Integrating the TDBU-ETSAP models in MCP format

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Introduction

- Soft-linked, Hard-linked and Integrated Models in MCP

- Advantages of MCP

- Reformulation of MSA in MCP (recent developments)

- Advantages of having MSA in MCP

- Linking TIMES and MSA using MCP (further research)

- Linking TIMES and other CGE models: an alternative approach

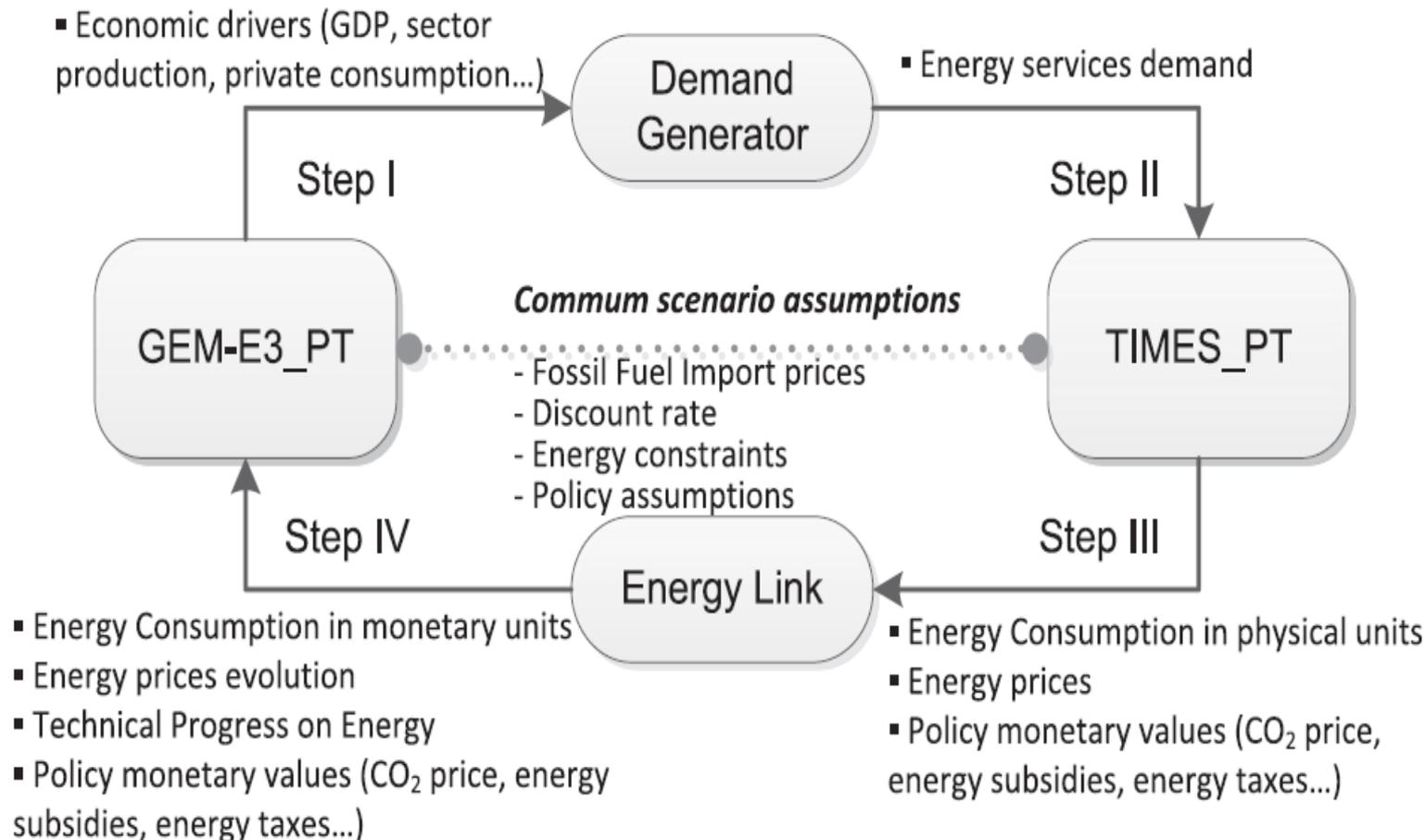# According to Böhringer & Rutherford (B&R)

Hybrid E3 models combining TDBU approaches are classified as:

a) Soft-linked models with different behavioural assumptions and accounting concepts that eventually become inconsistent.

b) Hard-linked models focusing in one part like e.g., TIMES-MACRO with detailed BU energy model and a simple MACRO-economy

c) Fully integrated models in MCP format. There are only some pedagogic examples in MCP format like those presented by B&R

