Residential energy efficiency and carbon policies: Rebound effects and emissions

CGE-analysis with bottom-up information on energy efficiency technologies

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Background

- Energy efficiency policies are important part of the road to low carbon economy
  - One of the three pillars in EU's energy and climate policy package for 2030
  - Energy Efficiency Directive (2012) emphasize on buildings
  - Interaction of the policies not thoroughly studied

➢ What is the effect of energy efficiency targets?

  ➢ How do the energy efficiency targets interact with CO_2 policies?

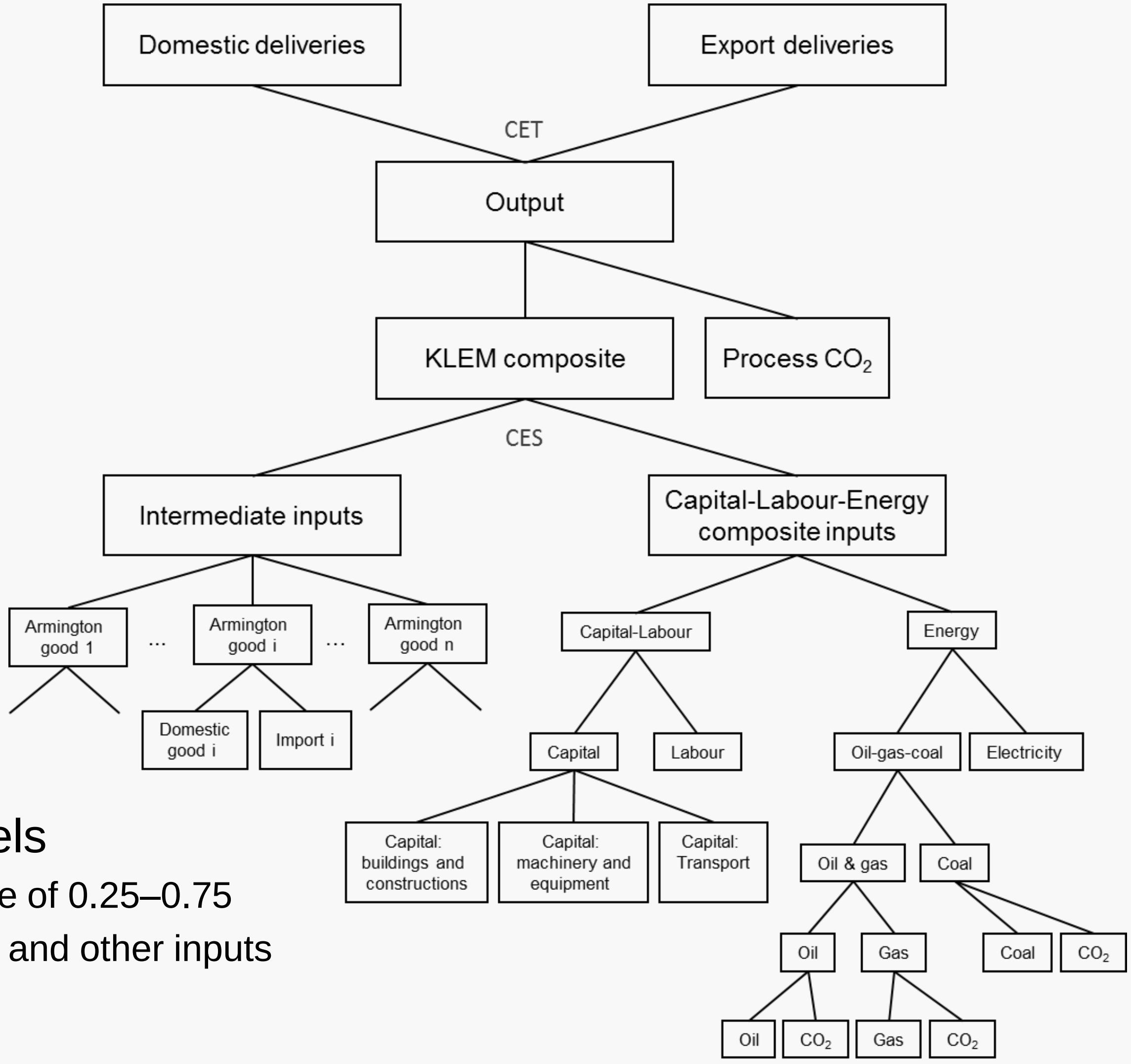
Our contribution

- Model energy efficiency investments, at increasing cost, in CGE model…
  - Costs of obtaining the energy efficiency increase are usually disregarded in CGE models (autonomous efficiency improvements)
- … based on a bottom-up approach
  - Detailed data on energy efficiency technologies and corresponding costs
- Policy analysis: Targets for residential energy use
  - Analyse various targets (caps) for energy efficiency in Norway
    - Similar energy efficiency improvements as in the EU 2030 goals
    - Interacts with EU and domestic carbon policies

