Macroeconomic modelling for energy and environmental analyses

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Background

- Multi sectoral general equilibrium models
  - Early approach (Johansen, 1960)
  - Current model, MSG-6, Heide et al (2004)
- Resource statistics (energy and environment, 1980-ies)
- Integrated Economy-Energy-Environment models since 1980-ies
- Regularly used by the Ministry of Finance and Statistics Norway for long term forecasting and policy analyses
- Consistent framework for economic and emission projections, and evaluation of climate policies
  - Economic welfare effects
- Mitigation – not adaption

The CGE model MSG-6

- General equilibrium model – equality in all markets in every period
- Detailed description of the production and consumption structures of the Norwegian economy, (60 commodities, 32 private industries, 19 consumer goods)
- Small, open economy characteristics (given interest rate, world market prices etc)
- Based on optimising behavior of consumers and producers
- Determines domestic production, consumption, export and import given the economy's resource constraints
- Reallocation of resources between industries and from leisure to labour
  - Measure economic welfare effects of different policies

MSG-6; an integrated economy-energy-environment model

- Detailed description of the use of energy by producers and consumers
  - Stationary (electricity, fossil fuels)
  - Transport (diesel, gasoline)
- Detailed description of production of energy mirroring Norway's special situation as a large producer of energy
  - Electricity produced by hydro power or new gas power production
  - Extraction, production and export of oil and gas from the petroleum reserves in the North Sea and the Barents Sea
- Detailed description of emissions to air – 12 pollutants
- Current carbon taxes are specified in the model
- State of the environment not included in the objective function

Calibration of MSG-6

- The economic model MSG-6 is calibrated to the National Accounts (NA)
- Empirical benchmarking of parameter values
  - Base year benchmarking to NA
  - Estimated parameters (consumer demand system using consumer survey data, production technology using NA)
  - Other relevant parameters from microeconometric analyses
- Technology is described by the base year NA
  - Only existing technologies are represented in the model
  - If new technologies are to be introduced (gas power, bio fuels in transport etc) this description must be changed

Calibration of MSG-6: Emissions

- Two sources of energy data
  - Energy data in NA based on value terms (Million NOK)
  - Energy data from the Energy Statistics are based on physical terms, (Twh, tons etc)
- Environmental statistics
  - Emission data based on Energy statisics and other sources (tons, ppt)
- Emissions data are linked to relevant economic variables in the economic model
  - 6 green house gases and
  - 6 other gases with local/regional effects
  - Calculates base year emission coefficients
- Emission model integrated part of the MSG-6 model

