

TIMES Simplified Dynamic Growth/Decay Constraints in ANSWER-TIMES

Introduction

The purpose of this note is to describe how to specify TIMES Simplified Dynamic Growth/Decay Constraints in ANSWER-TIMES.

TIMES (and ANSWER-TIMES) already supported the specification of Dynamic Growth or Decay Constraints prior to the development of the TIMES **Simplified** Dynamic Growth/Decay Constraint facility. However the **Simplified** facility greatly simplifies the specification of Dynamic Growth/Decay Constraints for Processes involving the ACT, CAP and NCAP variables:

- Whereas previously a separate User Constraint Name had to be specified for each instance of a Dynamic Growth/Decay Constraint, with the **Simplified** facility a single User Constraint Name may be specified and then a number of (similar) Dynamic Growth/Decay Constraints for Processes specified for that User Constraint Name.
- With the **Simplified** facility, the bulk specification of Dynamic Growth/Decay Constraints for a large number of Processes can be facilitated by the use of the Process Filter and Rule-based Constraint facilities.
- With the **Simplified** facility, there is the further simplification that just UC_ACT or UC_CAP or UC_NCAP Data Parameters need to be specified (in general using both Side=LHS and Side=RHS) and that no UC_RHSxxx Data Parameter needs to be specified.

For a brief explanation of some aspects of TIMES Simplified Dynamic Growth/Decay Constraints, see section 9.3 of TIMES Version 3.1 User Note "New Features in TIMES v2.1–v3.1" (author Antti Lehtila), which can be downloaded from the ETSAP website as *TIMES-New-Features.pdf*.

For concrete examples demonstrating TIMES Simplified Dynamic Growth/Decay Constraints, see the non-BASE scenarios **SDYNGRO1**, **SDYNGRO2** and the online Cases **SDYNGRO1**, **SDYNGRO2** in database Example4-v668.mdb (distributed with ANSWER-TIMES version 6.6.8 and higher).

Specification of Simplified Dynamic Growth/Decay Constraints in ANSWER-TIMES

To handle Simplified Dynamic Growth/Decay Constraints in ANSWER-TIMES:

- a new User-Defined Constraint type has been created, and
- a new TID Parameter UC_DYNBND has been introduced.

How this new Constraint type and new Parameter are used in the specification of Simplified Dynamic Growth/Decay Constraints will be made clear in the following examples.

An Example of a Dynamic Growth Constraint

Suppose that for Process RHE in region REG, you wish to specify that capacity in each time period is restricted to have at most 5% annual growth as compared with capacity in the previous time period, but with additional annual absolute growth in capacity of 0.2 allowed.

Mathematically, the above constraint restricting capacity in time period 2000 as compared with capacity in time period 1990 can be expressed as follows:

$$\text{VAR_CAP}(\text{REG},2000,\text{RHE}) \leq (1.05)^{10} * \text{VAR_CAP}(\text{REG},1990,\text{RHE}) + (0.2) * 10$$

Or, rearranging so that the term involving VAR_CAP(REG,1990,RHE) appears on the LHS:

$$-(1.05)^{10} * \text{VAR_CAP}(\text{REG},1990,\text{RHE}) + \text{VAR_CAP}(\text{REG},2000,\text{RHE}) \leq (0.2) * 10 \quad (1)$$

This rearrangement has the advantage of displaying on the RHS just the constant term indicating that additional annual absolute growth in capacity of 0.2 is allowed.

Similarly, the constraint restricting capacity in time period 2010 as compared with capacity in time period 2000 can be expressed as follows:

$$-(1.05)^{10} * \text{VAR_CAP}(\text{REG},2000,\text{RHE}) + \text{VAR_CAP}(\text{REG},2010,\text{RHE}) \leq (0.2) * 10 \quad (2)$$

etc.

How the ANSWER-TIMES Constraint Tab appears when the above Dynamic Growth Constraint has been specified

Before detailing the steps that are needed to create the above dynamic growth constraint using the **Simplified** facility, it is useful to see the end result of carrying out these steps on the Constraint tab, and note how they tie in with the mathematics above.