SNOW – a (static) CGE model for Norway

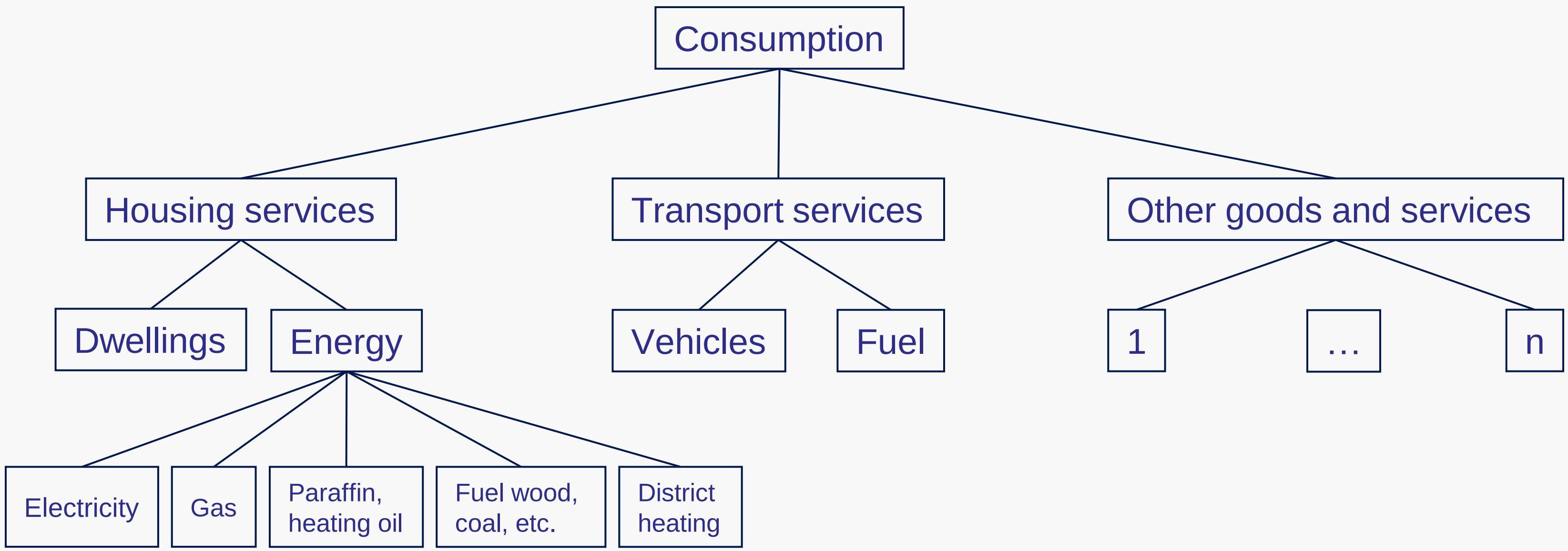
- Small open economy, rest of world exogenous
- Based on GTAP data structure modified to fit Norwegian National Accounts
  - 41 sectors, data for 2011
- Representative consumer maximises welfare
  - Income from labour, capital and natural resources
- Production technologies represented by nested CES-functions
  - Labour and capital mobile between sectors
  - Fossil fuels (crude oil, gas and coal) production endogenous, limited by the resource
  - Electricity mainly hydropower (emission-free)
- Trade
  - Armington: domestic and imported goods are imperfect substitutes
  - CET export functions
- Consumer preferences represented by nested CES-functions
- Policies and measures: taxes, subsidies and transfers
- CO_2 emissions: from energy use and from industrial processes

Production: nested CES functions



- Substitution at all levels
  - Elasticities in the range of 0.25–0.75
  - Leontief between CO_2 and other inputs