Figure 1. Data input to the CGE-model

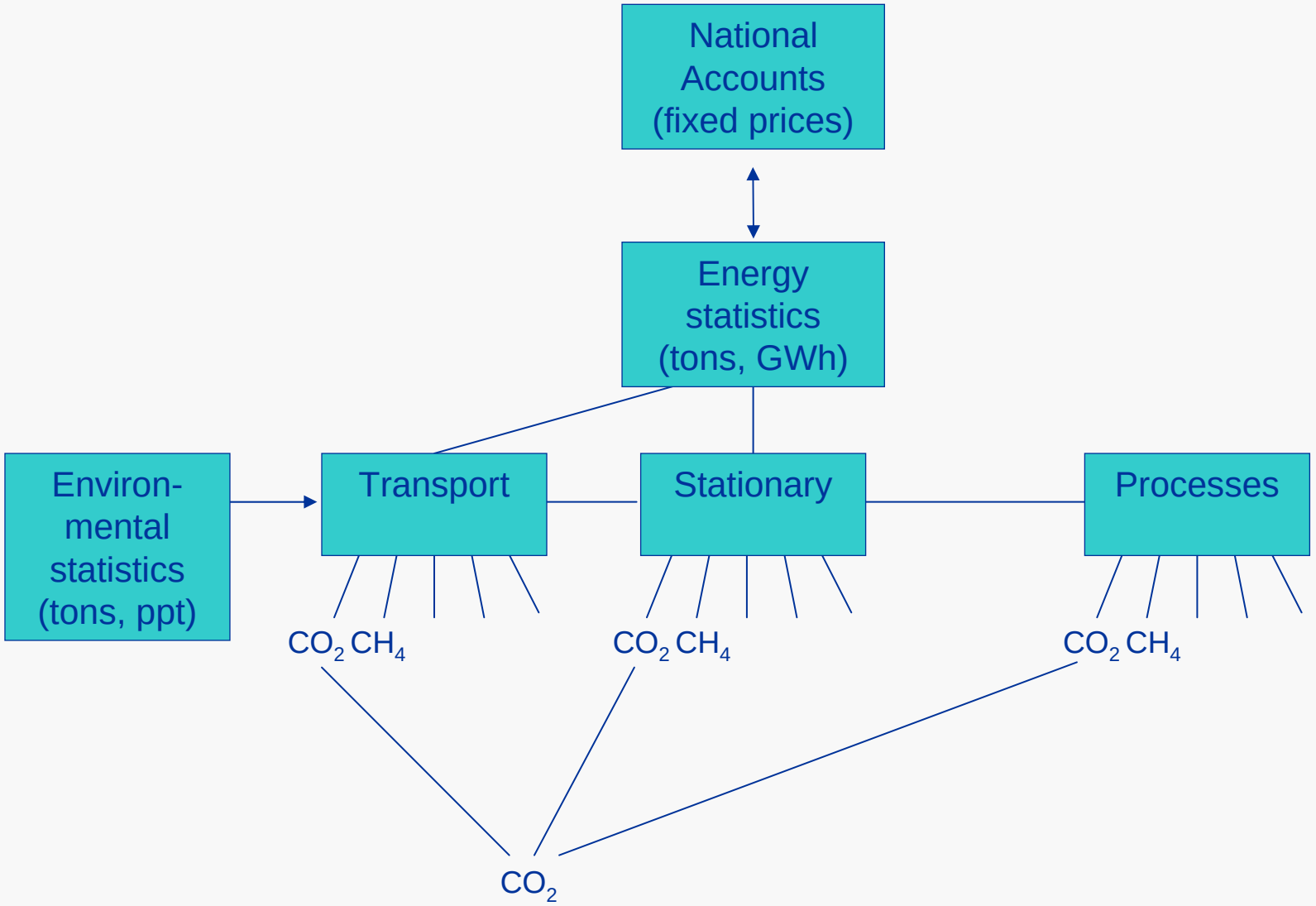


Figure 2. CGE-model

