Integrating bottom-up and top-down analyses of the Italian energy system

O. Amerighi, U. Ciorba, F. Gracceva, C. Martini, C. Notaro, M. C. Tommasino

Italian Agency for Energy,
New technology and Environment

ETSAP Semi-annual Workshop,
Fondazione Giorgio Cini
Isola di San Giorgio, Venezia,
16th June 2008

1. Integrating Markal-Italy with macroeconomic analyses: reasons, objectives

2. The Energy Extended Social Accounting Matrix
   • SAM Italy: construction methodology
   • Markal-Italy and SAM: an unidirectional Soft-link
   • Soft link: structural change and impact analysis

3. GTAP-E ITALY general equilibrium model
   • GTAP-E Italy: construction methodology
   • Markal-Italy and GTAP-E: an integrated analysis
Integrating Markal-Italy with macroeconomic analyses - Political relevance: threats/opportunities

Markal-Italy developed since 90’s, widely used to support policymakers:
- National Communications to UNFCCC
- analysis of EU package 20/20/20 for the Italian government (support for EU burden sharing)
- periodical elaboration of scenarios for the Ministry of Economic Development
- EU Commission: European firms must gain the leadership in the rapidly growing sector of low carbon technologies, because otherwise there is the risk to that "others will benefit of the transition to a low carbon economy"

Integrating Markal-Italy with macroeconomic analyses: modelling Energy/Economy interactions

- **Ideal** energy-environment policy model:
  - technologically explicit,
  - behaviorally realistic,
  - macroeconomic feedbacks
- **Hybrid** models: B-U or T-D that have made at least one modification that shifts them away from their conventional placement
- Reasons for moving toward hybrid from a B-U perspective

By P. Capros, L. Mantrou, V. Papandreeou, N. Tatsios
Primes Model - EghLab/NTUA
June 2008

Source: Hourcade et al., Energy Journal, 2006
Modelling energy/economy interactions from a Bottom-Up perspective

Towards hybrid from a Bottom-Up perspective – Markal-ED and Markal-Macro

- Partial equilibrium approach do not take into account redistributional effects, feedbacks, impact on non energy sectors and prices etc.

- Economy-wide perspective: readjustment of the economy
  But
  - no sectoral disaggregation and
  - "elephant and rabbit" metaphor
Need for a further step: to link or not to link

"Unidirectional " Soft-link

- Extend B-U models as far as possible w/o hitting technical limit and preserving technological detail
- Supplement B-U results with macroeconomic models:
  - with feedback: iterative scheme is time-consuming
  - w/o feedback: simpler implementation, quicker cycle time
- As feedback from economy to energy system are "not important" ➔ no iterations

Joint analysis: different models for different needs

- Distributional issues between economic agents or countries are better addressed with macroeconomic models
- Technological opportunities, interaction between demand and supply in energy markets, better addressed with energy models

1. Integrating Markal-Italy with macroeconomic analyses: reasons, objectives

2. The Energy Extended Social Accounting Matrix
   - SAM Italy: construction methodology
   - Markal-Italy and SAM: an unidirectional Soft-link
   - Soft link: structural change and impact analysis

3. GTAP-E ITALY general equilibrium model
   - GTAP-E Italy: construction methodology
   - Markal-Italy and GTAP-E: an integrated analysis
What is SAM?

- A Social Accounting Matrix (SAM) can be defined as an organized matrix representation of all transactions and transfers between different production activities, factors of production and institutions (like households, firms and government) within the economy and with respect to the rest of the world.

- SAM is a comprehensive accounting framework within which the full circular flow of income from production to factor incomes, household income to household consumption and back to production is captured.

- Each row gives receipts of an account while the column gives the expenditure.
  - An entry in, say, row i and column j represents the receipts of account from account.
  - The total of each row is equal to the total of each corresponding column.

What is SAM?

- A "snapshot" of the economy in the base year: the production side is aggregated into a set of sectors, each of which usually produces a single good.

- Row: amount of good produced must be sufficient to serve the sum of demands from other producing sectors plus the final demands of G, I, C, net EXP.

- Column: the amount of the good produced by an industry is just exhausted in the payments to its inputs, plus taxes.

