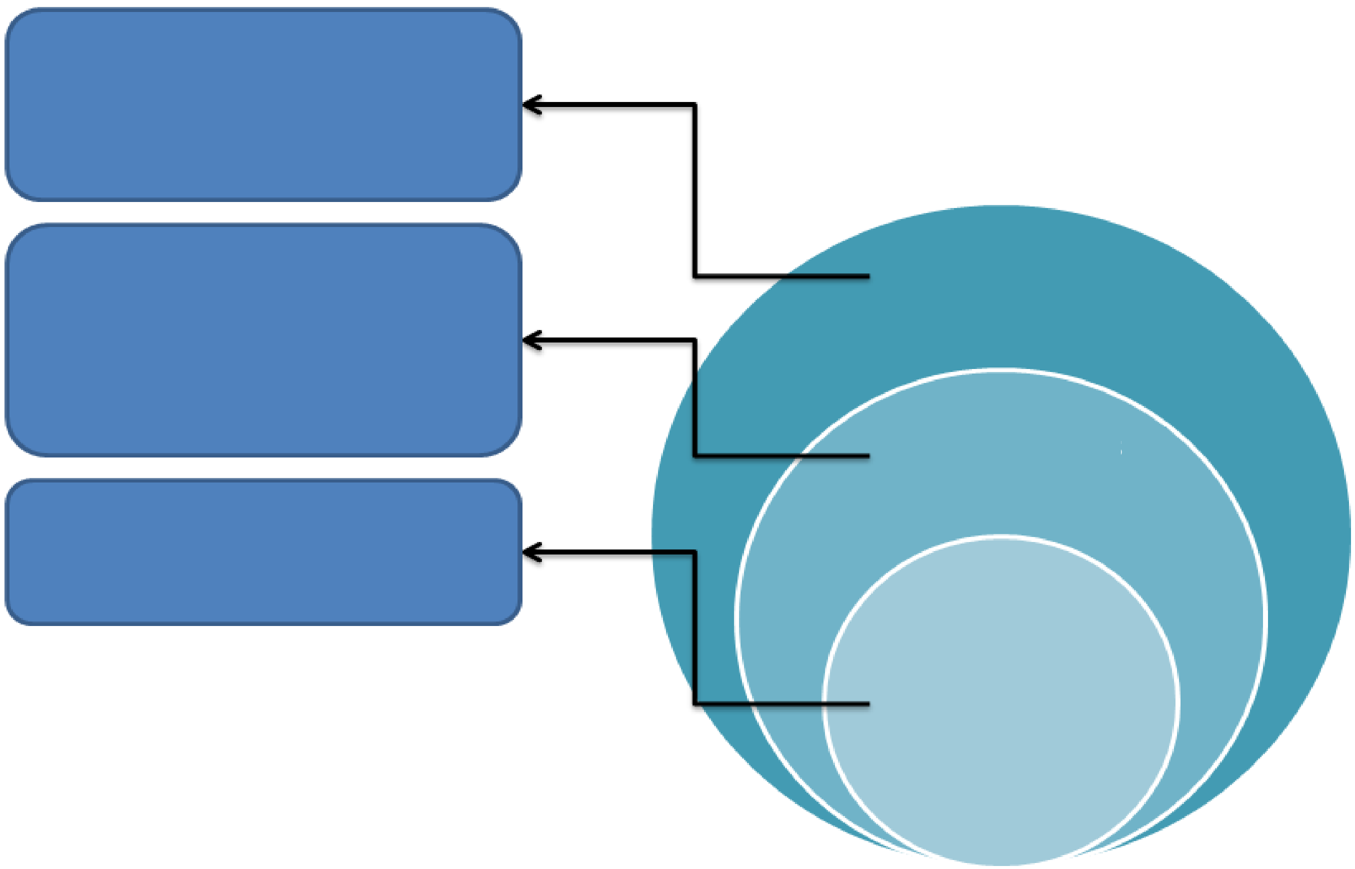
Motivation

- Motivation: "2030 Energy Strategy" (EC, 2014)
  - share of renewables in energy consumption should be at least 27%
  - share of renewables in **electricity** generation reaching at least 45%

- **Economy-wide analyses** is crucial
  - given the significant expansion under way
  - Possible spillover effects to other economic agents via shifts on markets; **not visible in narrow and partial technology specific comparisons** (e.g. traditional LCOE)

- We analyze the possible economy-wide implications of a large-scale expansion of
  - wind
  - photovoltaics (PV)
- Making use of a computable general equilibrium (CGE) model