Consumption: nested CES function

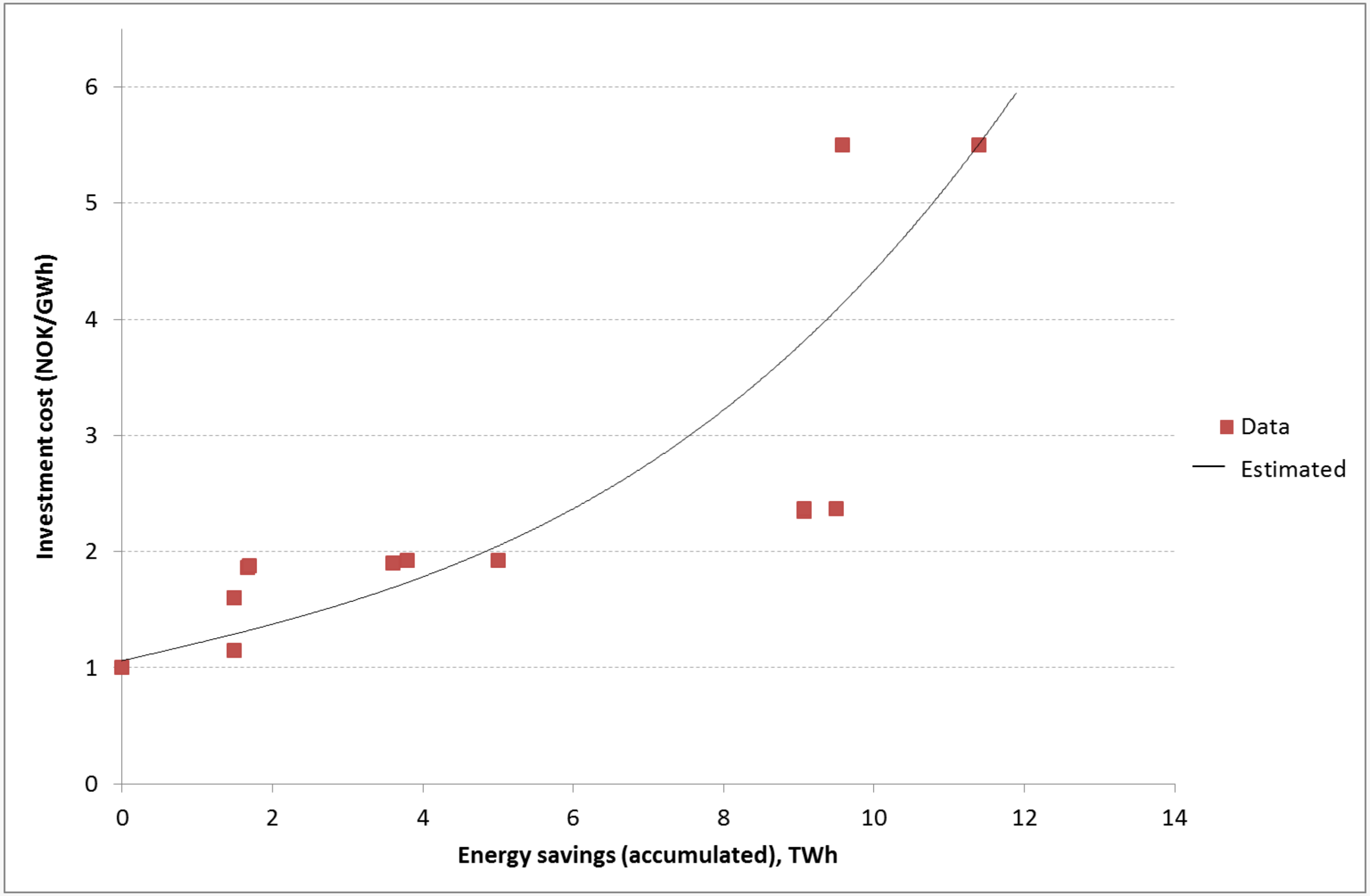


- Substitution at all levels
  - Elasticities = 0.5
  - Substitution elasticity between dwellings and energy = 0.3
- 90% of residential energy expenses in households from electricity
  - 80% in energy terms

Modelling energy efficiency investments

- Investments in dwellings are captured by substitution between the services from dwellings and energy
- Are empirical estimates for substitution elasiticity relevant?
  - Technological development takes place faster than before
  - Future technological potential as estimated on the most recent information is higher than in previous periods.
  - ➢ Base our estimate on technical experts' knowledge of possible new technologies, probabilities, potentials and costs
- Estimate the substitution elasticity between dwellings and energy
  - Based on detailed bottom-up energy technology data we estimate a marginal cost curve for energy efficiency investments
  - ➢ Best fit: elasticity of substitution = 0.3

Energy efficiency investments and calibrated substitution

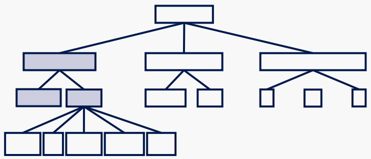


Scenarios for 2030

	High carbon pricing regime	Low carbon pricing regime
	EU 2030 climate policies • EU ETS: CO_2 price 37 EUR/ton • Non-EU ETS: CO_2-taxes 230 EUR/ton	**Climate policies as of 2011** • EU ETS: CO_2 price 20 EUR/ton • Non-EU ETS: CO_2-taxes as today (20-40 EUR/ton)
Reference scenario	Growth rates for L,K; efficiency improvements, etc.	Growth rates for L,K; efficiency improvements, etc.
Cap on energy use	27% reduction (from reference) of energy use in housing*	27% reduction (from reference) of energy use in housing
Cap on energy intensity	27% reduction (from reference) of energy use in housing per unit of dwelling	27% reduction (from reference) of energy use in housing per unit of dwelling

