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Abteilung

Costs of Climate Change in Switzerland CGE modeling with/without adaptation

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1. The Model

- World computable general equilibrium model

  GEMINI-E3 (fifth version)
- Recursive dynamic model
- The model contains:
  - 6 regions (including Switzerland)
  - 28 sectors (for Switzerland), including 5 energy sectors
  - 4 natural resources (land, snow, 2 raw water resources)
- Calibration: Database GTAP 6 (2001), Swiss Input-output table (2001).

2. The modeling approach

Climate scenario:

Regional Climate scenario based on ENSEMBLES European project and new Swiss climatic scenarios CH2011:

- CH2011: regional scenarios of temperature and precipitation at daily resolution based on probabilistic method (A1B and A2 emission scenarios)

- Four GCM-RCM couplings from the ENSEMBLES project (A1B emission scenario, 25 x 25 km grid)

2. The modeling approach

- *Comparison of model simulations* with endogenous adaptation and model simulations with combined endogenous and exogenous adaptation.
- *Endogenous adaptation* included as possibility to substitute between different production factors to find new equilibrium.
- *Exogenous adaptation* included as specific measures, e.g., subsidies, to achieve certain effect.

3. Results

3.1 Water Resources

3. Results

3.1 Water Resources

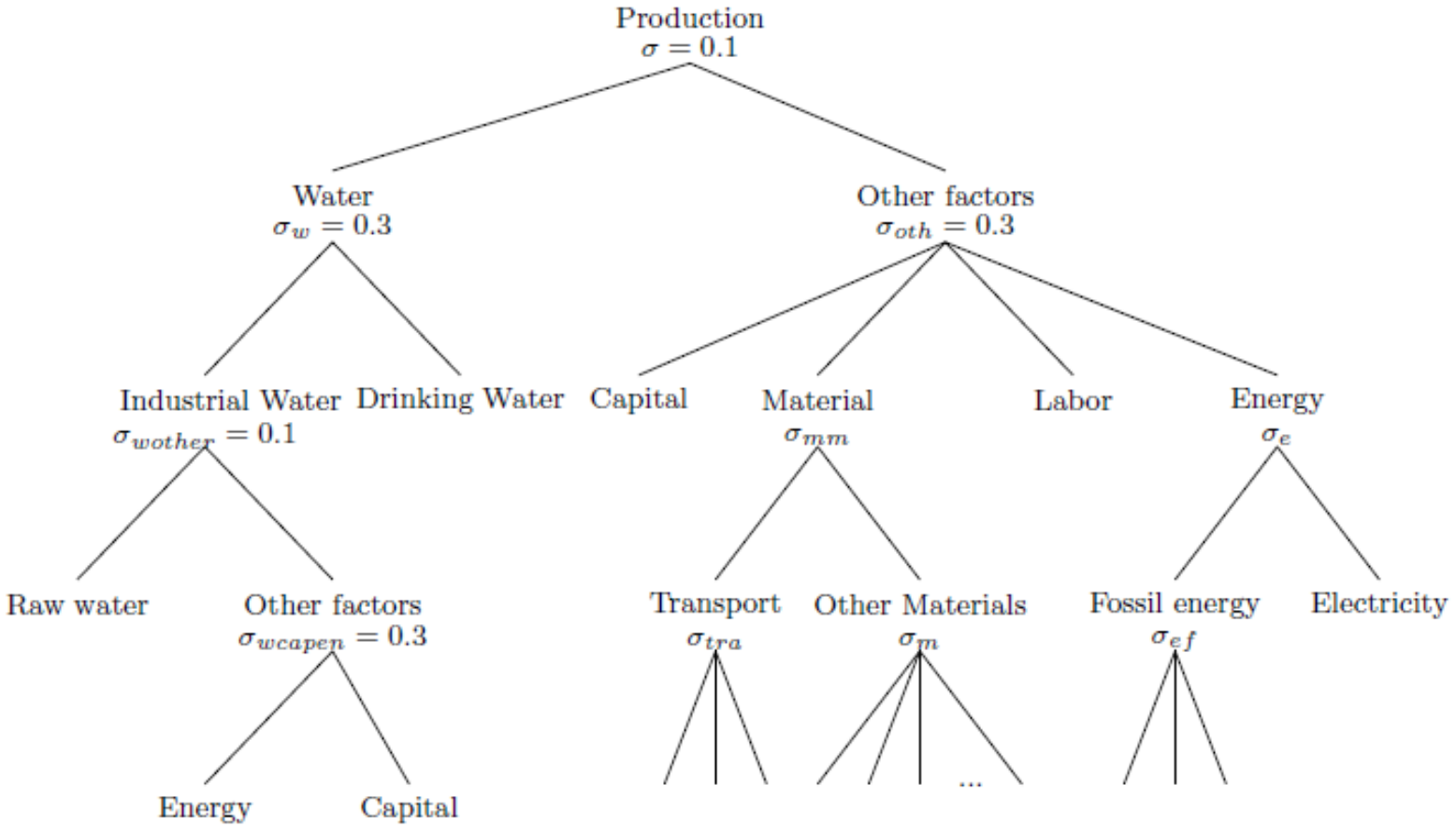
Methodology:

1. Include raw water resources and a drinking water distribution sector into model
2. Specify new production structures for
   - drinking water distribution sector
   - agriculture, industry and service sectors that use water as an input
3. Define impact of climate change on water resources
4. Simulate the economic impact of variations in raw water availability with and without exogenous adaptation

3. Results

3.1 Water Resources

Endogenous adaptation:



3. Results

3.1 Water Resources

Adaptation option:	Model
Supply side	
Investments in infrastructure to compensate for decrease in supply	x
- Interconnection of different water supply systems	
- Increase in water storage capacity	
- Diminution of leakages	
Subsidies of infrastructure investments	
Additional water treatment capacity	
Demand side	
Increase efficiency of water use in production process	x
Use of private wells and other sources	x
Policy measures – subsidies	x
Regulation of water use	x

Endogenous adaptation

Exogenous adaptation

3. Results

3.1 Water Resources

Model simulations with different climate scenarios, variations from baseline.

Scenarios	1	2	3	4
Climate Scenario	ETHZ	SMHI	-20%	Mean
Raw water	-6.8%	9.4%	-20.0%	-1.3%
Raw water for irrigation	-15.8%	-2.6%	-20.0%	-10.8%
Production price				
Industrial water	46.6%	-32.8%	229.9%	7.1%
Irrigation water	64.6%	7.7%	88.9%	38.2%
Drinking water	12.4%	-8.8%	60.9%	1.9%
Drinking water consumption				
Total	-3.2%	2.6%	-11.9%	-0.5%
Households	-2.3%	1.9%	-9.1%	-0.4%
Welfare change (mio CHF_{2010})	-61.2	31.9	-276.1	-14.0
Direct cost (mio CHF_{2010})	23.8	-31.3	68.3	5.1

3. Results

3.1 Water Resources

Exogenous Adaptation:

Introduce subsidies for households to compensate for higher price of drinking water.

Scenarios	ETHZ	ETHZ + Subsidy
ETHZ climate scenario		
Raw water	-6.8%	-6.8%
Raw water for irrigation	-15.8%	-15.8%
Production price		
Industrial water	46.6%	54.0%
Irrigation water	64.6%	64.4%
Drinking water	12.4%	14.4%
Drinking water consumption		
Total	-3.2%	-2.2%
Households	-2.3%	0.0%
Welfare change (mio CHF_{2010})	-61.2	-64.1
Subsidy (mio CHF_{2010})		147.7

3. Results

3.1 Water Resources

Summary

- High uncertainty related to climate scenarios
- Variations in water availability have a very large impact on water prices
- Global economic impact is rather limited
- Economic impacts most sensitive to the possibilities to replace raw water by other factors and industrial water by other factors
- Limitations and uncertainties:
  - Extreme events (flods, droughts) are not accounted for
  - Changes in seasonality only partly integrated in analysis
  - Impacts of climate change on the other regions are not considered

3. Results

3.3 Energy demand

3. Results

3.3 Energy demand

Methodology

1. Derive the evolution of two climatic indicators:
   - Heating Degree-Days (HDD) for heating
   - Cooling Degree-Days (CDD) for cooling
2. Compute ex-ante changes in energy demand compared to the baseline:
   - Econometrical analysis of the relationship between residential electricity demand and climatic conditions
   - We assume heating demand to be approximately proportional to the number of HDD