Different dimensions of costs for renewables deployment



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Categories of integration costs (cf. Hirth et al., 2015)

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Balancing costs

- Due to uncertainty and forecasting errors → costs of unscheduled ramping and cycling of residual power plants

Grid-related costs

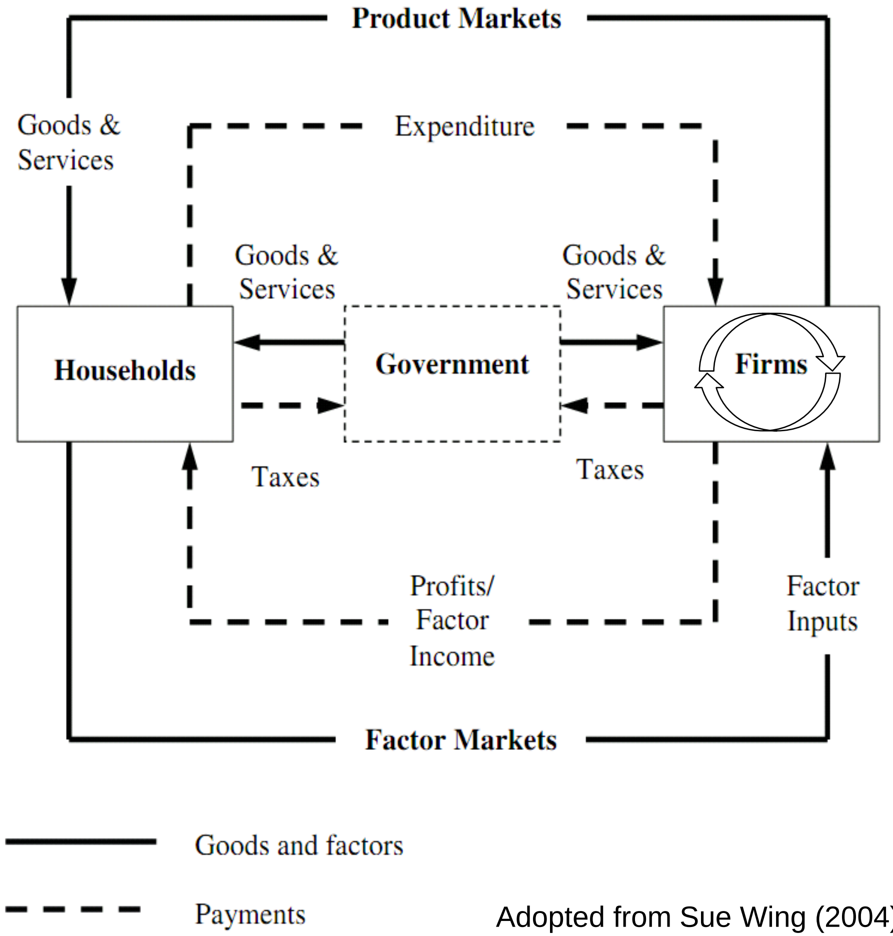
- Supply of a variable renewable is location-specific and productive sites are often far away from demand → transmission costs

Profile costs

- Supply profile ≠ demand profile → Scheduled flexible supply by residual power plants (*flexibility effect*)
- Reduced utilization of the residual power plant fleet → efficiency loss (*utilization effect*)

Methodology

Computable general equilibrium (CGE) model



Adopted from Sue Wing (2004)

- Global, multi-regional, multi-sectoral
- Economy as closed system of annual monetary flows across production sectors and demand agents (GTAP9 database, base year 2011)
- Flows in equilibrium
- All sectors and agents are interlinked (input-output structure)
- Producers (sectors) maximize profits, consumers (households and government) maximize utility out of consumption

Computable general equilibrium (CGE) model

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17 regions

- 6 European regions
  - northern (NEU), eastern (EEU), southern (SEU) and western Europe (WEU)
  - Greece (GRC), Austria (AUT) separately
    - cases with very different preconditions
- 11 further regional aggregates for rest of the world

15 production sectors

- Thereof, one “conventional” electricity sector (current mix)
- New “wind” and “PV” electricity technologies are introduced in simulation scenarios, replacing partly “conventional” electricity
  - To be policy relevant we assume technology cost forecasts for 2030

Computable general equilibrium (CGE) model

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- When equilibrium is disturbed ("shocked") a new equilibrium emerges, with changed relative prices and demanded/supplied quantities

