Technical change in CGE models: reconciling BU and TD through dual accounting

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Context

cf. Böhringer (1998); Ghersi & Hourcade (2006)

Premise of the demonstration

The representation of technical change in CGE models impacts the assessment of:

- climate and energy policies
- sustainable growth trajectories

$\Longrightarrow$ Improve technical realism of production and consumption choices

Some attempts at hybrid modeling have already been made:

Böhringer (1998); Böhringer & Rutherford (2008); McFarland *et al.* (2004); Schafer & Jacoby (2005); Schumacher & Sands (2007)...
$\Longrightarrow$ What methodological conclusions can we draw?

Approaches

Three types of methodologies

- **Soft-link**
  between a CGE top-down model with bottom-up models
  e.g. Schafer & Jacoby (2005); McFarland *et al.* (2004)

Alternative: **hard-linked model:**

- Mixed Complementarity Problems
  e.g. Böhringer (1998); Frei *et al.* (2003); Kumbaroğlu & Madlener (2003); Böhringer & Rutherford (2008)
- Double-accounting Social Accounting Matrices
  e.g. Bibas & Méjean (2012); Bibas (2013); Schumacher & Sands (2007); Sue Wing (2008)

The soft link approach

Methodology concept

- Preexisting Top-Down and Bottom-Up models
- Use of one (or more) linkage variable
  e.g. energy quantities
- Iterations for convergence of linkage variables

Existing attempts

McFarland *et al.* (2004); Schafer & Jacoby (2005)
For a survey, see Bataille *et al.* (2006)

The CES with Leontieff technologies approach

Numerical calibration (prices are unity)

$\Longrightarrow GEN^0 = \sum_t y_t^0$.

Conservation of energy

$\Longrightarrow \epsilon_{GEN}^0 GEN^0 = \sum_t \epsilon_t^0 y_t^0$ (ϵ energetic coefficient in kWh/$)

Non-linearity of the CES aggregator

$\Longrightarrow GEN = CES(y_1, \cdots, y_t)$

At non-benchmark prices

$\Longrightarrow \epsilon_{GEN}^0 GEN \neq \sum_t \epsilon_t^0 y_t$

Energy coefficient on aggregate generation output

is **endogenous**: $\epsilon_{GEN} = \frac{\sum_t \epsilon_t^0 y_t}{GEN}$, and will adjust as prices change.

The CES with Leontieff technologies approach

Conclusions

- Hybrid models energy accounting must be performed at the level of individual energy supply technologies
- Energetic coefficient on the output of the technology-rich sector varies endogenously with changes in prices
- The challenge of representing the inter-temporal dimension of technology substitution is far greater, as it necessitates modeling the process by which producers adjust stocks of technology-specific capital

Limits to soft-links

Consistency between top-down and bottom-up model

- Not full integration
- Often missing links
- From TD to BU, problems of prices disaggregations
- From BU to TD, often missing correct reagregation in quantities and costs

Representations

- Incompatibility of economic paradigm?
  $\Longrightarrow$ e.g. macroeconomic optimum vs. partial equilibrium dynamics

Dialogue with engineers and policy-makers

Missing dialogue variables: physical quantities, efficiency

The MCP approach

Methodology concept

- Integration of complementarity characteristics to market equilibrium optimization
- Mathematical format that covers weak inequalities, i.e. a mixture of equations and inequalities, and complementarity between variables and functional relationships
- Includes a wide range of mathematical problems (linear or nonlinear equations or mathematical programs)
- MCP formulation relaxes constraints $\Longrightarrow$ direct representation of market inefficiencies such as distortionary taxes or spillovers that cannot be readily studied in an optimization framework

Existing attempts

Böhringer (1998); Frei *et al.* (2003); Kumbaroğlu & Madlener (2003); Böhringer & Rutherford (2008)

Methodology concept

Dual economic circularity

- Principle of conservation (conservation of mass in physics)
- Flows in values and physical units linked by relevant price
  $\forall i,\ \sum_{Uses} Q^i_{Uses} = \sum_{Supply} Q^i_{Supply}$
  $\forall i,\ \sum_{Uses} V^i_{Uses} = \sum_{Supply} V^i_{Supply}$
  $\forall (i,o),\ V_{i,o} = P_{i,o} \times Q_{i,o}$
- No constraints on available metrics and goods heterogeneity
  - No need of prices indexes to derive volumes (Paashes. . .)
  - Rely on tangible physical units
    - Calorific content (ktoe,EJ,kCal. . .) / Mass (steel, cement) / Land (hectares) / water
    - Irreductible composite goods

Existing attempts

Schumacher & Sands (2007); Sue Wing (2008); Sassi *et al.* (2010); Bibas & Méjean (2012); Bibas (2013)

MCP hides an implicit dual accounting

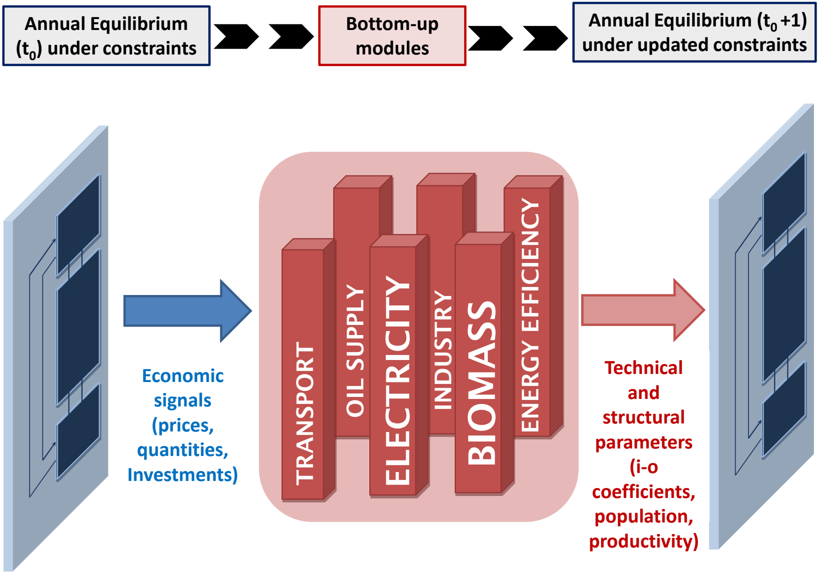
What data is needed…
…to translate additional constraints?
…to describe explicit technologies?

$\Longrightarrow$ Physical data coming from the technico-economic world

Model control relies on…

$\Longrightarrow$ Control variables
$\Longrightarrow$ relying on data coming from the technico-economic world
e.g. energy efficiency, physical constraints…

The Imaclim approach



Assessment criteria of hybrid CGE models

1. Flexibility of representations
   - Capacities constraints (Böhringer, 1998)
   - Imperfect expectations (Frei *et al.* , 2003)
   - Endogenous structural change (Crassous *et al.* , 2006)
2. Model control
   - Energy efficiency control
   - Physical quantities to economic quantities ratios
3. Dialogue enhancers
   - Physical determinants of households demand
   - Energy efficiency and industrial processes
   - Policy objectives in quantities

$\Longrightarrow$ See Bibas *et al.* (2012) for an example of dialogue with stakeholders with the Imaclim-R hybrid model

Thank you

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