Suppose that we are specifying the simplified dynamic growth constraint in non-BASE scenario SDYNGRO1 with constraint name GROWTH_RH. Then after carrying out the steps that will be detailed below, the Constraint tab will appear as follows:

The screenshot shows the 'Constraint' tab in the ANSWER-TIMES software. The 'Items Filter' is set to '*All User-Defined Constraints (UC_N)'. The main table lists two constraints:

Name	Region	Description	Status
GROWTH_RH	_GLOBAL	Simplified Dynamic Growth Cons...	SM
GROWTH_RH	REG	Simplified Dynamic Growth Cons...	SM

Below this is the 'Subset Parameters' table:

Scenario	Parameter	Region	Constraint	Side	Process	Time	I/E	1990	2000	2010	2015	
M	SDYNGRO1	UC_CAP	REG	GROWTH_RH	LHS	RHE	-	0	1.0500	1.0500	1.0500	1.0
M	SDYNGRO1	UC_CAP	REG	GROWTH_RH	RHS	RHE	-	0		0.2000	0.2000	0.2
Add	SDYNGRO1											

At the bottom, there is a table for limits:

Scenario	Parameter	Region	Constraint	Limit	Value	
M	SDYNGRO1	UC_DYNBND	_GLOBAL	GROWTH_RH	UP	1
Add	SDYNGRO1	UC_DYNBND	_GLOBE	GROWTH_RH		1

The following points should be noted:

- ANSWER-TIMES requires that a simplified dynamic growth constraint with the name GROWTH_RH be specified in the special _GLOBAL region, as well as in region REG. When this constraint is created in the _GLOBAL region, ANSWER-TIMES automatically

creates an instance of the TID Parameter UC_DYNBND, with the user needing to set Limit = UP. The **UP** setting corresponds to the \leq in equations (1) and (2) above.

- In the UC_CAP row with Side = LHS, the coefficient of **1.05** in the **1990** column corresponds to the $-(1.05)^{10} * VAR_CAP(REG,1990,RHE)$ term in equation (1) above.
- In the UC_CAP row with Side = RHS, the coefficient of **0.2** in the **2000** column corresponds to the RHS term $(0.2) * 10$ in equation (1) above.
- The fact that VAR_CAP(REG,2000,RHE) has coefficient of 1 in equation (1) above is implicitly assumed by the TIMES model generator and does not require any user input.

Details of Steps Needed to specify the above Dynamic Growth Constraint in ANSWER-TIMES

The following steps are needed to specify the above dynamic growth constraint using the **Simplified** facility:

- Create a new Constraint named GROWTH_RH in the _GLOBAL region with Constraint type **Simplified Dynamic Growth/Decay (UCRTP)** (by clicking on the **[New...]** button in the Item Management frame, filling in the New User Constraint form as below, and clicking on the **[OK]** button):

The screenshot shows the 'New User-Defined Constraint' dialog box. The title bar reads 'New User-Defined Constraint in scenario SYNDGR01'. Below the title bar, there is a small icon of a document and a paragraph of instructions: 'Enter Name and Description for the new User-Defined Constraint. Check the Region combobox setting. Specify Set Memberships, and change Units if necessary. Optionally enter Comment. After clicking OK, specify parameter data as appropriate.' The dialog is divided into several sections. The 'Item Information' section has a 'Scenario' dropdown set to 'SYNDGR01' and a 'Name, Desc' field with 'GROWTH_RH', '_GLOBAL', and 'Simplified Dynamic Growth Constraint'. Below this are two tabs: 'Set Memberships and Units' and 'Comment'. The 'Set Memberships and Units' tab is active, showing a tree view of constraint types. 'Simplified Dynamic Growth/Decay (UCRTP)' is selected and highlighted. To the right of the tree is an 'Additional Characterization' section with a checkbox for 'Rule-based (UCRULE)'. At the bottom of the dialog, there is a 'Units' field set to 'unit of user-defined constraint' and a 'Change Units' button. The dialog ends with 'OK' and 'Cancel' buttons.

