Computable General Equilibrium modelling for a sustainable future

Experiences with CGE models and environmental policies

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Outline

- Introduction
- Computable General Equilibrium (CGE) model and environmental policies
- Personal experiences
- AGE and evaluating water policy in the Netherlands
    - Comparative static model
    - Dynamic model
- Current work

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Computable General Equilibrium (CGE) models

- **What are CGE models?** CGE models are large numerical models which combine economic theory with real economic data in order to derive computationally the impacts of policies or shocks in the economy.
- to capture the structure of the economy and behavioral response of agents (firms, households, government)
- to simulate policy changes and trace the impact on key economic variables, including income and expenditure flows (ex-ante)

Computable General Equilibrium (CGE) models - characteristics

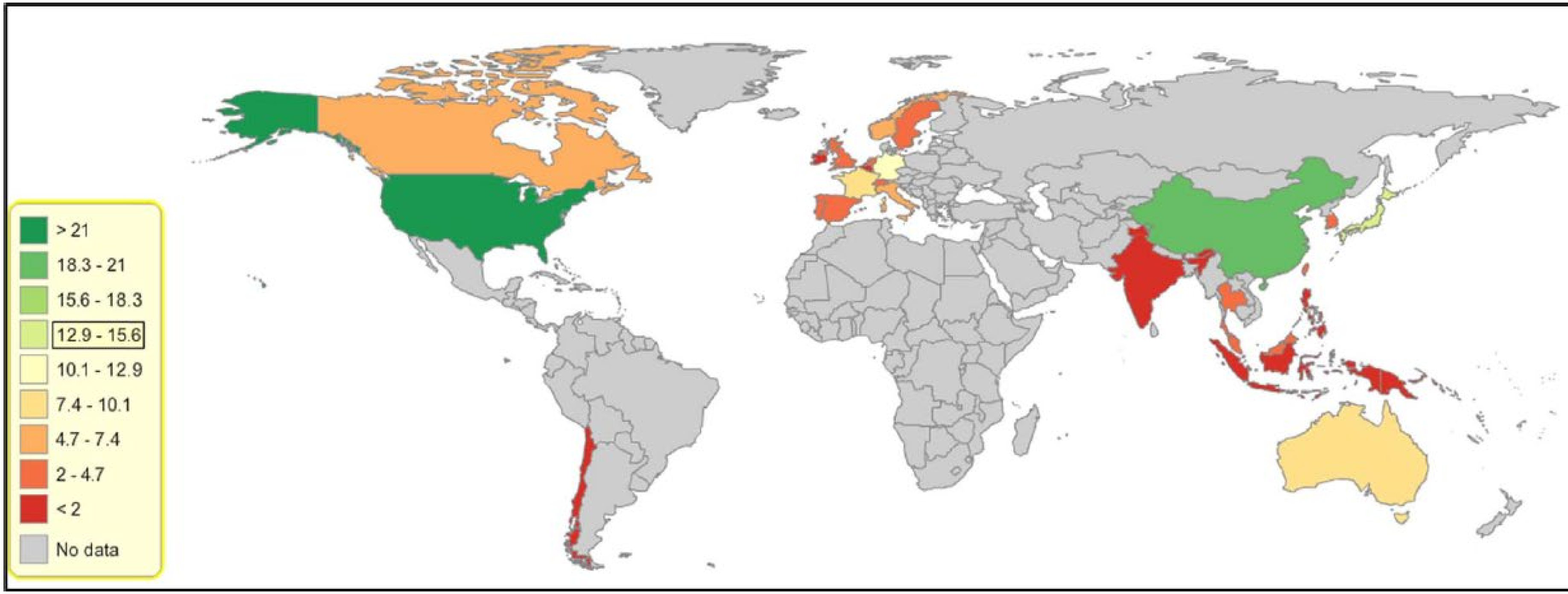
- Optimization models (demand = supply)
- Comparative static versus dynamic models
- Driven by relative prices of commodities and factor inputs
- Results: relative changes rather than absolute changes
- Alternative name of computable general equilibrium (CGE) model is Applied General Equilibrium model (AGE)

CGE models and environmental policies

- Climate change (adaptation/mitigation)
- Energy (fossil and non-fossil) (GEM-E3 for the EU)
- Water
  - Quantity/allocation (GTAP-Water)
  - Quality
- Agriculture and food and land use (CAPRI-EU; MAGNET/GTAP-World)

CGE and climate mitigation policy research

Geographic distribution of 154 research papers on CGE and its application to mitigation policies.