- We compare two states (equilibria) of the economy to each other

  1) Current status of the economy *without* expansion

  2) Another equilibrium representing the economy if a new technology had been expanded (*ceteris paribus*)

Implementation of integration costs in CGE model

- Grid-related costs
  - as additional investment (capital) costs for renewables

- Profile costs
  - utilization effect; as additional capital cost markup of residual power plant fleet (capital is less efficient)

Data and Scenarios

Underlying data and scenarios: direct costs

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Wind:

- EWEA's "central" scenario: 24.4% of the EU's electricity demand is covered by wind power by 2030 (EWEA, 2015)
- Regional shares of expansion from EWEA (2015)
- Investment costs **€960/kW** in 2030; O&M: **€50/kW** (IRENA, 2016)
- WACC: 5% in WEU - 12% in GRC (Angelopoulos et al., 2016)

PV:

- Share of PV of EU's electricity demand is 24.4% by 2030 (comparable to wind scenario)
- Regional shares of expansion based on insolation model (Grossmann et al., 2013)
- PV installation costs **€740/kW** in 2030 (upper bound), O&M: **€5/kW** (IRENA, 2016)
- WACC: 20% lower than for wind

Underlying data and scenarios: integration costs

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Based on Hirth, 2015 and 2013; Hirth et al., 2015; Holttinen et al., 2011:

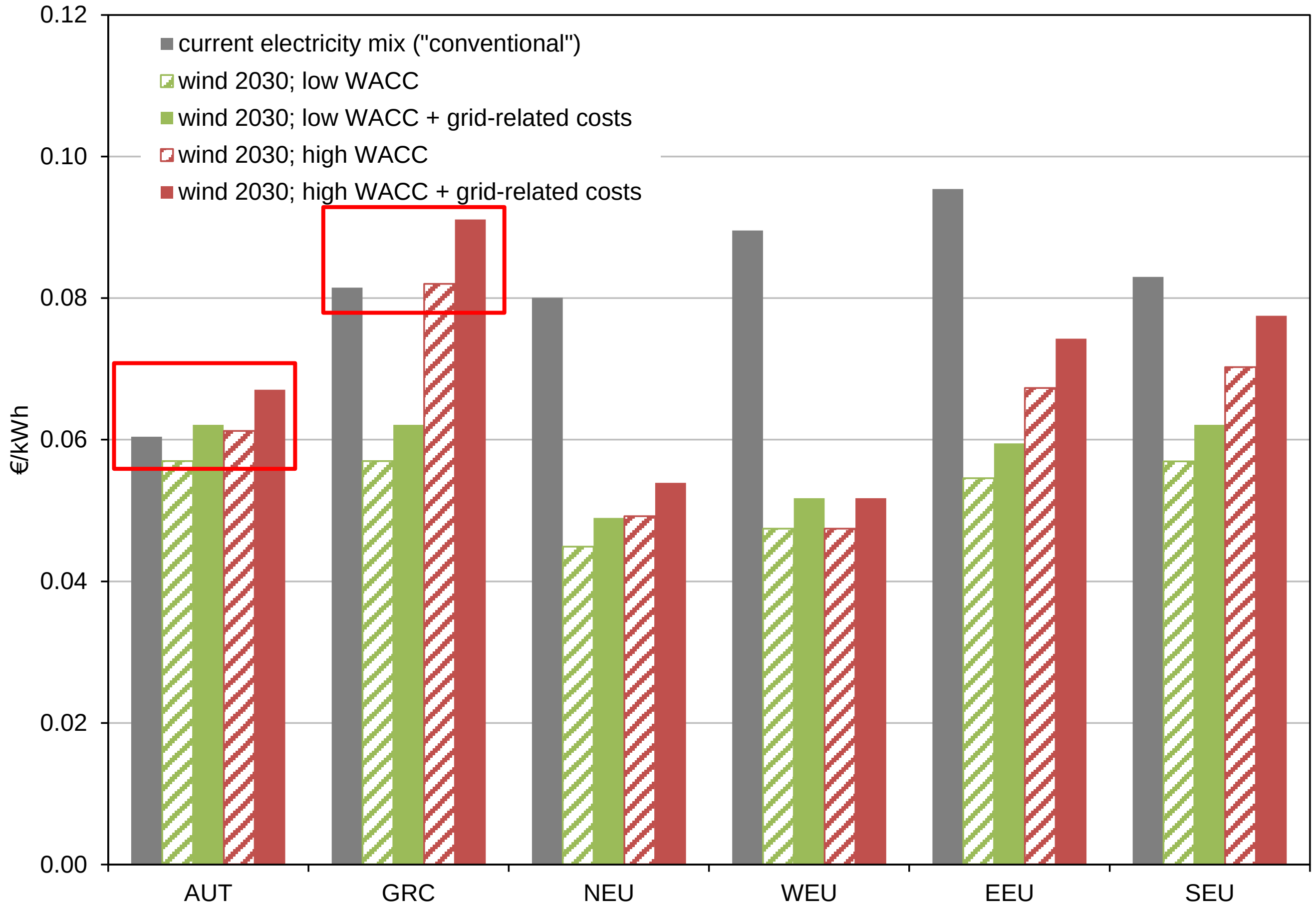
"Grid-related costs": estimated to be between €50-200/kW

