Coupling a Computable General Equilibrium Model with a Bottom-Up model: Lessons from GEMINI-E3 experiments

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04/02/2014

Outline

GEMINI-E3 model

- World computable general equilibrium model (CGE)
- Macro-economic energy model (5 energy sectors/goods)
- Fifth version (first version 1995) based on GTAP 8 Database
- Dedicated to the analysis of energy & climate change issues
- More than 30 publications in scientific journals
- More than 40 studies done with the model
  - Energy policies (nuclear moratorium, energy efficiency policy in housing, ...)
  - Climate change negotiation (Kyoto protocol, EU-ETS, 2°C target, ...)
  - Economics impacts of climate change (agriculture and energy sectors, sea-level rise, winter tourism, ...)
  - Other economic issues (tax reform, competitiveness, economy and monetary union, ...)
- http://gemini-e3.epfl.ch

Outline

Harmonization and exchange of information

- Usually done when we perform a common study with several models including bottom-up and top-down models
- Objective is to analyze with different models a same question
- Aims of this harmonization
  - Use the same assumptions and protocol
  - Incorporating macro-economic consistency in BU
  - Better representation of energy markets in CGE
  - Benefit from the technological representation of the BU
- Perform usually only for the baseline
- Example: Worldwide impacts of climate change on energy for heating and cooling, M. Labriet, S. Joshi, F. Babonneau, N. Edwards, P. Holden, A. Kanudia, R. Loulou and M. Vielle, *Mitigation and Adaptation Strategies for Global Change*, November 2013

Main lessons

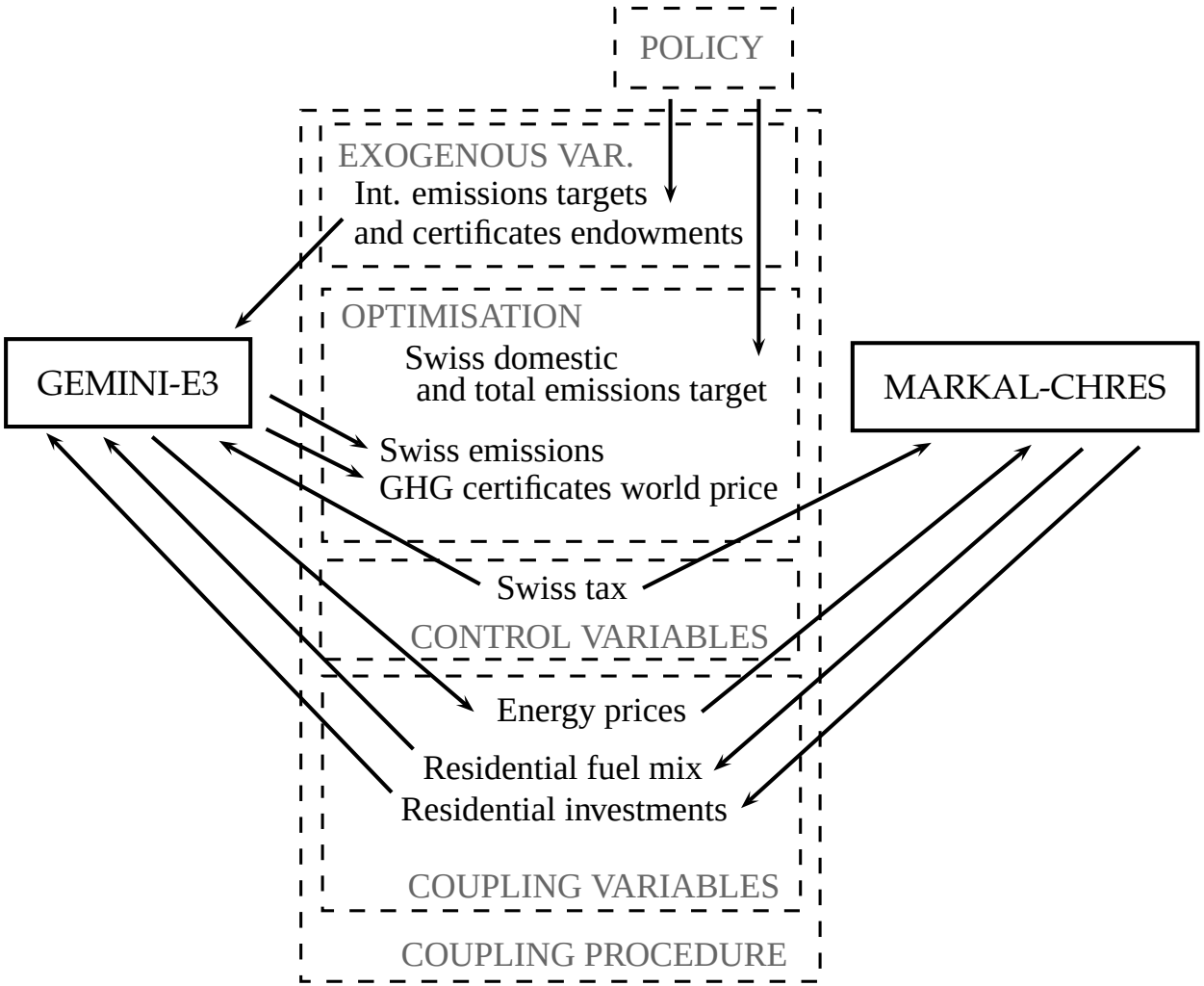
- Level of harmonization: Global carbon emissions, sectoral carbon emissions, energy balance, etc
- Tradeoff between internal consistency and harmonization
- How to reconciliate different classifications (at country level and sectoral level)
- How to reconciliate different accountings (national accounts *versus* energy balances) $\leftarrow$ Transport sector in BU $\neq$ Transport sector in CGE, residential sector in BU $\neq$ housing sector in CGE
- How to manage different units (physical unit *versus* monetary unit), different prices (price per toe *versus* price in respect to reference year)
- How to communicate on this harmonization (transparency *versus* black boxes)