Thus, PSI together with *Per Ivar Helgesen* made a proposal this year to work in the direction of b) and c) but without obtaining a clear support from ETSAP.
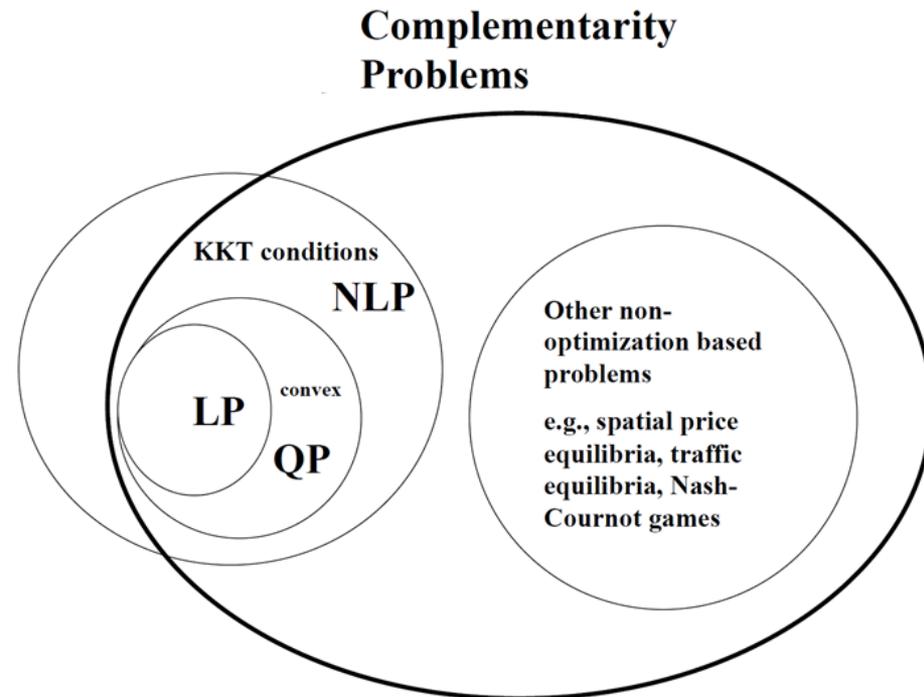
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HybTEP –Hybrid Technological Economic Platform

Source: Patricia Fortes

- Economic drivers (GDP, sector production, private consumption…)

Demand Generator

- Energy services demand

Step I

Step II

GEM-E3_PT

Commum scenario assumptions
- Fossil Fuel Import prices
- Discount rate
- Energy constraints
- Policy assumptions

TIMES_PT

Step IV

Step III

Energy Link

- Energy Consumption in monetary units
- Energy prices evolution
- Technical Progress on Energy
- Policy monetary values (CO_2 price, energy subsidies, energy taxes…)

- Energy Consumption in physical units
- Energy prices
- Policy monetary values (CO_2 price, energy subsidies, energy taxes…)

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Advantages of MCP

- MCP is not an alien: the concept of complementarity is synonymous with the notion of the **system equilibrium**:

  - The balance of supply and demand implies a complementarity relation between price and excess demand (when one is positive the other is zero)

- Examples of more advanced applications, solved by MCP:

  - Behavioural statements (e.g. transport)

  - General equilibrium problems

  - Game theoretic problems

  - Spatial price equilibria

Complementarity Problems

KKT conditions

NLP

LP

convex

QP

Other non-optimization based problems

e.g., spatial price equilibria, traffic equilibria, Nash-Cournot games

Source: Prof. Steven Gabriel

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What is already accomplished?

- **E. Panos has developed an operational version of MSA in MCP format linked and tested with TIMES (case UTOPIA)**
  - A documentation of the new formulation is being prepared
  - The code is generic and has been tested for errors, it is integrated into the TIMES version v371 and produces the same results as the original MSA optimization.
  - An application of TMSA in MCP format is needed and we are aiming to publish in a scientific journal.

- However:
  - The Global TIAM-MSA should be also tested
  - The MILES or PATH solver is needed to solve the model
  - Some knowledge of mixed complementarity theory would be beneficial to identify potential solution problems

Advantages of having MACRO in MCP

- The MCP format has the duals of the constraints as variables that become part of the model's equations

- This enables the introduction of different sectors with its own objectives like

  - Maximisation of Utility for Households
  - Minimisation of costs of industrial & energy sectors
  - Maximisation of profits for services

  At the end, all sectors reach an equilibrium point that minimizes the cost of energy (TIMES) and could include policy constraints.

