Sensitivity and Tradeoff analysis in TIMES

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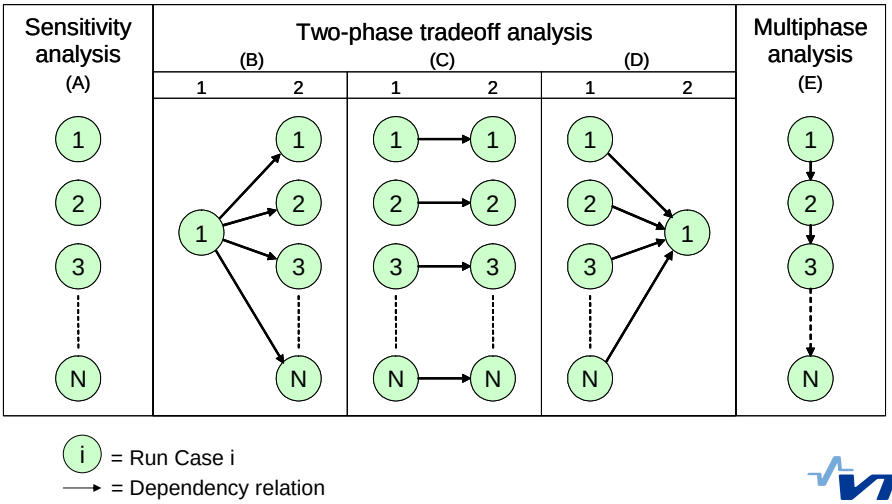
Sensitivity and Tradeoff Analyses

- **Simple sensitivity analysis:**
  - Several independent cases with variation in some parameter values
  - Can be performed by separate GAMS runs or by using the TIMES built-in sensitivity analysis facility
- **Tradeoff analysis:**
  - Two or more solution phases with user-defined objective functions in the initial phases
  - Several cases with both variation in some parameters and dependency of some bounds on the solution in previous phase (“deviation bounds” proportional to previous solution)

Possible set-ups for sensitivity or tradeoff analysis



Examples of sensitivity analysis (set-up A)

- **Constructing a marginal emission abatement cost curve, by either**
  - Running the model with a discrete set of different emission constraints, obtaining the marginal costs in each case; or
  - Running the model with a discrete set of assumptions on damage cost for the emissions, obtaining the resulting reduction levels.
- **Sensitivity analysis with a set of different resource potential estimates**

Examples of two-phase analysis (set-up B)

- **Tradeoffs between the standard objective and some auxiliary objective:**
  - First, optimize the problem with respect to a generic N row (Phase 1);
  - Then relax the optimal value of this auxiliary OBJ by n% and go back to the solution of an economic model by re-optimizing with the original objective function, i.e. total system costs or producer and consumer surplus (Phase 2);
  - By iterating over N discrete values of increasing n% one can build full tradeoff curves and calculate the supply (cost) curve of the public good reflected by row N.

Examples of two-phase analysis (set-up C)

- **Exploring the equivalence space of different objectives:**
  - First, set an upper bound on the standard cost objective (OBJZ) and, as in set-up B, optimize the problem with respect to a generic N row (Phase 1);
  - Then relax the optimal value of this auxiliary OBJ by n% and go back to the economic equilibrium by re-optimizing with the original objective function, i.e. the total discounted costs or surplus (Phase 2);
  - By iterating over N different rows, it is possible to explore the equivalence space of different public goods.

Examples of two-phase analysis (set-up D)

- **Analyzing the tradeoffs between the standard objective function and a set of simultaneous auxiliary objectives**
  - First, set an upper bound on the standard cost objective and optimize the problem separately with respect to a number of different generic N rows;
  - Finally, relax the optimal values of each of the auxiliary OBJ_i by n_i% and go back to the economic equilibrium by re-optimizing with the original objective function.
- **Caveat: In Phase 2 the model can easily become infeasible, if not sufficiently relaxed**

Uses of multiphase analyses (set-up E)

- **Enables making more complex multi-objective tradeoff analyses, combined with priorities**
  - Set-ups B and C can be represented as special cases of E
  - Deviation bounds can be defined to be persistent over all subsequent phases, or only in the next phase
- **Simple illustrative example:**
  - First, run the Baseline scenario with standard objective
  - Second, set deviation bounds on the costs for certain end-users or regions, and optimize with respect to policy objective
  - Finally, relax the auxiliary objective by n%, and re-optimize with the standard objective function

Facilities: The Case dimension

- **Built-in sensitivity and tradeoff analysis facilities are available under the stochastic mode only**
- **The Case dimension is provided by the stochastic scenario index (SOW)**
- **The uncertain attributes provide the tools for varying parameter values by Case**
- **The stochastic reporting attributes provide means of reporting the full results for each Case**
- **Run file settings for activating the facilities:**
  - $SET STAGES YES (standard, supports all set-ups)
  - $SET SENSIS YES (warm start between cases, set-ups A–C only)

Facilities: Uncertain attributes

- **Provides the tool for varying parameter values**
- **Currently available attributes:**
  - RHS of any User Constraints (all UC_RHSxxx parameters);
  - Demand projections (COM_PROJ)
  - Bounds on total installed capacity (CAP_BND)
  - Bounds on cumulative commodity total or net production (COM_CUMPRD, COM_CUMNET); e.g. for resources or emissions
  - Damage costs on commodity net production (DAM_COST)
  - Bounds on climate variables: concentrations, forcing, or temperature (CM_MAXC)
  - Climate sensitivity parameters (CS & SIGMA1)
- **Uncertain flavor of each attribute prefixed by ”S_”**

