A flexible, modular and extendable framework for CGE analysis in GAMS

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and
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Why a modular CGE in GAMS
Status of the project
Some results from structural sensitivity analysis
Next steps
Summary
Why a modular CGE?

- Vision: complement “one data base – many models”, by “one modeling platform - many model variants”

- In order to
  - easily change model set-up
  - specifically, allow for combinations of (GTAP)-extensions, for instance GTAP-E + GTAP-AEZ + GTAP-HET + MRIO + myGTAP
  - avoid duplicate coding efforts by teams, share modules
GLOBE, STAGE, ENVISAGE, MIRAGE, IFPRI-S, OECD Metro, GTAPinGAMS (only examples) in GAMS, potential collaborators

- Ease link up to PE or supply side models
- Built-in conditional includes and macros, eases modularity
- Support for NLP (constraint optimization) and MCP: simplifies data balancing problem(s) and KKT-conditions
Status of the project

- 2016 conference: standard GTAP plus GUI
- Now: GTAP extensions plus features from ENVISAGE, comparative-static or recursive-dynamic, global or single country
- Data driver, handles
  - GTAPAGG output (GTAP6-9) + Land use data (GTAP-AEZ)
  - MRIO split factors from METRO + SAM split + non-diag make
  - Regional SAMs for Europe (280 regions)
  - filter for small entries and re-calibration of global SAM

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Graphical User Interface:

- **Model and shock setup:** choice of modules, data base, numeraires, closures, edit and select shock file, design and run sensitivity analysis based on LHS..
- **Result exploration by maps, graphics and structured tables,** compare several runs (shocks, model variants ..)
Options for trade

- 2-stage Armington as in GTAP Standard
- Optional:
  - 2-Stage CET on the supply side
  - 3-Stage CES/CET (Leontief for small shares)
  - Aggregated Armington: over intermediate demand or all
- Melitz / Krugmann, either AKME or 2-stage CES
- MRIO based on split-factors from OECD-Metro model
Accounts and final demand

- Replication of GTAP Standard: Regional household and CDE
- LES or CD as alternatives
- Plus optionally:
  - CDE/LES/CD with product aggregates via CES-nests
  - myGTAP clone: Separate accounts for government and (multiple) households, with remittances, transfers ..., plus features from STAGE
Completely **flexible nesting** over multiple CES nests:

- using **dynamic sets**, i.e. no additional programming
- same input can be split into several nests, example: fixed costs in GTAP-HET
- pre-programmed nestings, e.g. GTAP-E, GTAP-AGR

- **Non-diagonal make** with CET/CES
- **GTAP-AEZ** and **GTAP-WATER** available
- **Sub-national disaggregation** (**Europe** with **280 regions**)

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Completely **flexible nesting** over multiple CET factor supply nests, based on dynamic sets

- Support for **fixed factor prices and price floors**

- CET for factor supply from nation to sub-regions (Europe)

- **Factor supply functions**

- **Vintage module**: capital split-up in new (fully or partially mobile) driven by investments and non-depreciated (sector specific) stock in comparative static mode

```
fNest("agr") = YES;
fNest_a_f("agr",agr,ffNest) = YES;
fNest_n_f("xft","agr",ffNest) = YES;
omegaFnest(r,"agr",ffNest) = omegaF(r,ffNest);

fNest("nonAgr")
fNest_a_f("nonAgr",nonAgr,ffNest) = YES;
fNest_n_f("xft","nonAgr",ffNest) = YES;
omegaFnest(r,"nonAgr",ffNest) = omegaF(r,ffNest);
```
Options:

- Global bank
- Fixed foreign savings
- Fixed regional allocation shares
- Driven by regional capital account balance under fixed exchange rate

Note: regional numéraire can be freely chosen
Model solution

- **Standard:**
  - One go CNS with CONOPT (square equation system in levels)

- **Options/Alternatives:**
  - (Multiple) **pre-solves** for single region models
  - One go **MCP (PATH)** to capture KKTs, e.g. emission quotas
  - MCP after CNS if CNS fails
  - **CONOPT4 (parallel)** instead of CONOPT3
Set-up of model variants which replicate core features of ENVISAGE, GLOBE, MIRAGE, compared to GTAP standard and a variant with GTAP-AEZ and Melitz ...

Explore boxed approach – combine different features and extensions to yield different model set-ups

57x10 data base (including AEZ land use)

50% multi-lateral trade liberalization experiment and a 20% TFP shock in North-America
- **GTAP Standard**: true replica

- **GTAPinGAMS** (replica): CD for private demand, total real gov demand fixed, gov and inv demand CD

- **“GLOBE”**: Armington aggregated, 2-stage CET, LES for final demand, separate accounts for private household and gov, CPI as regional numéraire, foreign savings fixed in international currency, flexible exchange rates close regional capital accounts

- **“MIRAGE”**: Krugman (a la AKME), global bank, sluggish factor mobility between agr and non-agr, total real gov demand fixed, LES for final demand, Armington aggregated
Example applications

- **“ENVISAGE”**: 2-stage CET, sluggish factor mobility between agr and non-agr, GTAP-E nesting, LES + CES sub-nests for energy in final demand, gov and inv demand CD, real gov saving and consumption fixed, gov account closed by direct tax rates, fixed foreign savings, vintage capital module
- **“CGEBOX”**: GTAP-AEZ + land supply, GTAP-E, GTAP-AGR, vintage capital module, 2-stage CET
- **“CGEBOX+”**: as before, but CET replaced by Melitz model for all manufacturing sectors (~20)
Main results

- EV US$ per capita under a 20% TFP shock in the North America

<table>
<thead>
<tr>
<th>Region</th>
<th>GTAP Standard</th>
<th>GTAPinGAMS</th>
<th>GLOBE</th>
<th>ENVISAGE</th>
<th>CGEBOX</th>
<th>MIRAGE</th>
<th>CGEBOX_plus</th>
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</table>
Main results

- **Trade lib shock:**
  - Especially new-trade theory models (Krugman in “MIRAGE”, Melitz in “CGEBox+”) lead (as expected) to considerably higher welfare gains, might quadruple standard results
  - Other configurations not much different in core results
  - CET + removal of global bank (GLOBE, ENVISAGE) somewhat dampen welfare gains

For more results and details, read paper …

Britz and Van der Mensbrugghe: CGEBox
Next steps

- Explore collaborations
- Discuss:
  - Cost savings? ... code is naturally more complex compared to a less flexible model layout
  - Common coding and documentation style
  - Quality management and testing
  - Incentives to contribute
  - IPR / trademarking
CGEBOX: freely distributed code base for CGE modeling, modular, flexible, in GAMS

Implements already various GTAP extensions and features found in well-known CGEs, sensitivity analysis

Data filtering and pre-solves permit solving models with highly dis-aggregated SAMs

Graphical User Interface for model configuration

Exploration tools to analyze results with pre-defined views

Survival and further development depends on take-up by users and active contribution