→ assume **€150/kW**

"Utilization effect": €15-20 for each MWh of generated variable renewable electricity (VRE) for penetration rates <40%

→ assume **€15/MWh**

Wind – LCOE comparison
Current Mix VS wind 2030



AUT: already cheap hydro power in conventional mix

GRC: currently high WACC

PV – LCOE comparison
Current Mix VS PV 2030

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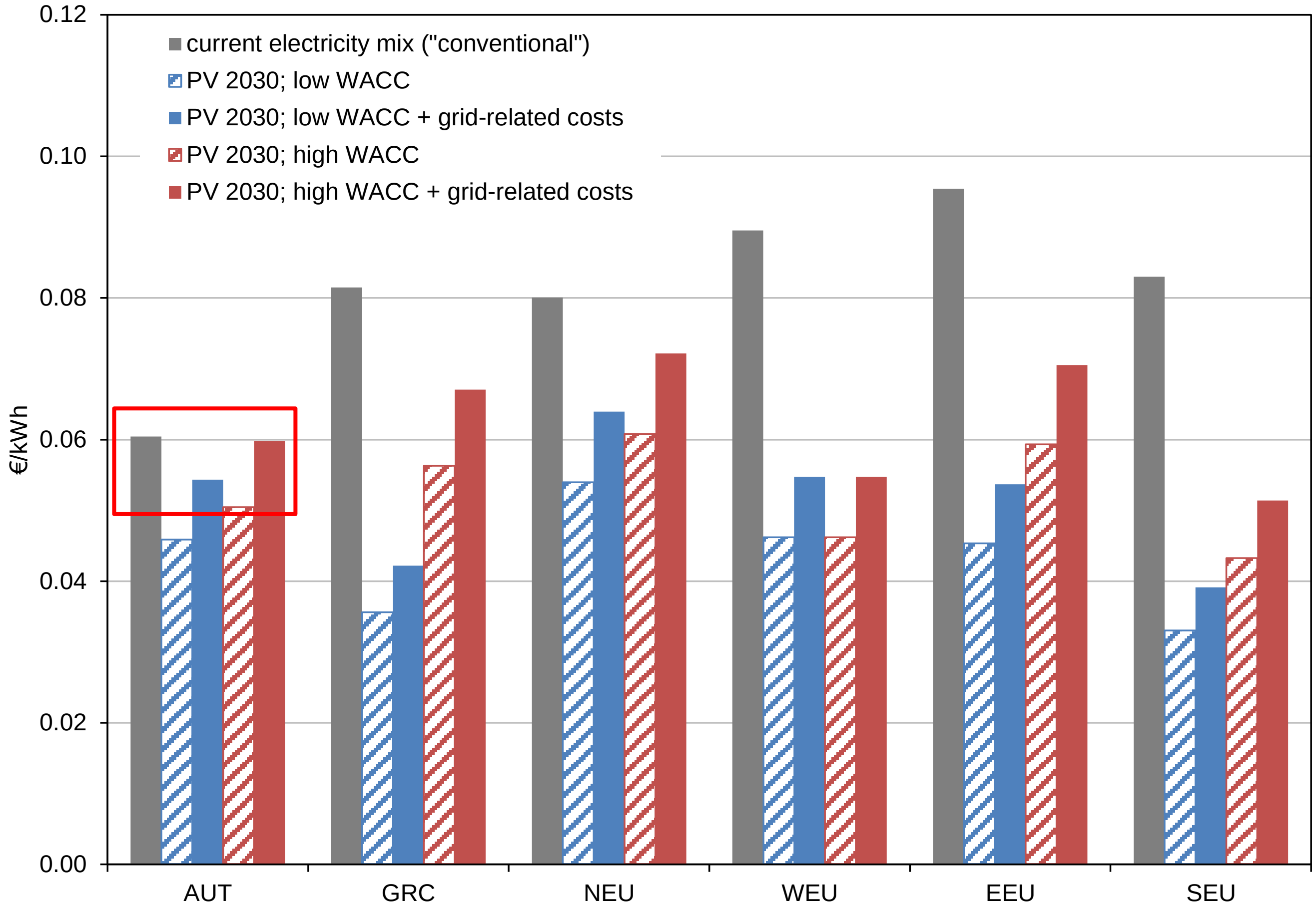

