TIMES Stochastic Programming Extension in ANSWER-TIMES (Revised August 2012)

Acknowledgement

Antti Lehtila of VTT Finland has been generous in providing assistance to clarify various technical points related to the TIMES Stochastic Programming Extension.

Introduction

The purpose of this note is to describe how to invoke the TIMES Stochastic Programming Extension in ANSWER-TIMES.

For more details regarding the TIMES Stochastic Programming Extension see:

- TIMES Version 2.5 User Note "Stochastic Programming and Tradeoff Analysis in TIMES" (authors Richard Loulou and Antti Lehtila) which can be downloaded from the ETSAP website as *TIMES-Stochastic.pdf*.

For a concrete example demonstrating the TIMES Stochastic Programming Extension, see the non-BASE scenario **STOCH5STG** and the online Case **STOCH5STG-001** in database Example4-v678.mdb (distributed with ANSWER-TIMES version 6.7.8 and higher).

- The stochastic example contained in non-BASE scenario **STOCH5STG** has the same event tree as the five-stage stochastic model specified in section 5.5 of *TIMES-Stochastic.pdf*, but uses parameter S_COM_CUMNET to specify cumulative bounds on emissions of CO_2 from 2010 to 2080 in stage 2 for sub-states 1,2, 3, rather than using mitigation parameter S_CM_MAXCO2C.

Specification of Stochastic Items in ANSWER-TIMES – new Stochastic Tab

Before Stochastic Data Parameters can be specified in ANSWER-TIMES, it is necessary to specify Stochastic Items to define the event tree that is being modelled. Stochastic Items are specified on the <u>new</u> **Stochastic** tab (between the **Constraint** tab and the **Parameter** tab).

- For the demonstration database Example4- v678.mdb, if you make the non-BASE scenario **STOC5STG** the editable scenario and move to the Stochastic tab, you will see displayed all of the Stochastic Items that are needed in ANSWER-TIMES to specify the section 5.5 *TIMES-Stochastic.pdf* five-stage stochastic model:
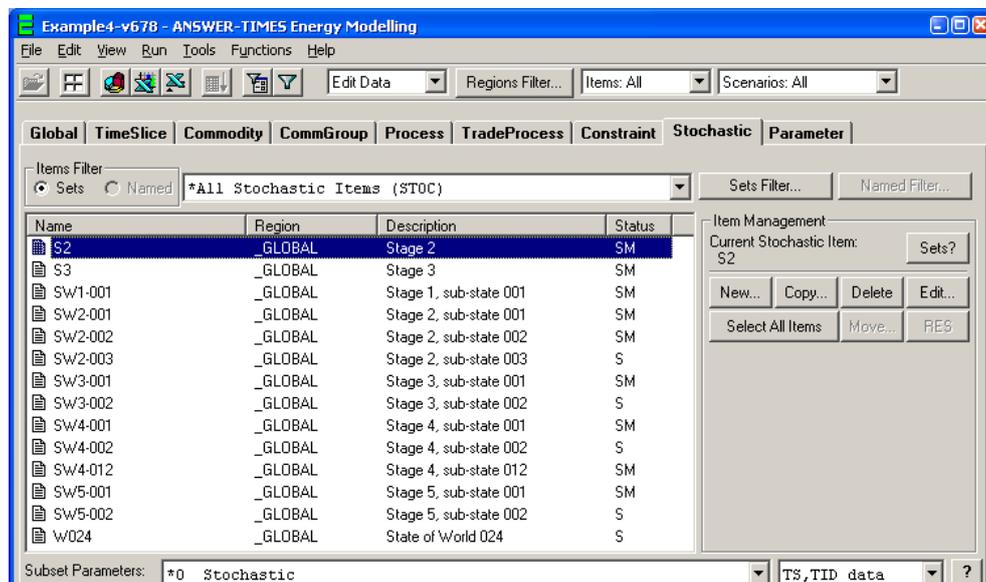
These Stochastic Items were created one at a time in the non-BASE scenario **STOC5STG** by use of the New... button (or where more convenient the Copy... button) in the Item Management frame.