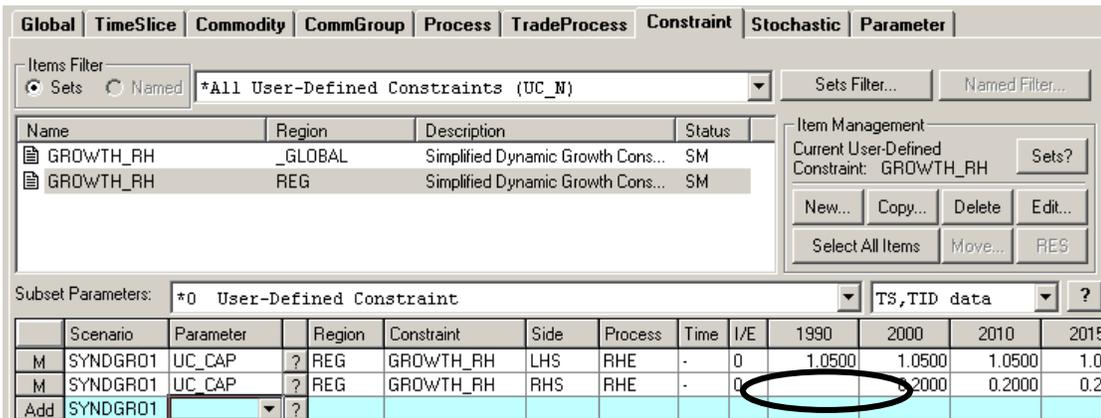
- In the TID Data spread, ANSWER-TIMES automatically creates an instance of the TID Parameter UC_DYNBND, initially with Limit = -none-, where -none- is a placeholder:

	Scenario	Parameter		Region	Constraint	Limit	Value
M?	SYNDGR01	UC_DYNBND	?	_GLOBAL	GROWTH_RH	-none-	1
Add	SYNDGR01	UC_DYNBND	?	_GLOBAL	GROWTH_RH		1

- Change the -none- placeholder to UP (by left-clicking on the cell containing -none- and selecting UP) so that the TID Data spread appears as follows:

	Scenario	Parameter		Region	Constraint	Limit	Value
M	SYNDGR01	UC_DYNBND	?	_GLOBAL	GROWTH_RH	UP	1
Add	SYNDGR01	UC_DYNBND	?	_GLOBAL	GROWTH_RH		1

- Create a new Constraint named GROWTH_RH in region REG, with Constraint type  **Simplified Dynamic Growth/Decay (UCRTP)** (by clicking on the **[New...]** button in the Item Management frame, filling in the New User Constraint form similarly to above but specifying region REG, and clicking on the **[OK]** button).
- Use the AddRow facility in the TS Data spread to create a UC_CAP parameter instance with Side = LHS for process RHE and with numeric coefficients of 1.05 in time periods 1990, 2000, 2010, Then use the AddRow facility in the TS Data spread to create a UC_CAP parameter instance with Side = RHS for process RHE and with numeric coefficients of 0.2 in time periods 2000, 2010, ... so that the TS Data spread for GROWTH_RH in region REG appears as follows:



The screenshot shows the 'Constraint' tab in the software interface. The 'Items Filter' is set to '*All User-Defined Constraints (UC_N)'. The 'Item Management' section shows the current user-defined constraint as 'GROWTH_RH'. Below this, the 'Subset Parameters' section shows a table with columns for Scenario, Parameter, Region, Constraint, Side, Process, Time, I/E, and years 1990, 2000, 2010, 2015. The table contains two rows for 'UC_CAP' in region 'REG' for process 'RHE'. The first row has Side 'LHS' and coefficients of 1.0500 for years 1990, 2000, 2010, and 2015. The second row has Side 'RHS' and coefficients of 0.2000 for years 2000, 2010, and 2015. The cell for the 1990 coefficient in the RHS row is circled in red.

Scenario	Parameter	Region	Constraint	Side	Process	Time	I/E	1990	2000	2010	2015
M	SYNDGR01	REG	GROWTH_RH	LHS	RHE	-	0	1.0500	1.0500	1.0500	1.0
M	SYNDGR01	REG	GROWTH_RH	RHS	RHE	-	0		0.2000	0.2000	0.2
Add	SYNDGR01										

Note: No coefficient should be specified in time period 1990 for the UC_CAP parameter instance with Side = RHS.