Source: Babatunde et al. (2017). Application of computable general equilibrium (CGE) to climate change mitigation policy: A systematic review. *Renewable and Sustainable Energy Reviews* 78, 61-71

Personal experience of using AGE models and environmental policies

- Applied general equilibrium models (AGE) not used in isolation
  - Sustainable Development Goals (SDG)
  - Climate change (COP21 and onwards)
  - COVID19 pandemic
- The system thinking and wider economic impact (feedback effects) are valuable for exploring economic processes

AGE modelling and environmental policies

Subject	Study	Type
Sustainability	Sustainable National Income (SNI) model (Hofkes et al. 2004)	AGE model for the NL including environmental emissions
Water quality	Economic impact of water quality policy (Brouwer et al. 2008)	AGE model for the NL including water emissions
Water quality	Economic impact of water quality policy (Dellink et al. 2011)	Dynamic AGE model including water emissions and quality
Waste	Waste Policy model to evaluate landfill taxation (Van Beukering et al. 2009)	AGE model for the NL with detailed waste sector
Waste	Effectiveness of deposit-refund model for batteries (Linderhof et al. 2019)	Partial equilibrium (PE) model
Electricity	EMELIE – liberalisation of electricity market (Lise et al. 2006)	Partial equilibrium (PE) model

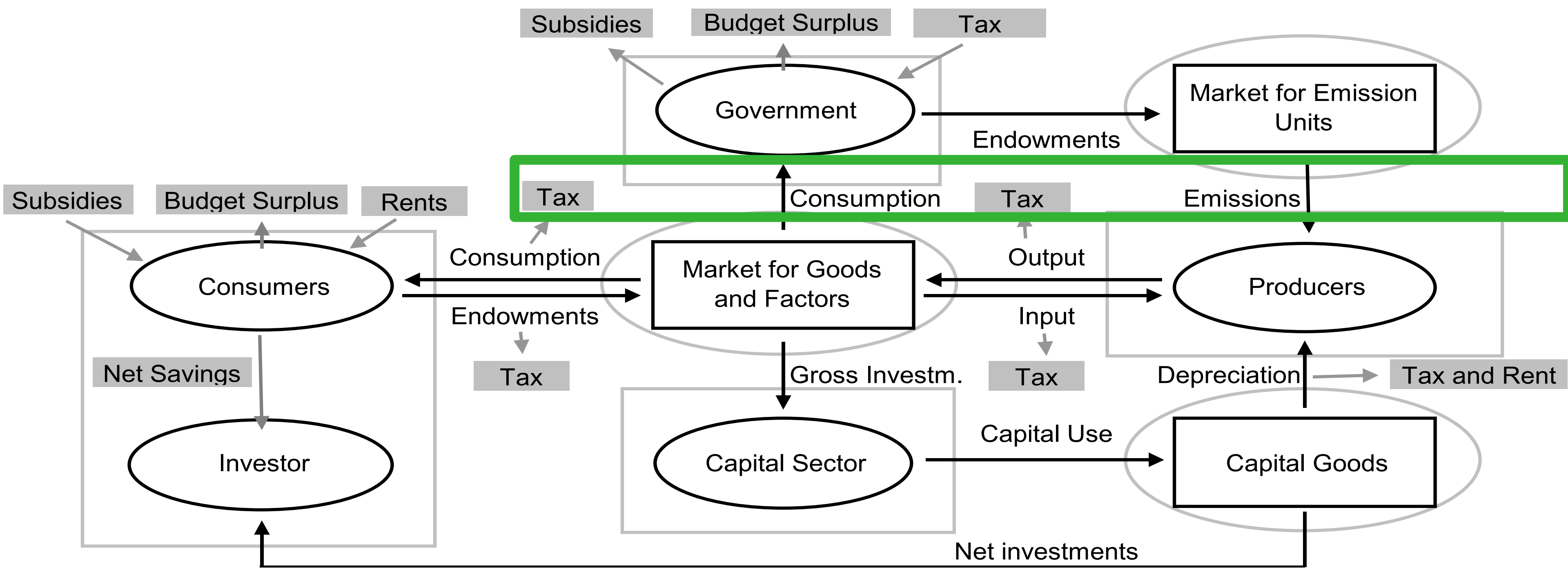
AGE model evaluating water quality policy (Brouwer et al., 2008)