Outline

Coupling a bottom-up submodule with a CGE

- Integrated Assessment of Swiss GHG Mitigation Policies After 2012, A. Sceia, J-C. Altamirano-Cabrera, L. Drouet, T. Schulz and M. Vielle, *Environmental Modeling & Assessment*, June 2012, Volume 17, Issue 3, pp 193-207
- Perform assessment of Swiss climate policies focusing on the residential sector
- Motivation: Introduce technological representation in CGE
- CO_2 Emissions from residential sector $\simeq$ 25% of Swiss emissions
- Models involved: MARKAL-CHRES and GEMINI-E3
- Time horizon: 2010-2050
- Funded by NSF-NCCR climate

Coupling framework



Comparison of GEMINI-E3 with the coupled model

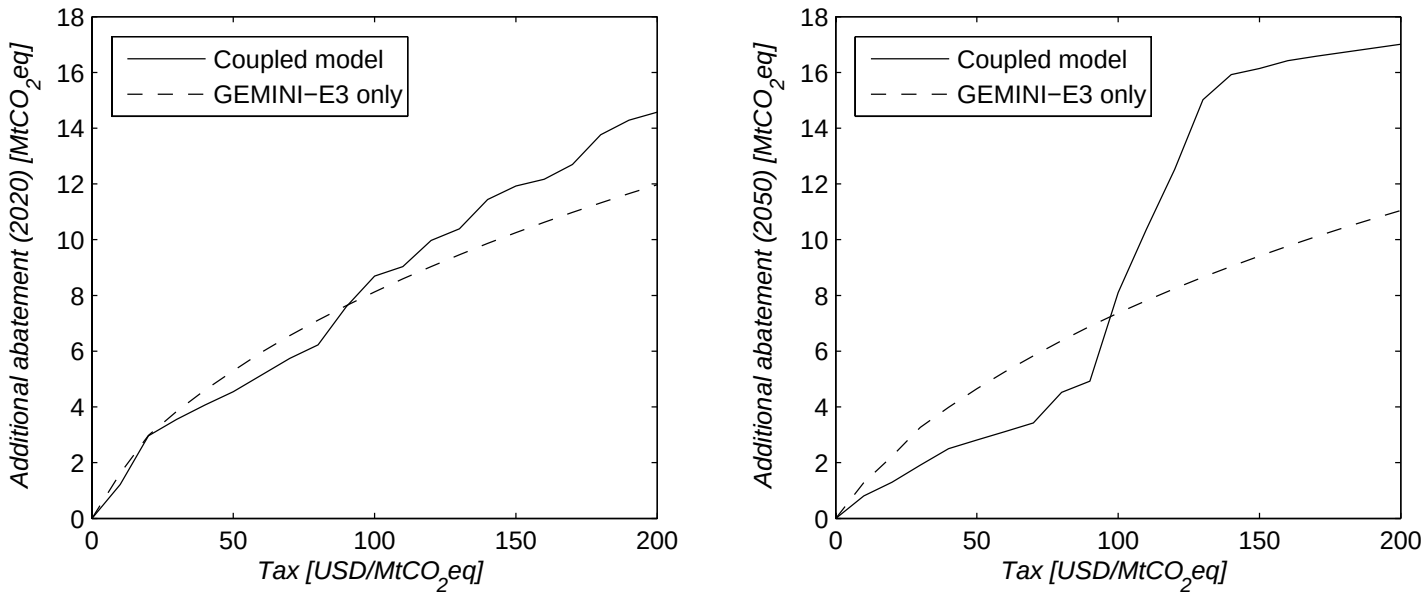


Figure 1: MAC curves in 2020 (left) and 2050 (right) description

$\mapsto$ More accurate representation of abatements with the technology description