- If constraint GROWTH_RH is selected for both the _GLOBAL region and for region REG, the TS and TID Data spreads appear as follows:

Global TimeSlice Commodity CommGroup Process TradeProcess Constraint Stochastic Parameter

Items Filter: Sets Named *All User-Defined Constraints (UC_N)

Name	Region	Description	Status
GROWTH_RH	_GLOBAL	Simplified Dynamic Growth Cons...	SM
GROWTH_RH	REG	Simplified Dynamic Growth Cons...	SM

Item Management: All 2 items selected

Subset Parameters: User-Defined Constraint TS, TID data

	Scenario	Parameter	Region	Constraint	Side	Process	Time	I/E	1990	2000	2010	2015
M	SDYNGR01	UC_CAP	? REG	GROWTH_RH	LHS	RHE	-	0	1.0500	1.0500	1.0500	1.0
M	SDYNGR01	UC_CAP	? REG	GROWTH_RH	RHS	RHE	-	0		0.2000	0.2000	0.2
Add	SDYNGR01		?									

	Scenario	Parameter	Region	Constraint	Limit	Value
M	SDYNGR01	UC_DYNBND	? _GLOBAL	GROWTH_RH	UP	1
Add	SDYNGR01	UC_DYNBND	? _GLOBAL	GROWTH_RH		1

- If when you carry out Run Model (being sure to have 1990, 2000, 2010, ... as your milestone years) you run with `OPTION LIMROW=999` in the *.GEN file for the model run, and then search the Equation Listing in the resulting GAMS *.LST file for `EQN_UCRTP`, you will be able to verify that the equations that are generated are what would be expected, the first 2 instances of which are shown below, corresponding to equations (1) and (2) above:

```
---- EQN_UCRTP =L=
```

```
EQN_UCRTP(GROWTH_RH,REG,2000,RHE,CAP,UP)..
```

```
- 1.62889462677744*VAR_CAP(REG,1990,RHE) + VAR_CAP(REG,2000,RHE) =L= 2;
```

```
EQN_UCRTP(GROWTH_RH,REG,2010,RHE,CAP,UP)..
```

```
- 1.62889462677744*VAR_CAP(REG,2000,RHE) + VAR_CAP(REG,2010,RHE) =L= 2;
```

(Note that $(1.05)^{10} = 1.62889462677744$ and of course $(0.2) * 10 = 2$.)

- A strength of the **Simplified** facility is that if you wish to specify similar dynamic growth constraints for other Processes, it is **not** necessary to create new Constraints with Constraint type **Simplified Dynamic Growth/Decay (UCRTP)**. All that is needed is to use the AddRow facility in the TS Data spread to create additional UC_CAP parameter instances for each of the other Processes for which you wish to specify a dynamic growth constraint. So for example, you could specify pairs of UC_CAP parameter instances for Processes RHG, RHH, RHO that are similar to the pair of such instances specified above for Process RHE, so that the TS Data spread appears as follows:

Items Filter: Sets Named *All User-Defined Constraints (UC_N)

Name	Region	Description	Status
GROWTH_RH	_GLOBAL	Simplified Dynamic Growth Cons...	SM
GROWTH_RH	REG	Simplified Dynamic Growth Cons...	SM

Item Management
Current User-Defined Constraint: GROWTH_RH

Subset Parameters: *0 User-Defined Constraint

Scenario	Parameter	Region	Constraint	Side	Process	Time	I/E	1990	2000	2010	2015
M	SDYNGR01 UC_CAP	REG	GROWTH_RH	LHS	RHE	-	0	1.0500	1.0500	1.0500	1.0
M	SDYNGR01 UC_CAP	REG	GROWTH_RH	LHS	RHG	-	0	1.0500	1.0500	1.0500	1.0
M	SDYNGR01 UC_CAP	REG	GROWTH_RH	LHS	RHH	-	0	1.0500	1.0500	1.0500	1.0
M	SDYNGR01 UC_CAP	REG	GROWTH_RH	LHS	RHO	-	0	1.0500	1.0500	1.0500	1.0
M	SDYNGR01 UC_CAP	REG	GROWTH_RH	RHS	RHE	-	0		0.2000	0.2000	0.2
M	SDYNGR01 UC_CAP	REG	GROWTH_RH	RHS	RHG	-	0		0.2000	0.2000	0.2
M	SDYNGR01 UC_CAP	REG	GROWTH_RH	RHS	RHH	-	0		0.2000	0.2000	0.2
M	SDYNGR01 UC_CAP	REG	GROWTH_RH	RHS	RHO	-	0		0.2000	0.2000	0.2
Add	SDYNGR01										

The above screen snapshot reflects that for each of the Processes RHG, RHH, RHO the same restrictions apply as for Process RHE: growth in capacity in each time period can be at most 5% annual growth (as compared with capacity in the previous time period), and additional annual absolute growth in capacity of 0.2 is allowed. Of course it is perfectly OK to specify different % annual growth coefficients and different annual absolute growth coefficients for each Process.