AUT: already cheap hydro power in conventional mix

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Results

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Effects on the electricity market: Relative electricity prices

Relative electricity prices after the expansion of wind (a) and PV (b) in the high-WACC scenario, including integration cost (after economy-wide feedback effects)

Macroeconomic effects: Welfare effects

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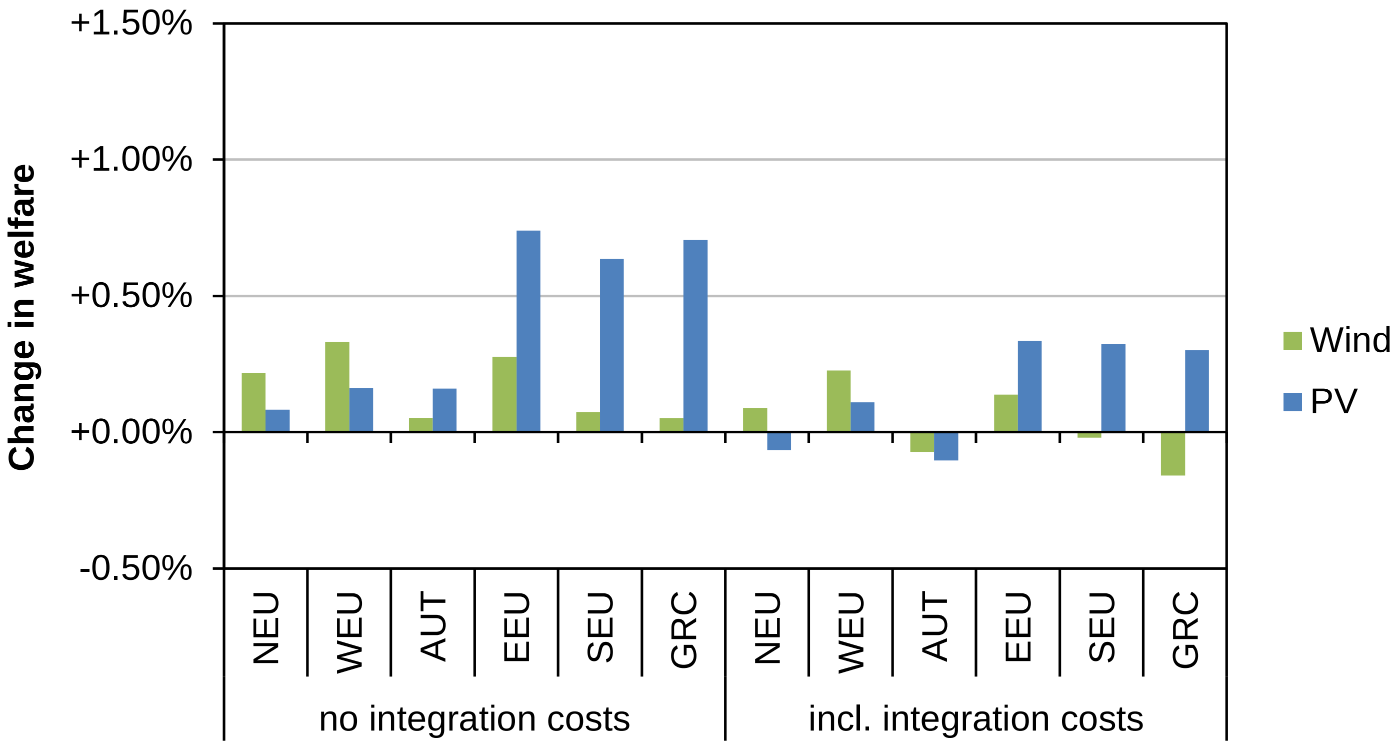

Welfare effects after the expansion of wind and PV (high-WACC scenario)

