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

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Outline

1. GEMINI-E3 model
2. Harmonization and exchange of information
3. Integrating a bottom-up submodule into a CGE model
4. Coupling a bottom-up model with a CGE model
5. Conclusion
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
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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
Main lessons

- Level of harmonization: Global carbon emissions, sectoral carbon emissions, energy balance, etc
- Tradeoff between internal consistency and harmonization
- How to reconcile different classifications (at country level and sectoral level)
- How to reconcile 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)
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Coupling a bottom-up submodule with a CGE

- Perform assessment of Swiss climate policies focusing on the residential sector
- Motivation: Introduce technological representation in CGE
- $\text{CO}_2$ Emissions from residential sector $\approx 25\%$ of Swiss emissions
- Models involved: MARKAL-CHRES and GEMINI-E3
- Time horizon: 2010-2050
- Funded by NSF-NCCR climate
Coupling framework

Figure 2 presents the coupling schema. The GHG progressive tax vector, defined by the value of the tax in 2050, is the variable that allows to control both models. The residential fuel mix and the annualized investments over the whole time frame are the coupling variable ensuring that GEMINI-E3 calculates emissions and adjusts the residential investments in GEMINI-E3 on the basis of the MARKAL-CHRES simulations. The fuel shares are used as a proxy for the variation of the share parameters in the residential energy nest, which elasticity ($\sigma_{hres}$) is set to 0, whereas the variation of the total fuel consumption and the variation of annualized investments are used, respectively, to update the values of the technical progress on energy and on construction in the residential nest, which is also transformed into a Leontief function ($\sigma_{hres}=0$). Furthermore, total Swiss emissions and world price of GHG certificates in 2050 are the variables used for ensuring that the coupled models converge to the targets defined in the scenarios. Finally, the international policy scenarios are set exogenously, i.e. defining emissions certificates endowments.

A technical description of the coupling procedure is provided in algorithms 1 and 2 (see appendix A).
Comparison of GEMINI-E3 with the coupled model

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

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
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- 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 TOSCIIN project
Coupling framework

![Diagram of Coupling framework]

- Energy mix
- Energy prices
- Technical progress
- Investment costs
- CO2 price (climate runs)

**GEMINI-E3**

**Macro-drivers (GDP, Industrial outputs)**

**Demand functions**

\[ \text{demand} = \text{driver}^{\text{elast}} \]

**TIAM**

**Service demands**
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)
    \[\rightarrow Coupling \text{ needs strong motivations}\]

- A challenging task
  - The solutions that we used follow a pragmatic and heuristic approach
  - Black boxes \textit{versus} transparency & consistency
    \[\rightarrow Lost \text{ in coupling}\]

- Other perspectives
  - Advanced coupling technologies: CIAS (Community Integrated Assessment System) and BFG (Bespoke Framework Generator) \[\rightarrow \text{see FP7 Ermitage Project}\]
Thank you for your attention!