- All LP models like TIMES can be defined in MCP format (B&R)

- CGE is per-se formulated in MCP format and now also MSA

- Ultimately as MSA and TIMES can/are defined in MCP format this allows to fully integrate them having a consistent model

NLP formulation of the MACRO-SA

$$\max U = \sum_{t=1}^{T} \sum_{r} nwt_r \cdot pwt_t \cdot dfact_{r,t} \cdot \ln(C_{r,t}) \tag{1}$$

$$Y_{r,t} = C_{r,t} + INV_{r,t} + EC_{r,t} + NTX_{r,t} \tag{2}$$

$$Y_{r,t} = \left(akl_r \cdot K_{r,t}^{kpvs_r \cdot \rho_r} \cdot l_{r,t}^{(1-kpvs_r) \cdot \rho_r} + \sum_k b_{r,k} \cdot DEM_{r,t,k}^{\rho_r} \right)^{\frac{1}{\rho_r}} \tag{3}$$

$$DET_{r,t,k} = aeeifac_{r,t,k} \cdot DEM_{r,t,k} \tag{4}$$

$$K_{r,t+1} = tsrv_{r,t} \cdot K_{r,t} + \frac{1}{2}\left(d_t \cdot tsrv_{r,t} \cdot INV_{r,t} + d_{t+1} \cdot INV_{r,t+1} \right) \tag{5}$$

$$K_{r,T} \cdot \left(growv_{r,T} + depr_r \right) \leq INV_{r,T} \tag{6}$$

$$INV_{r,t} + EC_{r,t} - y0_r \cdot l_{r,t}^{ivetol_r} \leq 0 \tag{7}$$

$$\sum_r NTX_{r,t} = 0 \tag{8}$$

$$EC_{r,t} = qa_{r,t} + \sum_k qb_{r,t,k} \cdot DET_{r,t,k}^2 + amp_{r,t} \tag{9}$$

What is done for converting MSA to MCP?

We applied the standard procedure and nothing new, e.g.:

Given the following problem:

$\max f(x)$ s.t. $g_i(x) \leq 0, i = 1..m$ and $x \geq 0$ we can define the function

$$L(x,u) = f(x) - \sum_{i=1}^{m} u_i \cdot g_i(x) \qquad \text{(Lagrangian)}$$

The Karush-Kuhn-Tucker (KKT) conditions for maximization are:

$$\frac{\vartheta L(x,u)}{\vartheta x} \leq 0 \perp x \geq 0 \text{ and } \frac{\vartheta L(x,u)}{\vartheta u} \geq 0 \perp u \geq 0 \qquad \text{while}$$

when some constraints $g_i(x) = 0.0$, then the corresponding u_i variable is free.

The MCP formulation in GAMS for MSA needs to declare variables and equations and code all equations for MSA, to define coefficients and bounds and solve the problem by maximizing the same objective function using MCP. Then, iterations between TIAM and MSA are done in exactly the same way as in the case of NLP optimization.

The next steps of work in MCP format

As the MCP code is generic it can be applied to any TIAM model (instead of Utopia) but to prove that we need to go to the final stage of work under the approval of ETSAP and test:

1. MACRO-SA in MCP, TIAM in LP and the current decomposition algorithm (we have already done it for UTOPIA)
2. MACRO-SA in MCP, TIAM in MCP (perhaps via EMP) and one integrated model (for UTOPIA)
3. MACRO-SA in MCP, TIAM in LP and MPEC with TIAM as the upper level problem, the link is defined on demands and energy costs (as in the decomposition algorithm) but if successful it could be applied to large TIAM models.

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Another idea of TIMES-CGE integration

1. An alternative would be to link CGE and TIMES in modular form where:

   a. Electricity (other sectors) will be defined with explicit technologies where…

   b. A proper data structure by technology should be obtained (i.e., with Investment cost having sectoral shares and primary factor input shares)

   c. Calibration: The sum of initial penetration activity by technology times their shares should be consistent with the social accounting matrices and statistics

   d. Technology penetration should be defined either via TIMES (or ad-hoc if CGE model is applied alone)

   e. The TIAM solution (i.e., via the shares and technology activities for the sector) defines for CGE the intermediate demands and incomes of primary factors

   f. Eventually, after the CGE solution we will change investment cost, fixed and O&M cost in TIMES based on CGE prices for primary factors K,L,E,M.

   g. Solve CGE & TIMES as hard-linked models but in modular form and in a recursive dynamics mode.

2. Whatever the final choice, ETSAP support is needed and we will apply again for that as until now work was done for free to demonstrate feasibility and because will believe this is the way to go.

Linking TIMES LP and other CGE models

- Economic drivers
- Prices of primary factors (K,L,E,M)

- Energy service demands
- Altered INVCOST, FOM

Demand & Tech Costs Generator

1

2

CGE with Technologies

Common scenario assumptions

TIMES

4

3

Energy Link & Tech penetration

- Energy consumption in monetary units
- Demands/incomes of primary factors based on tech shares & tech activities per sector
- Energy prices (evolution)
- Technical progress & Technology penetration

- Energy consumption in physical units
- Energy prices (shadow prices)
- Policy monetary values
- Technology mix

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Adapted from P. Fortes