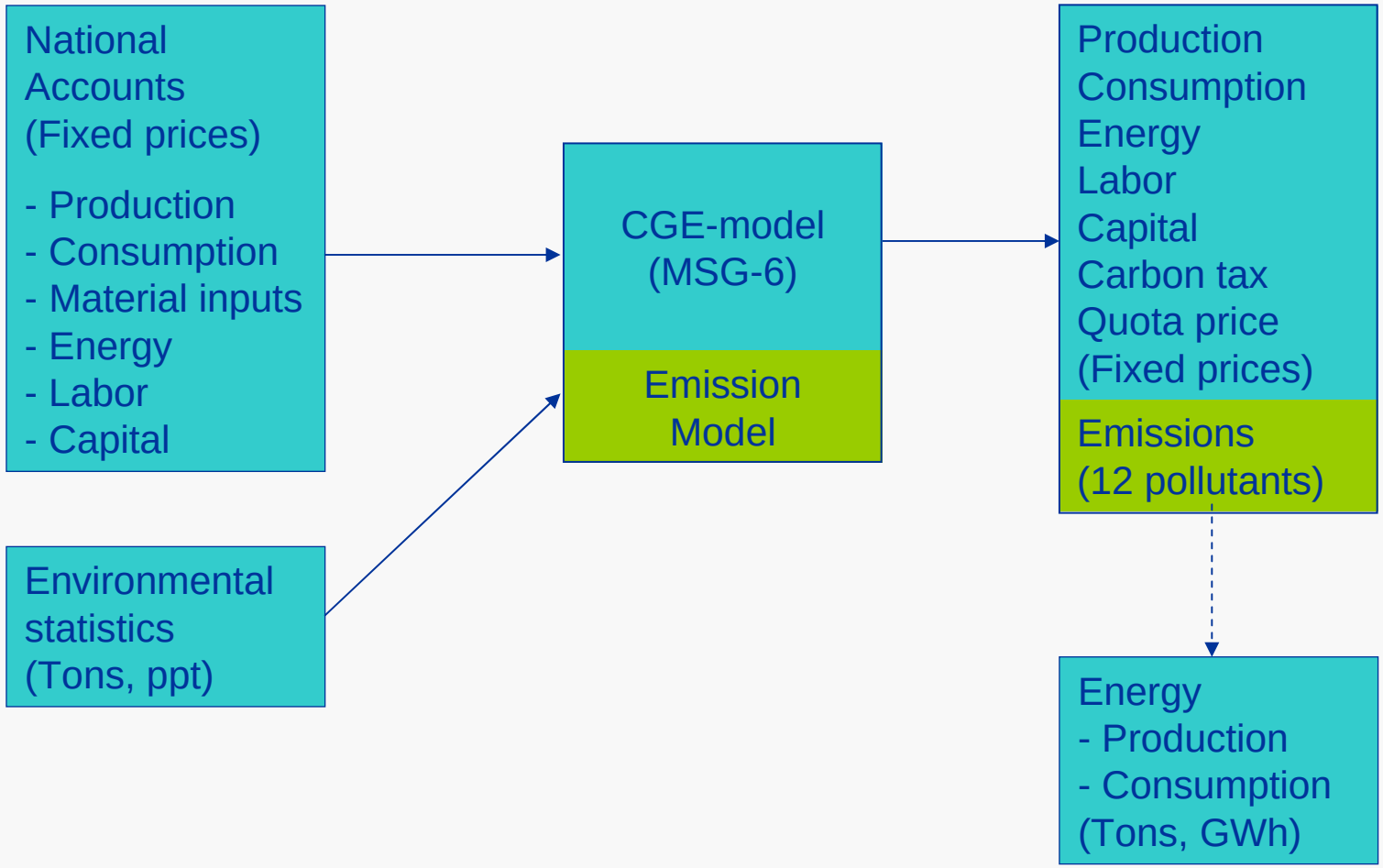


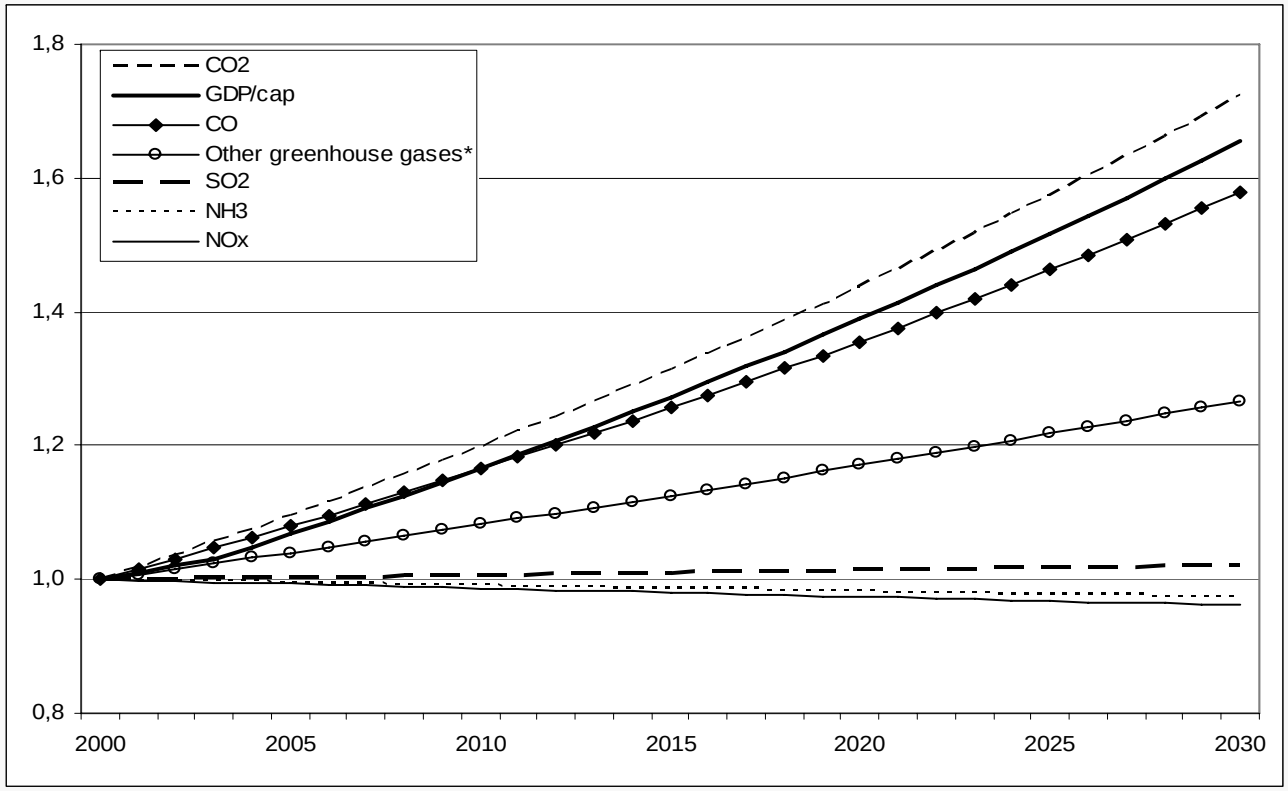
Table 1: Air pollutants and important sources in MSG-6