- What are the direct and indirect economic impacts of water quality improvements in the Netherlands at national and river basin scale
- Focus on water-related environmental themes (eutrophication and heavy metals)

AGE model for the Netherlands

- 27 economic sectors plus capital sector, labour sector and environmental services (mitigation measures)
- Sustainability standards to be met with
  - Abatement technologies (except for dehydration and soil contamination) from environmental services sector
  - Emission permits
- Revenues of emission permits are recycled by either tax reduction or lump sum subsidies to households

AGE model for the Netherlands



Sources: Gerlagh et al. (2002); Brouwer et al. (2008)

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Before running scenarios with the AGE model

- Calibration
  - Endogenous variables of the model (prices) => starting values
  - Parameters: Elasticity of substitution for production (CES functions) and consumption
  - Reproduce current status
- Sensitivity analysis on parameters
- Validation
  - Compare results with other models and methods

Data requirements for AGE modelling

- Data
  - Quantification of indicators for production, inputs, intermediate deliveries, outputs, use/consumption (values) => Social Accounting Matrices (SAMs)
  - Elasticity of substitution for production (CES)
    - Literature
    - Econometric analyses
  - Annual data (standard measurement period)

Social accounting matrix and emissions to water

Table 1 – Social Accounting Matrix (SAM) and Net National Income in the Netherlands in 2000 (in billion euros)

	Primary sector	Secondary sector	Tertiary sector	Capital	Abatement	Trade balance	Net investments	Consumption	Endowments	Sum
Primary sector	18.4	−10.3	−0.9	−0.6	0.0	−4.5	0.0	−2.1	–	0
Secondary sector	−5.5	170.4	−52.5	−59.6	−0.1	0.9	0.0	−53.7	–	0
Tertiary sector	−2.8	−56.9	313.2	−23.1	−0.1	−10.7	0.0	−219.8	–	0
Capital	−3.1	−18.0	−40.1	91.4	0.0	0.0	−30.1	0.0	–	0
Abatement	0.0	−0.1	0.0	0.0	0.2	0.0	0.0	−0.1	–	0
Labour	−1.9	−41.6	−122.7	0.0	0.0	0.0	0.0	0.0	166.2	0
Profits	−4.6	−26.6	−59.4	0.0	0.0	0.0	0.0	0.0	90.6	0
Taxes	−0.5	−17.0	−37.7	−8.1	0.0	0.0	0.0	−20.0	83.3	0
Sum	0	0	0	0	0	−14.3	−30.1	−295.7	340.1	0

Source: Statistics Netherlands.

Table 3 – Emissions in the Netherlands in 2000

	Primary sector	Secondary sector	Tertiary sector	Consumption	Total
Eutrophication (million P-equivalents)	90.4	15.8	11.6	19.6	137.4
Dispersion of toxic substances (billion AETP-equivalents)	0.8	61.7	7.8	17.9	88.3

Source: Brouwer et al. (2008)

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Abatement technologies in abatement cost curves

