Business from technology

The MACRO Decomposition Algorithm and Other Recent Enhancements in TIMES (v3.3.1 — v3.4.0)

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ETSAP ENERGY TECHNOLOGY SYSTEMS ANALYSIS PROGRAM

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The MACRO Decomposition Algorithm

- TIMES includes a macroeconomic module MACRO:
  - MACRO maximizes an inter-temporal utility function for a single representative producer-consumer agent
  - Can be very useful for estimating the macro-economic implications of environmental policies, e.g. climate policies
- Earlier implementation has notable shortcomings:
  - Well-justified only for single-region models: Does not consider inter-temporal trade imbalances or income disparities
  - Formulation as big NLP model leads to poor performance of solvers compared to LP models already in the single-region case
  - Moreover, also the Baseline calibration of DDF factors and labor growth rates is both cumbersome and time-consuming
- Decomposition method offers the solution
  - Similar approach successfully employed in MESSAGE-MACRO

TIMES-MSA – Calibration

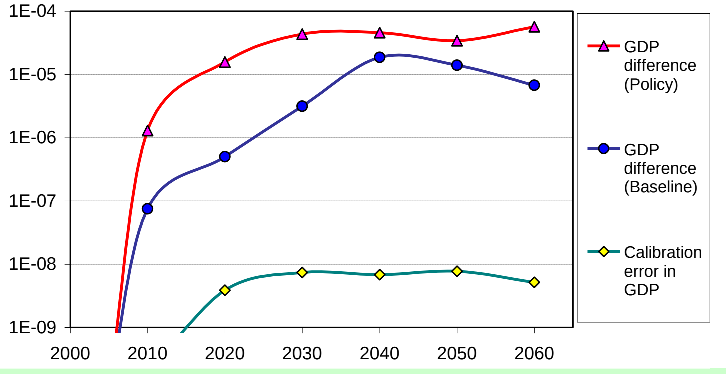
- Step 1: Solve the Baseline TIMES-LP model:
  - 1a: MIN ObjZ = SUM{ (r,t), Coef_PVT(r,t) * Var_EC(r,t) }
  - 1b: Calculate Quadratic Supply Functions for the demands
- Step 2: Solve the stand-alone MACRO model (MSA):
  - 2a: Calculate new DDF factors and labor growth rates
  - 2b: MAX UTIL = SUM{ (r,t), TM_DFACT(r,t) * LOG(Var_Y(r,t)−Var_INV(r,t,)−Var_EC(r,t)) }
  - 2c: If max. error in demands and GDP are above tolerance, goto 2a
- Step 3: If multi-regional, iterate MSA with Negishi weights
  - 3a: Calculate initial Negishi weights NWT(r)
  - 3b: MAX UTIL = SUM{ (r,t), NWT(r) * TM_DFACT(r,t) * LOG(Var_Y(r,t)−Var_INV(r,t,)−Var_EC(r,t)−Var_NMR(r,t)) }
  - 3c: Calculate new NWT(r), and if difference is above tolerance, update DDF factors and go back to Step 3b
- Step 4: Write final calibration parameters into a DD file

TIMES-MSA – Policy Evaluation

- Step 1: Solve the Policy Scenario TIMES-LP model:
  - 1a: MIN ObjZ = SUM{ (r,t), Coef_PVT(r,t) * Var_EC(r,t) }
  - 1b: Calculate Quadratic Supply Functions (QSF) for the demands
  - 1c: Read the calibrated DDF factors and labor growths from DD file
- Step 2: Solve MSA (with Negishi loop if multi-regional):
  - 2a: Calculate initial Negishi weights NWT(r)
  - 2b: MAX UTIL = SUM{ (r,t), NWT(r) * TM_DFACT(r,t) *
    LOG(Var_Y(r,t)−Var_INV(r,t,)−Var_EC(r,t)−Var_NMR(r,t)) }
  - 2c: Calculate new NWT(r), and if change is above tolerance, goto 2b
  - 2d: If error in demand levels is below tolerance, proceed to Step 3
  - 2e: Update the LP demands according to MSA results and resolve:
    MIN ObjZ = SUM{ (r,t), Coef_PVT(r,t) * Var_EC(r,t) }
  - 2f: Calculate new QSF for MSA and go back to Step 2b
- Step 3: Calculate all model results and finish

TIMES-MSA – Validation

- Good convergence to the same solution as in TIMES-MACRO
- BUT: Systematic differences could only be eliminated after harmonizing the discount factors applied in TIMES-LP and Macro
  - Additional discount rate updating was added into the algorithm



Calibration error and GDP differences for the single-region TIAM-USA model

TIMES-MSA — Performance

- Tests carried out with subsets of the ETSAP-TIAM model:
  - Single-region model for the USA (run also with TIMES-MACRO)
  - Six-region model (EEU + WEU + USA + AFR + CHI + MEA)
  - Ten-region model: (EEU + WEU + USA + JPN + AFR + CHI + CSA + IND + MEA + ODA)
- Test results indicate that TIMES-MSA is perhaps even 100+ times faster than TIMES-MACRO
- Full TIAM not yet tested because of problems e.g. with FSU

Run time	**TIMES-MSA**		**TIMES-MACRO**	
(minutes)	**Calibration**	**Policy run**	**Calibration**	**Policy run**
TIAM-USA	<1	2	~250	~200
TIAM-6R	4	28	NA	NA
TIAM-10R	7	58	NA	NA