Pollutant	Important sources MSG-6 industry in parenthesis
Kyoto gases	
Carbon Dioxide (CO2)	Combustion of fossil fuels (Several) Reducing agents (Manufacture of metals) Gas power generation (Electricity, Oil and Gas Extraction)
Methane (CH4)	Livestock, manure management (Agriculture) Landfills Production and use of fossil fuels and fuel wood (Several)
Nitrous Oxide (N2O)	Fertilising (Agriculture), fertiliser production (Manufacture of Industrial chemicals) Road traffic (Road Transport)
Perflourocarbons (PFCs)	Aluminium production (Manufacture of Metals)
Sulphur Hexafluoroides (SF6)	Magnesium production (Manufacture of Metals)
Hydrofluorocarbons (HFCs)	Cooling fluids (Several)

Table 1 cont.

Other pollutants	
Sulphur Dioxide (SO2)	Combustion (Several) Process emissions (Manufacture of Metals)
Nitrogen Oxides (NOx)	Combustion (Several)
Carbon Monoxide (CO)	Combustion (Several)
Non-Methane Volatile Organic Compounds (NMVOCs)	Oil and gas-related activities Road traffic Solvents (Oil Refining, Road Transport, Households)
Ammonia (NH3)	Road traffic (several) Fertilising (Agriculture)
Suspended Particulates (PM2,5 and PM10)	Road traffic (Households, Agriculture, Road Transport) Fuel wood (Households)

Projections, Business as Usual (BAU)



* CH4 and N2O.

Figure 2. *GDP per capita and domestic emissions, 2000–2030, 2000 = 1.00. Source: Bruvoll and Fæhn (2006)*

Climate policies and emission targets

- Indirect regulations
  - Carbon taxes
  - Tradeable quotas
    - Free
    - Auctioned
  - Given an emission target – what is the optimal carbon tax or quota price?
    - Can be calculated by using the integrated MSG-6 model
    - Quality of data at all steps in the analysis process crucial for obtaining results that we can recommend

Climate policies cont.

- Direct regulations as:
  - Enforcement of technology changes
    - Changes in exogenous parameters in the emission model
    - Changes in factor productivity in the economic model
    - Not trivial (Low emission commision, Ministry of the Environment 2006)
      - New technologies and new products are not represented in the base year NA since they are non-observable from the statistician's point of view.
      - What are the implementation costs?
  - Issuing of non-tradeable emission quotas
    - Implemented as direct production dependent transfers

Recent climate policy analyses

- Carbon taxation and quotas
  - Double dividend (carbon tax combined with lower labour tax), B. Bye (2000a, b),
  - Differentiated taxes vs. Grandfathered quotas, Bye and Nyborg (2003),
- Environmental Kuznets curves, trade and emission leakages
  - Bruvoll, Fæhn and Strøm (2003), Bruvoll and Fæhn (2006, 2007)
- Calculations for the Norwegian Low Emission Commision
  - Åvitsland (2006)
- Norwegian carbon quota scheme
  - Bjertnæs, Hagem and Strøm (2007), Norwegian Commision on excise taxation

Trade, carbon policy and emission leakages

- Cost efficient and strengthened domestic climate policy
  - Uniform carbon tax, increasing over time (13 Euro in 2000, 58 Euro in 2030).
  - Domestic CO2-emissions are reduced by 25 % compared to BAU in 2030.
  - Small domestic welfare loss
- The pollution haven hypothesis is supported
  - Net leakages are positive
  - Global environmental benefits are reduced
- In **interaction** with the trade regime
  - Abatement costs to some extent shared with foreigners
  - Environmental costs imposed on foreigners