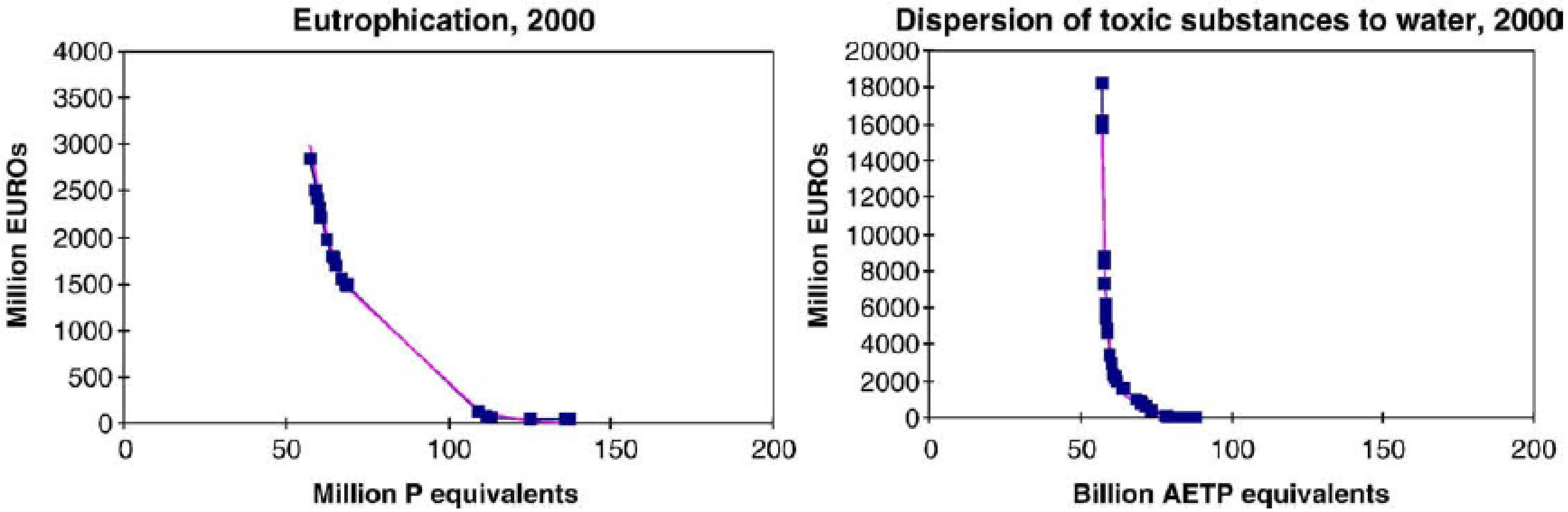

Fig. 2 – Estimated abatement cost curves for eutrophication and the dispersion of toxic substances to water.

Source: Brouwer et al. (2008)

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Water policies

- Reduction of emissions to water with 10, 20 and 50% of emissions in the baseline for
  - Eutrophication
  - Toxic substances

Variants	Policy	Impacts
Unilateral	Dutch water policy	goods with polluting production more imported
Multilateral	EU water policy	polluting production reduced

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Results of AGE model for water quality policy in the Netherlands

The impact of different emission reduction scenarios on NNI for the unilateral and the multilateral variants

	Emission reduction of		
	10%	20%	50%
Unilateral variant			
NNI (bln)	339.3	338.4	329.6
Loss in NNI (bln)	0.7	1.6	10.5
Relative change	-0.2%	-0.5%	-3.1%
Multilateral variant			
NNI (bln)	339.4	338.1	308.0
Loss in NNI (bln)	0.7	1.9	32.1
Relative change	-0.2%	-0.6%	-9.4%

Source: Brouwer et al. (2008)

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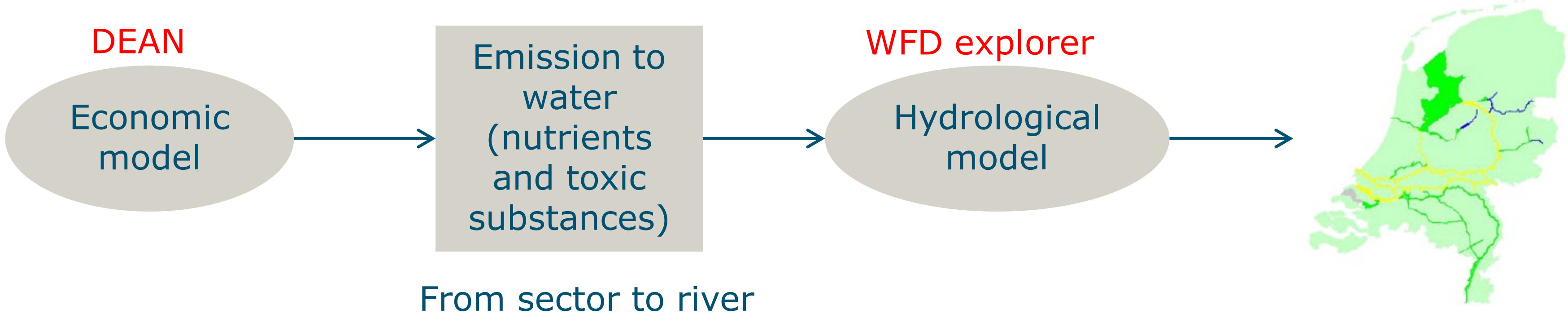
Dynamic AGE model for water quality policy (Dellink et al., 2011)