- X is the technology in use in the benchmark year ➔ amounts of various inputs applied to produce a unit of each sector’s output (Leontief-type representation at sector level).
The Italian SAM Estimation Methodology

DATA BASE DEFINITION:
- SYSTEM OF NATIONAL ACCOUNTS
- TIME SERIES OF MAKE&USE TABLES
- NATIONAL STATISTICS

DEFINITION OF THE INPUT-OUTPUT MATRIX ON THE BASIS OF THE MAKE&USE TABLES TIME SERIES

TIME SERIES VARIABLES DETREND AND DEFINITION OF THE CORRELATION MATRIX

ESTIMATION OF 1,000 MATRIXES THROUGH MONTE CARLO SIMULATION

RAS routine Implemented through MATLAB:
1,000 Matrixes 65X65
1,000 multiplayer matrices

Integrating Markal-Italy with Italian SAM:
a possible methodology

ENERGY SCENARIO FROM MARKAL-TIMES

Disaggregation of the original energy vectors in the SAM:
- ‘Coal’
- ‘Oil refining’
- From ‘Mining and quarrying’ in the SAM into ‘Crude oil’ and ‘natural gas’
- From ‘Electricity and gas’ to ‘Electricity’, ‘Renewable electricity’ and ‘Natural gas’

Definition of a “bridge matrix“:
- Energy flows among energy sources and productive sectors (from Markal-Times)
- Price of the energy sources (from different statistics)

RAS ROUTINE IMPLEMENTED THROUGH MATLAB:
EXTENDED ENERGY MATRIX
Disaggregation of the Energy Sector in the SAM

In order to disaggregate the SAM it is necessary to define:

- energy flows among industries (intermediate demand);
- energy flows between industries and consumers (final demand including exports);
- imports of energy products;
- the cost structure of energy producing industries

Bridge Matrix (oil sector flows in a SAM)
Integrating Markal-Italy with Italian SAM: impact analysis

- From the B-U model ➔ detailed schedule of investments and other expenditures, and of prices, by each sub-sector, at each time-period
- These parameters are input into the corresponding SAM, which calculates the impacts on sectoral value added, on disposable income, on consumption, on labor and wages, etc.
Impact analysis through SAM multipliers

- The Extended SAM allows to analyze the economic impacts at a disaggregated level - by sectors and by socio-economic groups in the country - of energy policies.
- The output multiplier of a sector for example measure the amount by which the total output increases for a unit increase in the output of that sector:
  - Total Income multipliers give direct and indirect increase in GDP due to a unit increase in the value of output of a final demand vector
  - Household income multiplier gives the corresponding effect on the incomes of the household due to a unit increase in the value of output of a final demand vector

Impact analysis through SAM multipliers: an application to the Civil Sector

Evaluation of the economic impact of an investment in the Italian civil sector for the energy upgrading of the public building

| NET IMPACT | INVESTMENT COST (000/€) | 8.242 |
| CROWDING OUT (%) | 50% |
| VALUE ADDED (000/€) | 14.303 |
| PRODUCTION (000/€) | 19.001 |
| HOUSEHOLDS (000/€) | 1.802 |
| ENTERPRISES (000/€) | 10.268 |
| GOVERNMENT (000/€) | 2.232 |
| LABOUR (UNITY) | 147.834 |
| DELTA GDP (%) | 0.59% |

<table>
<thead>
<tr>
<th>Multipliers</th>
<th>Impact</th>
<th>Historic Value</th>
<th>Net Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value added</td>
<td>3.66</td>
<td>3.12</td>
<td>0.54</td>
</tr>
<tr>
<td>Input Output</td>
<td>4.90</td>
<td>4.22</td>
<td>0.69</td>
</tr>
<tr>
<td>Households</td>
<td>2.64</td>
<td>2.25</td>
<td>0.38</td>
</tr>
</tbody>
</table>
Integrating Markal-Italy with Italian SAM: modeling structural change (1a)

Markal/Times → Bridge matrix → Energy extended SAM

Econometric estimation of non energy coefficients

New structure of the economy, with energy technologies as key drivers

Integrating Markal-Italy with Italian SAM: modeling structural change (1b)

- If mitigation strategies imply adjustments of the whole economic system (far from "marginal"): can they stimulate innovative changes of social/economic systems that make crisis/policies a mechanism of economic dynamics?
- Cost of sustainability is in fact an investment cost: significant adjustment costs, but ultimate extensive and positive changes of the economic systems

Source: IEA, 2004
1. Integrating Markal-Italy with macroeconomic analyses: reasons, objectives

2. The Energy Extended Social Accounting Matrix
   - SAM Italy: construction methodology
   - Markal-Italy and SAM: an unidirectional Soft-link
   - Soft link: structural change and impact analysis

3. GTAP-E ITALY general equilibrium model
   - GTAP-E Italy: construction methodology
   - Markal-Italy and GTAP-E: an integrated analysis

What is GTAP?

- GTAP (Global Trade Analysis Project) is a multi-regional Applied General Equilibrium model.

- It captures world economic activity in 57 different sectors of 113 regions (Data Package 7).