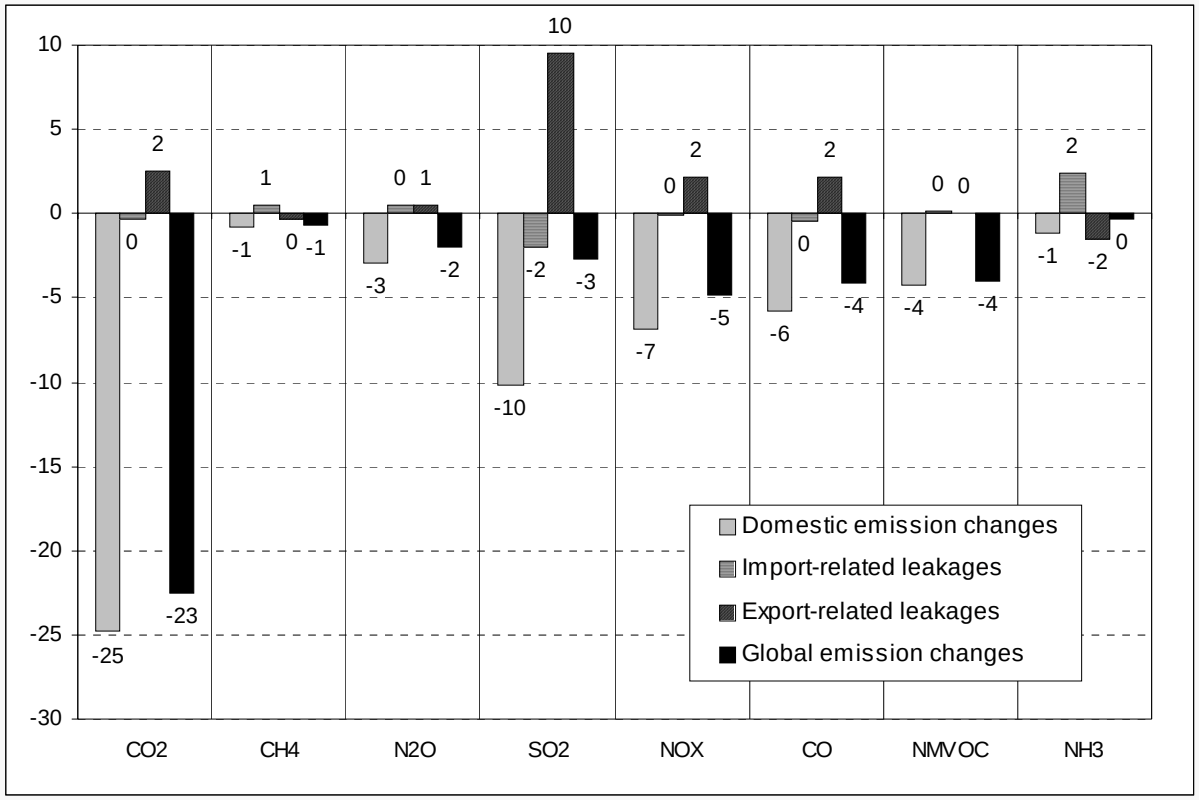
Leakages cont.

- Foreign emissions are linked to trade

  Import up -> production abroad up -> Emissions abroad up

  Export down -> substituted by foreign production -> Emissions abroad up
- Emission coefficients
  - Industry- and country specific unit emissions
  - Weights: import/export

Figure 1: Long-run changes compared to the benchmark in domestic emissions, leakages, and global emissions due to carbon taxes, in percentages.
Source: Bruvoll and Fæhn (2007)



Concluding remarks and further challenges

- Consistent and high quality data at all steps in the model building process
  - Economic - > Energy - > Emissions
- Modelling technological change
  - Reaserch and Development (R&D) activities are (at present) not specified in the NA
    - R&D Statistics
  - Recent modelling development at Statistics Norway includes R&D activities, general and environmental, in a CGE model
    - Bye et al (2006, 2007, 2008)
  - R&D promoting policies and carbon emission restrictions
    - Heggedal and Jacobsen (2008)

Concluding remarks cont.

- New technologies
  - How to represent new technologies (bio-fuels, Carbon Capture and Storage etc.)
- Abatement costs
  - Resources to abatement activities are not specified in the NA
  - How to measure abatement activities
    - Where are abatement activities produced and how?
- Feed back effects?
  - Transparent indicators for sustainable development preferred
- Keep the model as simple as possible!