3. Results

3.3 Energy demand

Changes in Heating Degree-Days (HDD) for heating

Δ_{2050}/HDD_{ref} = - 14.6%

(Threshold θ_{HDD} = 10 °C)

Changes in Cooling Degree-Days (CDD) for cooling

Δ_{2050}/CDD_{ref} = + 138.5%

(Threshold θ_{CDD} = 18.3 °C)

3. Results

3.3 Energy demand

Adaptation option:	Model
Demand side	
Increase in air conditioning demand	x
Decrease in heating demand	x
Demand side management (incl. smart grid)	
Increase in energy efficiency of air conditioning	

Endogenous adaptation

Exogenous adaptation

3. Results
3.3 Energy demand

Climate change induced decrease in heating energy consumption

	All sectors	Impacted sector ($\theta_{th} = 10^{\circ}C$) Housing	Service	Industry
Energy consumption				
Petroleum products	-3.6%	-2.3%	-1.2%	-0.1%
Natural gas	-1.4%	-0.6%	-0.6%	-0.2%
Electricity	0.5%	0.7%	-0.2%	0.0%
CO_2 emissions	-3.2%	-2.1%	-1.0%	-0.1%
Welfare change in Mio CHF_{2010}	1404	937	382	87
As a % of consumption	0.22%	0.15%	0.06%	0.01%

3. Results
3.3 Energy demand

Climate change induced increase in cooling electricity consumption

	Total	Residential	Service
Energy consumptions			
Petroleum products	-0.03%	-0.06%	0.03%
Natural gas	0.88%	0.34%	0.54%
Electricity	0.98%	0.40%	0.58%
CO_2 emissions	0.12%	0.00%	0.11%
Direct costs in Mio CHF_{2010}**	248	97	151
Welfare change in Mio CHF_{2010}	-178	-84	-94
As a % of consumption	-0.03%	-0.01%	-0.01%

3. Results

3.3 Energy demand

Summary

- Decrease in heating energy demand is most important effect of climate change on the Swiss energy sector.
- Cooling demand increases but the economic impact is smaller than economic impact of decrease in heating demand
- Limitations and uncertainties:
  - Some aspects are missing: extreme events with impacts on electricity network, impacts on renewables (wind, solar)
  - Impacts of climate change on the other regions are not considered
  - Optimistic assumption on the cost of renewable electricity generation
  - The penetration of air conditioning in the reference case is uncertain

4. Benefit of endogenous adaptation

a) Direct costs larger than welfare loss

Benefit of endogenous adaptation is calculated as difference of *direct costs* of climate change shock applied to the model and *welfare loss* after economic system has adapted to new situation.

Cooling energy demand:

Direct costs:	248 Mio. CHF
Welfare loss :	178 Mio. CHF
Benefit:	70 Mio. CHF

4. Benefit of endogenous adaptation

b) Direct costs smaller than welfare loss

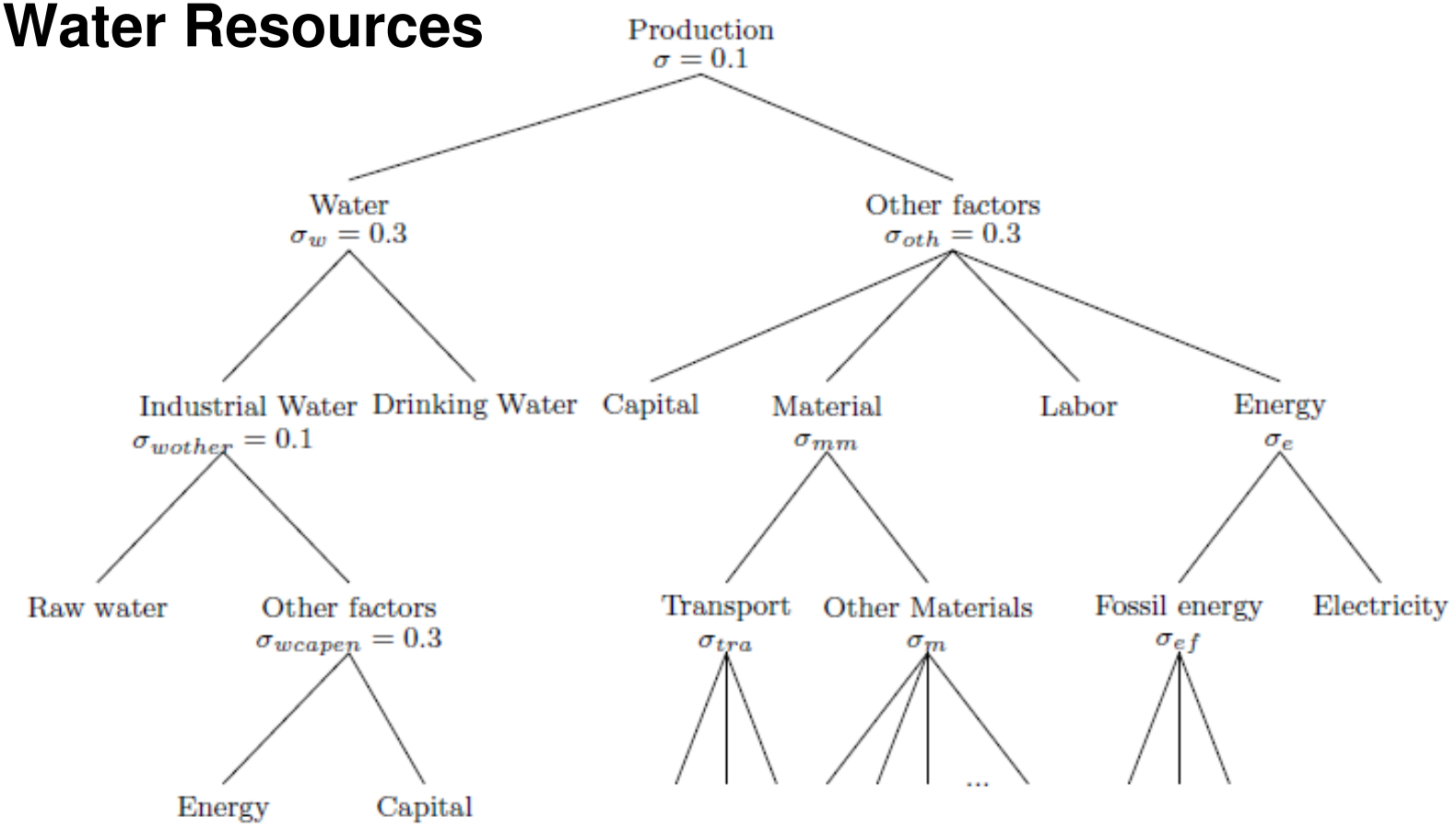
Sensitivity analysis to assess endogenous adaptation:

Modify elasticities of substitution between different inputs to make it more or less difficult to substitute away from water.

4. Benefit of endogenous adaptation

b) Direct costs smaller than welfare loss

Water Resources



4. Benefit of endogenous adaptation

b) Direct costs smaller than welfare loss

Modification of elasticities:

- Raw water - other inputs
- Industrial water - other inputs
- Irrigation - land
- Drinking water - industrial water / irrigation water
- Water - other goods in household consumption

Highest impact on welfare:

- Raw water - other inputs
- Industrial water - other inputs

4. Benefit of endogenous adaptation

b) Direct costs smaller than welfare loss

Scenarios	1	Low adaptation	High adaptation
Climate scenario	ETHZ	ETHZ	ETHZ
Raw water	-6.8%	-6.8%	-6.8%
Raw water for irrigation	-15.8%	-15.8%	-15.8%
Production price			
Industrial water	46.6%	149.4%	28.0%
Agricultural water	64.6%	269.7%	36.6%
Drinking water	12.4%	39.7%	7.3%
Drinking water consumption			
Total	-3.2%	-2.2%	-3.2%
Households	-2.3%	0.0%	-2.8%
Welfare change (mio CHF_{2010})	-61.2	-92.4	-55.5

5. Conclusions

- Model was successfully adapted to simulate adaptation in five sectors (water resources, agriculture, energy demand an supply, tourism).
- Despite endogenous adaptation is included into the model, the results show a loss of welfare in most cases.
- The residual loss of welfare implies that endogenous adaptation is not sufficient to compensate for climate change impacts.
- Adaptation policy is needed to induce planned adaptation measures to minimize the costs caused by climate change.