- Additions to Brouwer et al. (2008): 1) pathways of change 2) emission reduction translated into reduction of nutrient concentrations

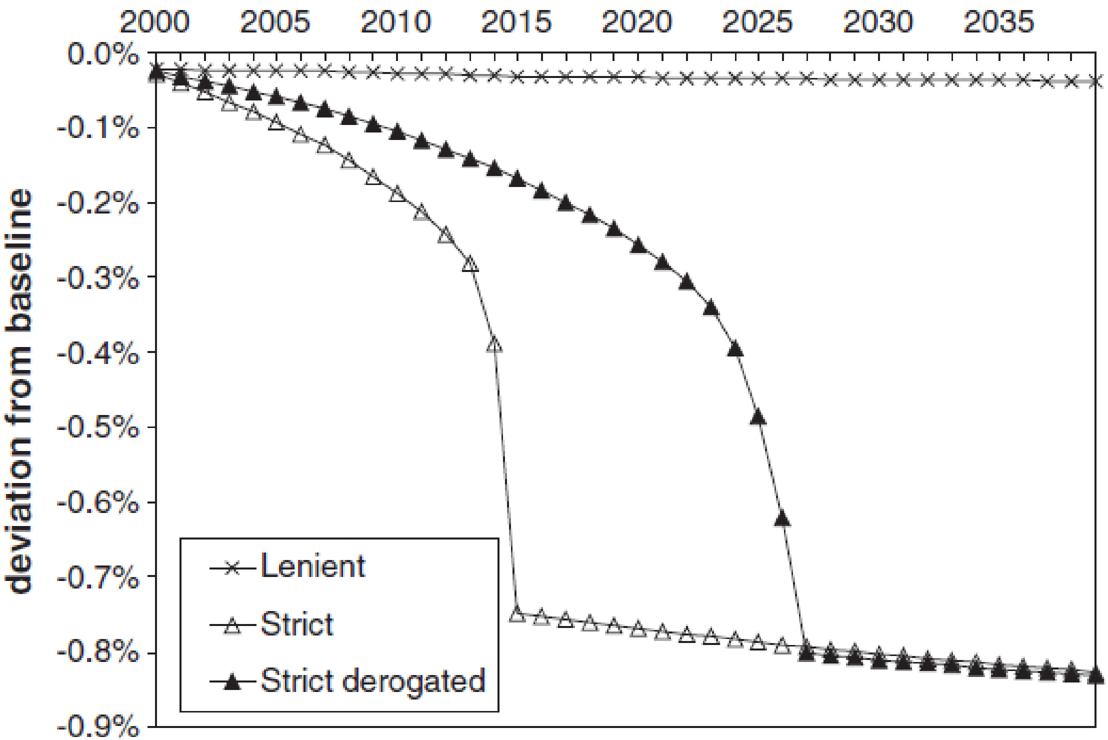


From sector to river basin NAMWARiB Brouwer et al. (2005)

Results for phosphates in 2027

- The economic model is a forward-looking neo-classical growth model (based on DEAN, Dellink (2003))

Results of AGE model for water quality policy in the Netherlands



Source: Dellink et al. (2011)

- Water policy to be realised in 2027
- Baseline growth rate is around 2%
- Iterative process for achieving good water quality

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Issues to keep in mind with using AGE models

- Relative prices
- Inclusion of policy interventions
    - taxes/subsidies relative to price
    - a ban can be reflected in a high autonomous tax
- All commodities included in the model need to have a non-zero price such as carbon emission tradable permits
- Alternatives cannot enter or exit the model
- Shocks and major transitions like extreme weather events not included

Current work – Serious Games (SIM4NEXUS: www.sim4nexus.eu)

Thank you for your attention

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