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TIMES-MSA — Usage Notes

- New control switches for activating TIMES-MSA
  - $SET MACRO CSA – activate MSA in calibration mode
  - $SET MACRO MSA – activate MSA in policy run mode
  - $SET OBJANN YES – activate discount factor updating (optional)
- The following input parameters are mandatory for MSA:
  - TM_GDP0(r) – GDP in base year (currency units)
  - TM_GR(r,t) – GDP growth projection (per cent / a)
- New result attribute available in both MSA/TIMES-MACRO:
  - TM_RESULT(item,reg,year), [*Var_Macro in VEDA-BE*]; where item=
    - GDP-REF – Baseline GDP projection
    - GDP-ACT – Actualized GDP in scenario
    - PRD-Y – Production
    - CON-C – Consumption
    - INV-I – Investments
    - ESCOST – Annual energy system costs
    - GDPLOS – GDP loss in per cent (policy runs)

TIMES-MSA – Open Issues & Further Work

- Which period-wise discount factors should be applied?
  - Should one use the energy system discount factors in TIMES-LP, or harmonize them with the effective "utility discount factors" of MSA?
  - Full convergence to the TIMES-MACRO solution may only be obtained with consistent discount factors, but is that necessary?
  - Handling of the last period has been changed for now (partly due to similar reasons); see the MACRO documentation for details
- Should energy trade balances be explicitly modeled in MSA?
- Should income elasticity of demands be incorporated?
  - The MARKAL income elasticity option is currently not available
- How to eliminate problems arising from poorly behaving models (e.g. the FSU region of ETSAP-TIAM)?
- Would a more elaborated MACRO module be desired?

Grid Modeling in TIMES

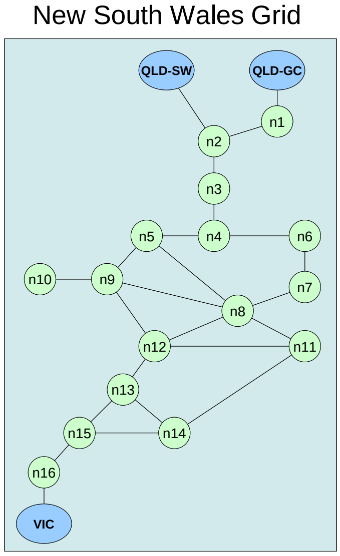
- TIMES electricity grids may consist of both inter-regional and intra-regional transmission lines
- Grid lines are modeled by bi-directional trade processes
- Grid nodes are represented by TIMES commodities (node balance = commodity balance)
- Transmission losses can be easily defined for each line
- Generation and demands may be either explicitly modeled for each grid node, or may be allocated in a semi-automatic way to the nodes
  - With the automated allocation facility, detailed grid analysis can be implemented to any existing model as an add-on
- Optional DC linear power flow analysis feature available

Grid Modeling – Power Flow Equations

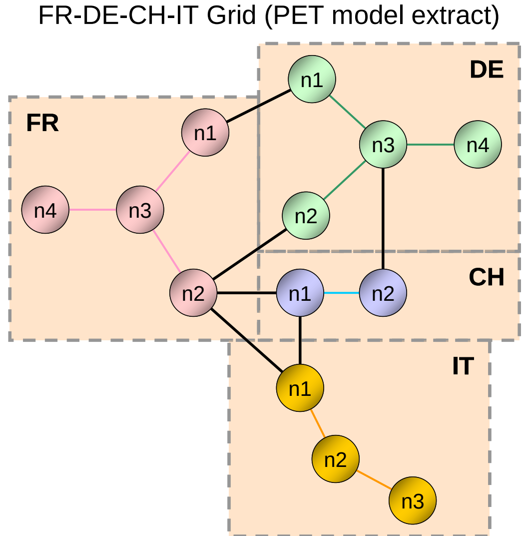
- Standard linear DC power flow equations now supported
- Simulate real power flows in the transmission system
- Can be useful for analyzing grid bottlenecks and integration of large amounts of variable generation into the system
- Requires only one new input parameter: PRC_REACT(r,y,p)
  - Specifies the reactance of the transmission line *p*
  - Units don't matter, only the relative value among all lines
  - Defines also the grid topology for the purposes of the automated facility for allocating generation and loads
  - If PRC_REACT(r,y,p)=0, the line is included in the grid but excluded from the power flow equations
- Has been successfully tested with small grid models

Grid Modeling – Simple Examples

New South Wales Grid



FR-DE-CH-IT Grid (PET model extract)



Other Minor Enhancements in TIMES

- Semi-continuous investment variables now supported
  - New capacity variables VAR_NCAP required to be either VAR_NCAP(rtp) = 0 or VAR_NCAP(rtp) ≥ NCAP_SEMI(rtp)
  - Available in the DSC extension
- New process type for generalized timeslice storage
  - For example, generalized DAYNITE level storage can store energy also between seasons or even between periods
- FLO_COST and FLO_DELIV can now be specified for storage (FLO_COST applied to charging and FLO_DELIV to discharge)
- Uncertain parameter S_FLO_FUNC can now be applied also to FLO_EMIS / IRE_FLOSUM transformation of IRE processes
  - Syntax: S_FLO_FUNC(reg,y,prc,com,com,stage,sow)
- Fixing first periods is now supported in a flexible way under Time-stepped mode (fixed periods may vary between regions)

Documentation Status

- Updated document on the TIMES Control Switches
- Pending: Documentation of TIMES-MSA
- Pending: Documentation of grid modeling features
- Base documentation and supplementary notes cover features up to TIMES v3.1.x:
  - Documentation for the TIMES Model (Parts I-III)
  - Document on TIMES enhancements in v2.1 – v3.1
  - User Notes on TIMES extensions
- All components of the TIMES documentation available for download at the ETSAP website:

www.iea-etsap.org