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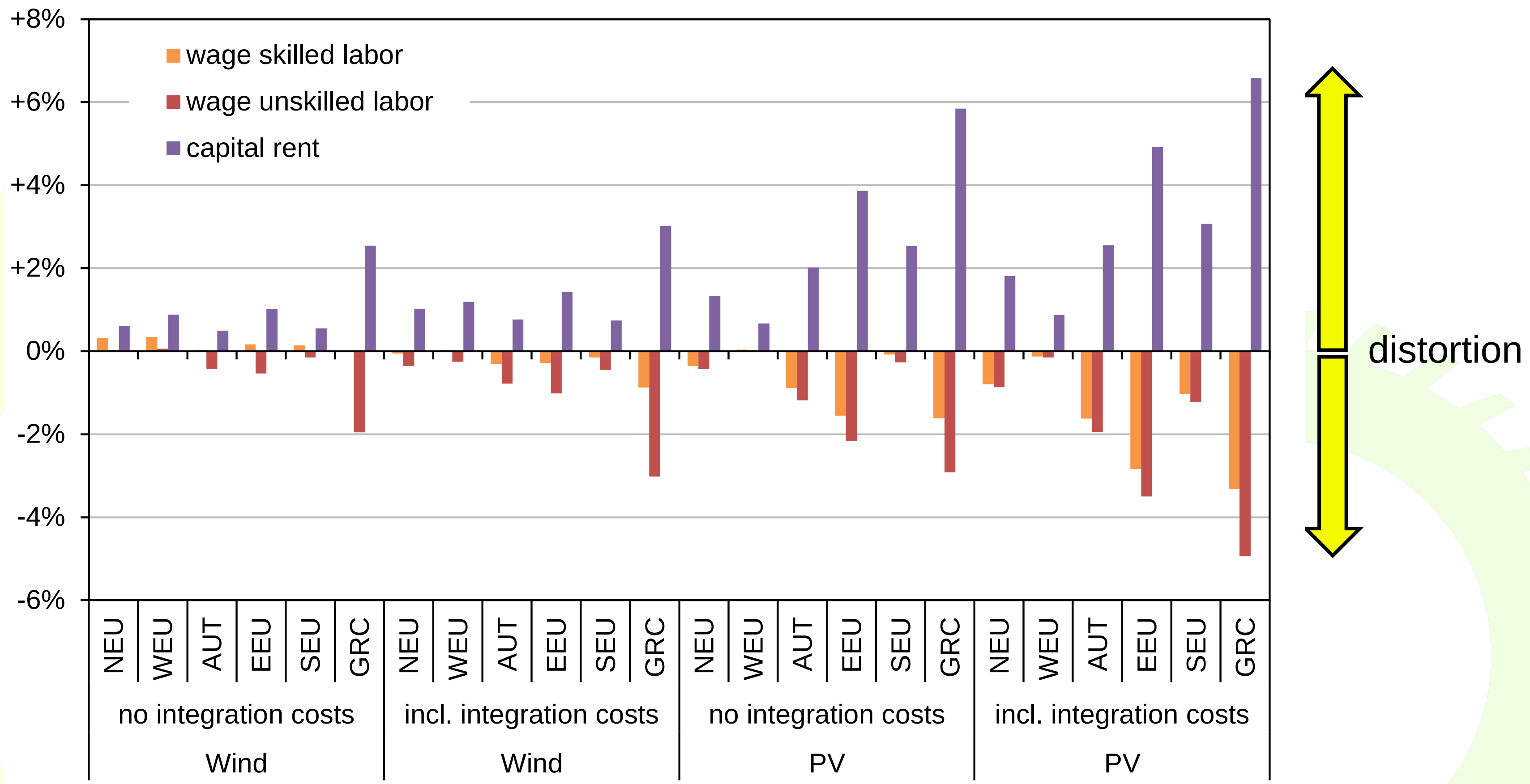
Macroeconomic effects: Factor prices



Conclusions

Conclusions

- Regional welfare effects tend to be positive and depend on
  - (i) relative generation costs, (ii) relative capital intensity
  - to a considerable part on (iii) integration costs

  ➔ Can we reduce integration costs? How? Decentralized energy systems? Power-to-X? Vehicle-to-grid systems?

- Traditional bottom-up LCOE comparison might be misleading
  - Integration costs as additional cost components
  - High capital intensities lead to higher prices for capital (capital rents)

  ➔ Higher generation costs than anticipated from a bottom-up perspective

- Substantial distributional effects: wages decline, capital income increases
  - positive welfare effects may be distributed very unevenly
  - Distortion stronger in PV case

  ➔ Ways to re-distribute possible welfare gains and losses evenly?

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