- It includes two kinds of equations:
  1. accounting relationships
  2. behavioral equations

- It allows to obtain the impacts of policies in terms of GDP and trade variation, sectoral impacts, allocation effects, etc.
GTAP structure

What is GTAP-E?

- In the standard GTAP model, there is no inter-fuel, nor fuel-factor (energy - primary factor) substitution
- GTAP-E includes CO2 emissions and volume data on energy use, which enter in demand and production structure
- First version (Burniaux, Truong, 2002) and latest revised version (McDougall, Golub, 2007)
- GTAP-E has been specifically designed to simulate GHG mitigation policies; usefulness of an integrated analysis with Markal/Times models
In order to build the GTAP-E ITALY it has been necessary to:
1. Choose the GTAP-E version (McDougall, Golub, 2007);
2. Define the regional and sectoral disaggregation (reference to IEA Energy Balances);
3. Use the GTAP 7 Data Package to derive the energy data for the GTAP-E version;
4. Derive Italian CO\textsubscript{2} sectoral emissions from GTAP CO\textsubscript{2} Emissions Data;
5. Provide the files needed by RunGtap to compute the general equilibrium solution.
Regions

<table>
<thead>
<tr>
<th>GTAP-E regional disaggregation</th>
<th>GTAP-E Italy regional disaggregation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 USA</td>
<td>1 Italy</td>
</tr>
<tr>
<td>2 European Union (14 members)</td>
<td>2 USA</td>
</tr>
<tr>
<td>3 Eastern Europe and FSU</td>
<td>3 European Union (14 members)</td>
</tr>
<tr>
<td>4 Japan</td>
<td>4 Eastern Europe and FSU</td>
</tr>
<tr>
<td>5 Other Annex I Countries</td>
<td>5 Japan</td>
</tr>
<tr>
<td>6 Net Energy Exporters</td>
<td>6 Other Annex I Countries</td>
</tr>
<tr>
<td>7 China and India</td>
<td>7 Net Energy Exporters</td>
</tr>
<tr>
<td>8 Rest of World</td>
<td>8 China and India</td>
</tr>
</tbody>
</table>

Sectors

<table>
<thead>
<tr>
<th>GTAP-E sectoral disaggregation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Agriculture</td>
</tr>
<tr>
<td>2 Forestry</td>
</tr>
<tr>
<td>3 Coal</td>
</tr>
<tr>
<td>4 Crude Oil</td>
</tr>
<tr>
<td>5 Natural Gas</td>
</tr>
<tr>
<td>6 Refined Oil Products</td>
</tr>
<tr>
<td>7 Electricity</td>
</tr>
<tr>
<td>8 Mineral Products</td>
</tr>
<tr>
<td>9 Chemical, Rubber, Plastic Products</td>
</tr>
<tr>
<td>10 Metal Products</td>
</tr>
<tr>
<td>11 Paper Products</td>
</tr>
<tr>
<td>12 Transport</td>
</tr>
<tr>
<td>13 Sea Transport</td>
</tr>
<tr>
<td>14 Air Transport</td>
</tr>
<tr>
<td>15 Services</td>
</tr>
<tr>
<td>16 Dwellings</td>
</tr>
<tr>
<td>17 Other Industry and Services</td>
</tr>
</tbody>
</table>
GTAP-E ITALY potential

- Italian general equilibrium model calibrated on 2004 data (first time GTAP-E is updated to GTAP 7 Data Package)
- Detailed sectoral structure (energy and emissions data)
- Wide range of countries included

Possible applications:
- Computation of the economy-wide impacts of energy policies, such as carbon taxation or emission trading (i.e. carbon leakage)
- Integrated analysis with Markal-Times models

MARKAL-ITALY AND GTAP-E: A JOINT ANALYSIS (1)

Need for:
- **internal consistency** between the different elements of a same scenario: the influence of energy costs on the energy system, as modeled by the energy model, is consistent with the influence of energy costs on the optimal mix of production factors as modeled in the macroeconomic model
MARKAL-ITALY AND GTAP-E: A JOINT ANALYSIS (2)

- To ensure consistency, **harmonization of the two types of models** to same type of behavioural/technological assumptions: substitution elasticity of production function in macro model should reflect the technological substitution in energy model

  ➔ **A tentative strategy**

  **Iterations** for alignment of elasticites: convergency of energy use in the two models induced by the same variation of energy costs
  - Macroeconomic model: integrate the different possible responses of the energy system to a policy
  - Partial equilibrium model: integrate price mechanism to reflect the possible interaction outside the energy system

**Thanks**

(francesco.gracceva@enea.it
chiara.martini@enea.it)