Main lessons

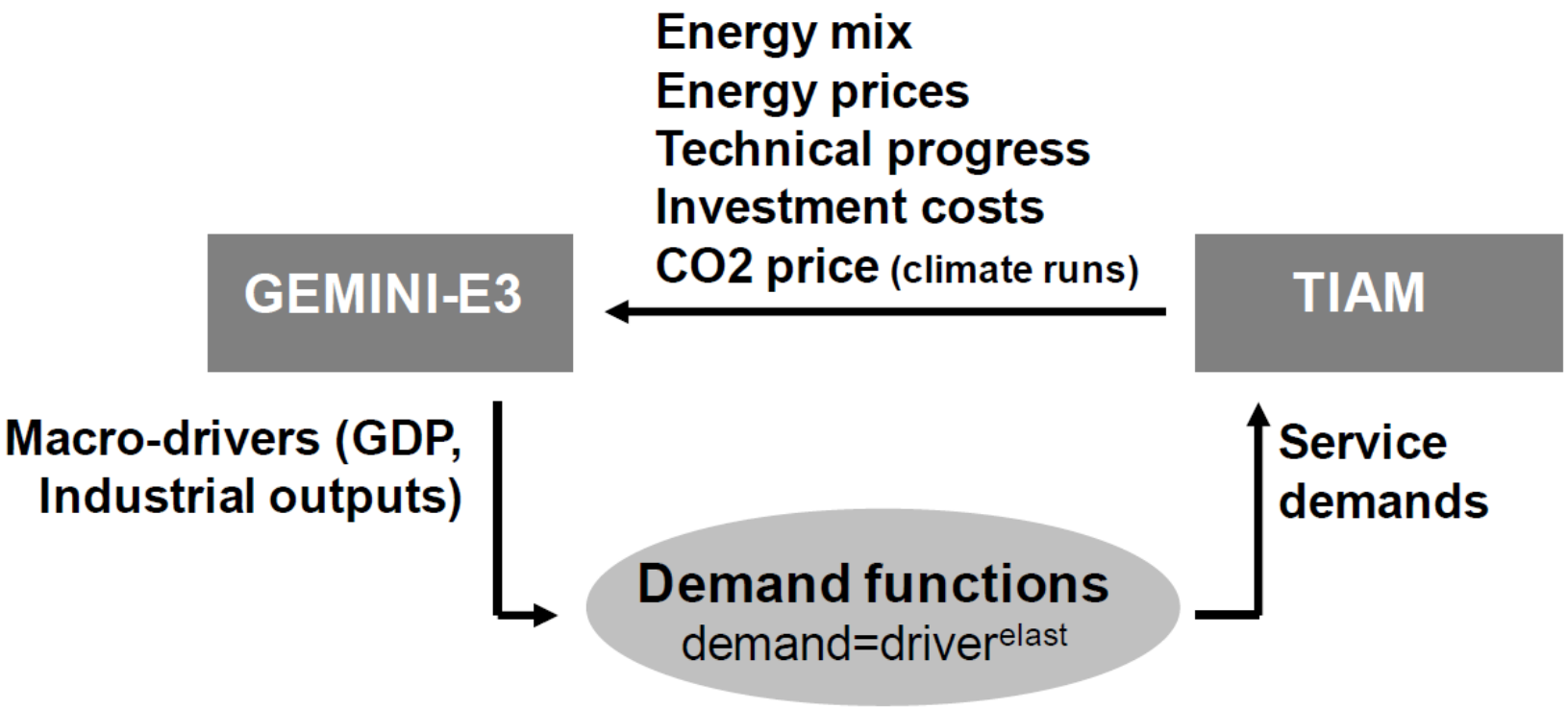
- Better representation of technologies
- Implementation of non-price instruments (norms, energy efficiency program, etc)
- Integration of macro-economic feedback into the bottom-up representation
- Integration of international framework into the bottom-up representation
- Increase the need of harmonization between models
- Need of software and coupling algorithm skills, no real coupling tool in GAMS $\mapsto$ use of Matlab interface