* Sensitivity on substitution elasticity

Cap on residential energy use: effects on households



- Consumer welfare is reduced
  - The energy efficiency cap puts restrictions on the use of energy – shadow price of the restriction corresponds to 175% energy tax
- Lower consumption of energy, dwellings and housing services
  - Initial effect:
    - 3.2% increase in dwelling investments
  - Substitution and income effects:
    - 3.2% decrease in demand for dwellings
    - 5.8% decrease in demand for housing services
  - Lower consumption of energy is mostly lower use of electricity (27%)
- Higher consumption of transport goods

Cap on residential energy use: effects on rest of the economy

- Lower residential electricity demand

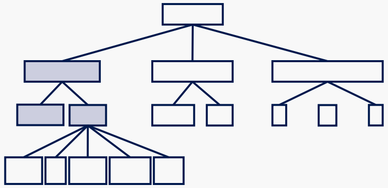
  → domestic electricity price falls

- Lower construction activity

  → costs of labour and capital fall

- Electricity, labour and capital are reallocated to energy intensive trade exposed (EITE) industries
  - Production in EITE-industries increases 15%
  - Emissions increase
    - Process emissions!
- Rebound effects:
  - Electricity rebound 37%
  - CO_2 emissions increase 2.4%

Cap on energy use vs. cap on energy intensity



- Welfare cost is higher
  - The energy intensity cap of 27% is the same as a cap on energy use of 29.7%, i.e., more stringent policy.
  - Shadow price of the cap = 210% tax
- Lower demand for electricity and dwellings lead to a larger fall in prices of electricity, labor and capital.
- Reallocation of resources to the EITE industries is larger
- Economy-wide electricity rebound effect is larger (40%)
- Larger increase in CO_2 emissions (3.1%)
  - Mostly process emissions from increased EITE production

Interaction of the climate policies

- Scenario with low carbon price regime
  – EU and Norwegian climate policy for 2030 *as of 2011*

- Welfare cost of energy cap is higher with high carbon price
  – More costly to substitute electricity for fossil fuels
  – Even lower electricity price
  – More positive effect on EITE production
- Electricity rebound is 14 percentage points higher
- CO_2-emissions are higher
  – Relatively larger increase in process emissions and smaller in transport emissions with a strict carbon policy initially

Rebound effects: Changes from baseline in electricity use and CO_2 emissions

	High carbon pricing regime (EU 2030 policy)		Low carbon pricing regime (EU policies as of 2011)	
	Energy use cap	**Energy intensity cap**	**Energy use cap**	**Energy intensity cap**
Electricity use, mill. 2011-NOK and (%)				
Households	-2.3 (-27%)	-2.6 (-29%)	-2.4 (-27%)	-2.6 (-30%)
EITE industries	0.6 (35%)	0.7 (44%)	0.4 (17%)	0.5 (20%)
Other	0.3 (5%)	0.3 (5%)	0.1 (2%)	0.2 (3%)
Total	**-1.5 (-9%)**	**-1.5 (-9%)**	**-1.8 (-10%)**	**-2.0 (-11%)**
Total rebound (%)	37 %	40 %	23 %	25 %
CO_2 emissions, mill. tons				
Households, residential	-0.2	-0.3	-0.3	-0.3
Households, transportation	0.1	0.1	0.3	0.3
EITE industries	1.7	2.1	1.2	1.4
Other	-0.3	-0.4	0.0	0.0
Total	**1.2**	**1.6**	**1.2**	**1.4**
Total CO_2 emissions (%)	**2.4**	**3.1**	**1.8**	**2.1**

Concluding remarks

- Analyse the impacts of energy efficiency targets for households
  - Taking into account that the energy efficiency investments are costly
  - Cost estimates based on experts' guesstimates
- Energy efficiency policies in households increase total CO_2 emissions
  - Due to process emissions in industries
  - Higher CO_2 price aggravates this effect
  - Substitution possibilities matter for the costs
- Rebound effects
  - Small within households
  - Large economy-wide (37-40%)
- Illustrate the effects of policies implemented in part of the economy
  - Similar energy efficiency targets for all sectors would modify the results

Further research and refinements

- Include energy efficiency (and low-carbon technologies) investments in the whole economy
- Consequences for international market prices (EITE-industries) and global CO_2-emissions
- The role of market imperfections and alternative behavioural assumptions (e.g. hyperbolic discounting)

Thank you for your attention!

Bye, B., T. Fæhn, O. Rosnes (2015):

Residential energy efficiency and European carbon policies:
A CGE-analysis with bottom-up information on energy efficiency technologies.

Discussion Papers No. 817, Statistics Norway.