Facilities: User-defined objective functions

- **Provides a tool for analysing tradeoffs between objectives**
  - Can be used in Phase 1 of two-phase tradeoff analysis, and in all phases of multiphase analysis
- **Attribute for defining user objectives:**
  - S_UCOBJ(uc_n,sow) (uc_n = name of user constraint)
  - Can include names of any global user constraints (summed over regions and periods), representing their LHS expression
  - Can include the standard objective function (uc_n = 'OBJZ')
- **Non-constraining UCs can be defined:**
  - By specifying a negative RHS value of the 'N' bound type
  - Optional discounting of any flow-based UC component in objective function: UC_ATTR(reg,uc_n,side,*'PERDISC'*,uc_grptype)

Facilities: Deviation bounds

- **Bounds can be specified on the proportional deviation of model solution from that in previous phase**
- **Attributes for specifying deviation bounds:**
  - All RHS constant attributes for User Constraints (all UC_RHSxxx and S_UC_RHSxxx parameters)
  - Specified by supplying a non-negative value for the 'N' bound type
  - A negative 'N' bound indicates a non-constraining equation
- **Can be used for bounding any quantity that can be represented by LHS expressions of UC constraints**
- **Can be used for bounding pre-defined 'system' UCs:**
  - OBJZ (standard objective function: global and by region)
  - OBJ1 (user-defined objective function: global)

Other New Features in TIMES Versions 2.2 – 2.5

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Regional bounds on cost components

- **New attributes for bounding regional costs**
  - Investment costs, taxes, subsidies
  - Fixed costs, taxes, subsidies
  - Commodity costs, taxes, subsidies
  - Flow taxes and subsidies
  - Any combination of the above components
- **Bounds can be set on both:**
  - Annual costs in individual years; and
  - Cumulative annual costs during a range of years
- **New attributes:**
  - REG_BNDCST(r,y,item,cur,bd) – bound on individual year
  - REG_CUMCST(r,y1,y2,item,cur,bd) – cumulative bound

Annualized investment costs in user constraints

- **Bounds on investment costs often useful for selected technologies in one or several regions**
- **User constraints can be conveniently used for defining any groups of technologies**
- **New UC_ATTR modifiers available for UC_NCAP:**
  - INVCOST – annualized investment cost payments
  - INVTAX – annualized investment tax payments
  - INVSUB – annualized investment subsidies
- **Several UC_ATTR modifiers can be combined**
- **If all technologies in a single region are included, the constraint is equivalent to using REG_BNDCST**

Shaping of demand elasticities

- **Demand elasticities are by default constant over elastic changes in the demand level (= base elasticity)**
- **New attribute COM_ELASTX for shaping of elasticities:**
  - COM_ELASTX(r,y,com,bd) – shape index for demand of com in year y, in the upper or lower direction (bd = up/lo)
  - The actual shape curve is defined in the SHAPE table
- **SHAPE(j,pc) – shape curve with index j**
  - The level of the elasticity in relation to the base value (1=base level) at a demand change of **pc** percent
  - Fully interpolated over pc points specified by the user
- **An easy and accurate tool for defining elasticities as a function of the proportional shift in demand**

Stochastic TIMES – New attributes

- **Some new uncertain attributes (prefixed by "S_"):**
  - RHS of any User Constraints (all UC_RHSxxx parameters) *NEW*
  - Demand projections (COM_PROJ)
  - Bounds on total installed capacity (CAP_BND)
  - Bounds on cumulative commodity total or net production (COM_CUMPRD, COM_CUMNET); useful for constraining resource use or emissions
  - Damage costs on commodity net production (DAM_COST) *NEW*
  - Bounds on climate variables: concentrations, forcing, or temperature (CM_MAXC)
  - Climate sensitivity parameters (CM_CONST(CS / SIGMA1))
- **UC_RHS bounds can now also be specified on the standard objective function (total and by region)**

Climate Module – Recent Enhancements

- **Endogenized forcing/temperature equations**
  - Endogenous forcing/temperature variables
  - Linearized forcing equations: time-dependent linear functions
  - Enables defining limits for temperature change
- **Uncertain climate sensitivity**
  - Available under stochastic mode
  - Very useful for analysing hedging strategies
- **Using climate variables in user constraints**
  - New attribute: UC_CLI(uc_n,side,reg,y,item), item=clim.var.
  - Can be used for incorporating climate feedbacks
- **Option for separate modeling of non-CO_2 concentrations and forcing**

GAMS Savepoint / Loadpoint support in TIMES

- **GAMS Savepoint / Loadpoint facility enables the use of so-called warm start to speed-up model solution**
- **New TIMES control variables (run file):**
  - $SET SPOINT 1 – save solution point file
  - $SET SPOINT 2 – load %run_name%_p.gdx
  - $SET SPOINT 3 – save and load %run_name%_p.gdx
  - $SET LPOINT loadname – load %LPOINT%_p.gdx
- **Can considerably speed up successive solution of models with small differences**
- **Provides a tool for more efficient sensitivity analysis when the uncertain attributes are not sufficient**

Summary

- **Many features for enhancing sensitivity and tradeoff analyses introduced in 2007**
- **Flexible cost bounding attributes introduced**
- **Various climate feedbacks can now be incorporated by using user constraints**
- **Definition of non-constraining equations now possible with UC constraints, both for tradeoff analysis and reporting purposes**
- **Many other small improvements in the code**

Ú **TIMES Version 2.5 now available**