Outline

Coupling a bottom-up model with a CGE model

- Coupled bottom-up and top-down modelling to investigate cooperative climate policies, M. Labriet, L. Drouet, M. Vielle, A. Kanudia and R. Loulou, *Les Cahiers du GERAD*, May 2010, G-2010-30
- Assessment of globally and partially cooperative climate agreements with a coupled bottom-up and top-down modelling
- Models involved: TIAM-WORLD and GEMINI-E3
- Motivation: Better representation of demand for energy services in TIAM-WORLD, by replacing the elastic demand version
- Time horizon: 2000-2050
- Funded by FP6 TOSCIN project

Coupling framework



Main lessons

- Important challenge, several difficulties (harmonization, coupling, software)
- We succeed to run the coupled model (convergence reaches in 6 iterations)
- Difference concerning demands for energy service between TIAM-World alone and Coupled-models
  - Agriculture, commercial, residential and road transport behave similarly
  - All industry demands decrease in TIAM-World alone, while the dynamic is more complex with the coupled models
  - Iron & Steel world production $\mapsto$ -14% coupled Models, -8% TIAM-WORLD, but changes are more contrasted across regions in the coupled models (with positive and negative changes)

Variation of iron & steel consumption and trade flows

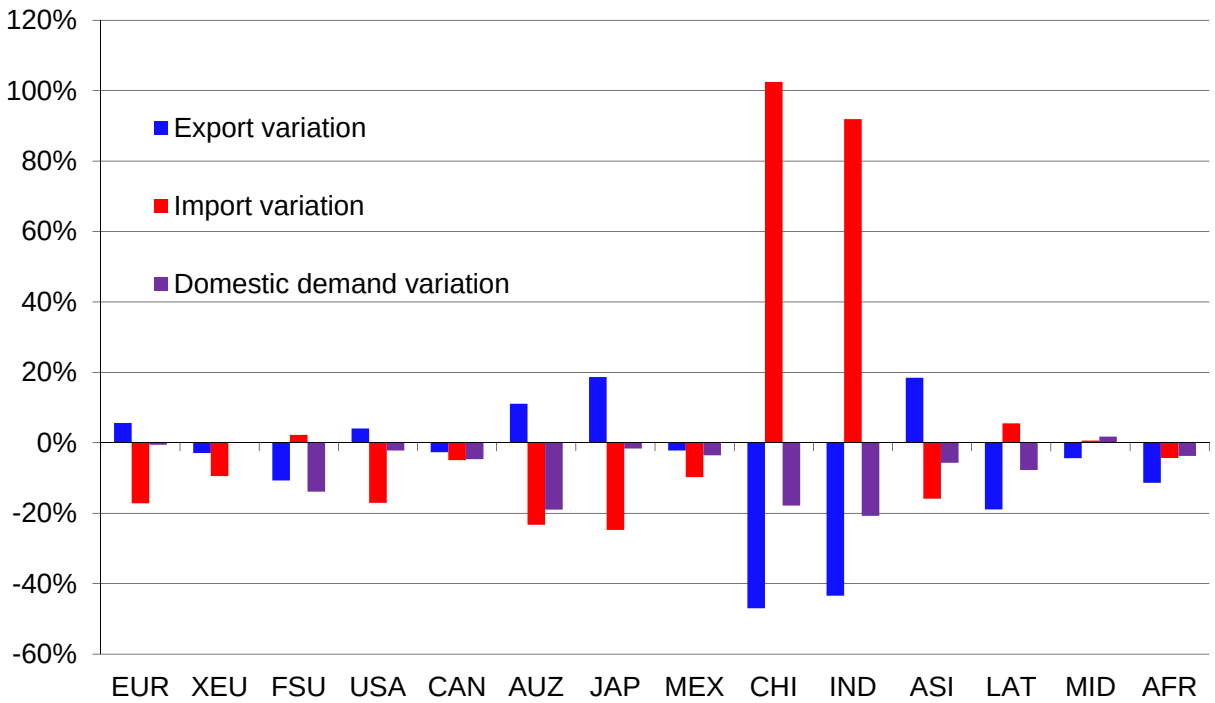


Figure 2: Global cooperative climate agreement - 2050

Conclusion

- Why coupling ?
  - Overcome the limitations of individual modelling tool/paradigm
  - Requests from model users (Ministry, European Commission, etc)
    $\mapsto$ *Coupling needs strong motivations*
- A challenging task
  - The solutions that we used follow a pragmatic and heuristic approach
  - Black boxes *versus* transparency & consistency
    $\mapsto$ *Lost in coupling*
- Other perspectives
  - Advanced coupling technologies: CIAS (Community Integrated Assessment System) and BFG (Bespoke Framework Generator) $\rightarrow$ see FP7 Ermitage Project
  - Statistical emulation and coupling: see A robust meta-game for climate negotiations, F. Babonneau, A. Haurie and M. Vielle, *Computational Management Science*, Volume 10, Issue 4, pp 299-329

Thank you for your attention !