Using the Simplified Dynamic Growth/Decay Constraint facility in conjunction with the Process Filter and Rule-based Constraint facilities

Where the same annual growth coefficients and same annual absolute growth coefficients do apply for each Process (as is depicted above), the **Simplified** facility – in conjunction with the Process Filter and Rule-based Constraint facilities – allows an even simpler specification than that depicted above to be used.

- On the Process tab, create a Process Filter ALL_RH_PROC that selects each of the desired Processes (RHE, RHG, RHH, RHO). For example such a Process Filter might be as simple as one that selects all Processes that are DMDs whose Name begins with RH.

Edit Process Items Filter

Edit Name or Description or Comment, or optionally modify Filter for Process Items Filter
ALL_RH_PROC: All DMD Processes whose Name begins with RH.

Name: ALL_RH_PROC Description: All DMD Processes whose Name begins with RH

Comment:

Processes to be Included:

	Process Name	Process Desc	Process Sets	Input Comm Na	Input Comm De	Input Comm Sel	Output Comm N	Output Comm D	Output Comm S
Look for:	Like "RH"		DMD						
or:									
or:									

Return to the Constraint tab.

- Create a new **rule-based** Constraint named GROWTH_RH2 in the _GLOBAL region with Constraint type **Simplified Dynamic Growth/Decay (UCRTP)** by ensuring that the Rule-based (UCRULE) checkbox in the Additional Characterization frame is checked.
- In the TID Data spread, change the -none- placeholder to UP in the UC_DYNBND Parameter instance that ANSWER-TIMES automatically creates.
- Create a new **rule-based** Constraint named GROWTH_RH2 in region REG with Constraint type **Simplified Dynamic Growth/Decay (UCRTP)** by ensuring that the Rule-based (UCRULE) checkbox in the Additional Characterization frame is checked.
- Use the AddRow facility in the TS Data spread to create a **UCRULE_CAP** parameter instance with Side = LHS for **Process Filter** ALL_RH_PROC and with numeric coefficients of 1.05 in time periods 1990, 2000, 2010, Then use the AddRow facility in the TS Data spread to create a **UCRULE_CAP** parameter instance with Side = RHS for **Process Filter** ALL_RH_PROC and with numeric coefficients of 0.2 in time periods 2000, 2010, ...
- If constraint GROWTH_RH2 is selected for both the _GLOBAL region and for region REG, the TS and TID Data spreads appear as follows:

The screenshot shows the 'Constraint' tab in a software application. The 'Items Filter' section shows '*All User-Defined Constraints (UC_N)'. The main table lists two constraints: 'GROWTH_RH2' for '_GLOBAL' and 'GROWTH_RH2' for 'REG', both with the description 'Simplified Dynamic Growth Cons...' and status 'SM'. The 'Subset Parameters' section shows a table with columns: Scenario, Parameter, Region, Constraint, Side, Proc/Filter, TimeS, I/E, 1990, 2000, 2010, 2010. The first two rows are for 'UCRULE_CAP' with 'LHS' and 'RHS' sides, both linked to 'GROWTH_RH2' and 'ALL_RH_PROC'. The first row has coefficients of 1.0500 for 1990, 2000, and 2010. The second row has coefficients of 0.2000 for 2000 and 2010. Below this is another table with columns: Scenario, Parameter, Region, Constraint, Limit, Value. The first row is for 'UC_DYNBND' in the '_GLOBAL' region, linked to 'GROWTH_RH2', with a limit of 'UP' and a value of 1. The second row is for 'UC_DYNBND' in the 'GLOB' region, linked to 'GROWTH_RH2', with a limit of 'UP' and a value of 1.

The compactness of the specification that is possible when using the Simplified Dynamic Growth/Decay Constraint facility in conjunction with the Process Filter and Rule-based Constraint facilities is evident!