Some General Points re Stochastic Items in ANSWER-TIMES

In most ways the operation of the top half of the Data Screen on the **Stochastic** tab is exactly similar to the operation on most other tabs. Note that in ANSWER-TIMES there are 3 different subsets of Stochastic Items, as can be seen by clicking on the New... button:
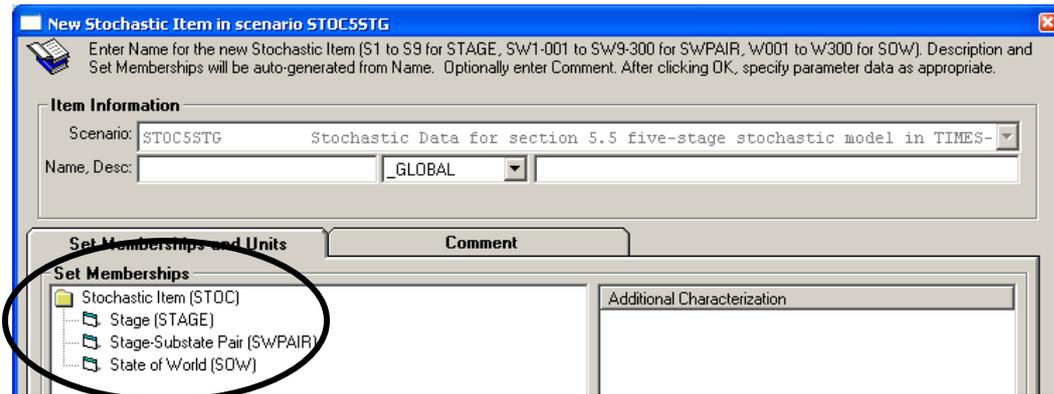
and for each of these subsets the Stochastic Items have tightly controlled Naming conventions:

- The **Stage** subset is used to specify members j corresponding to what is described as "stochastic stage j" in *TIMES-Stochastic.pdf*. In ANSWER-TIMES, these members must have Names taken from among S1, S2, S3, …, S9. (Their auto-generated Descriptions will be Stage 1, Stage 2, Stage 3, …, Stage 9 respectively.)

- The **Stage-Substate Pair** subset is used to specify members (j,w) that are pairs corresponding to what is described as "sub-state w at stage j" in *TIMES-Stochastic.pdf*. In ANSWER-TIMES, these members must have Names taken from among:

  SW1-001,
  SW2-001, SW2-002, …, SW2-300,
  SW3-001, SW3-002, …, SW3-300,
  …
  SW9-001, SW9-002, …, SW9-300

  Thus SW3-002 specifies pair (j=3,w=2) corresponding to "sub-state w=2 at stage j=3"; its auto-generated Description will be Stage 3, sub-state 002.

- The **State of World** subset is used to specify members w corresponding to what is described as "final states SOW" in *TIMES-Stochastic.pdf*. In ANSWER-TIMES, these members must have Names taken from among W001, W002, W003, …, W300. (Their auto-generated Descriptions will be State of World 001, State of World 002, State of World 003, …, State of World 300 respectively.)

  Note: *In ANSWER-TIMES, it is necessary to define the State of World Item that corresponds to the largest SOW in the event tree*, even where no State of World Items are needed to define Stochastic Data Parameters. So for example in non-BASE scenario **STOC5STG**, the State of World Item W024 must be defined, corresponding to the largest SOW W024 in the event tree for the section 5.5

TIMES-Stochastic.pdf five-stage stochastic model. (Note that W024 is the bottom Stochastic Item in the screen snapshot at the bottom of page.)

The New/Copy/Edit Item facilities on the **Stochastic** tab ensure that the Names for Stochastic Items satisfy the above rules, and auto-generate appropriate corresponding Descriptions.

- The user simply has to enter a valid Stochastic Item Name in the Name textbox, and then ANSWER auto-generates the Description and also selects the appropriate Set Memberships. So for example if the user enters Name of SW4-001, ANSWER auto-generates Description "Stage 4, sub-state 001" and also selects Set Memberships of "Stage-Substate Pair (SWPAIR)".

- **Note also that in ANSWER-TIMES, Stochastic Items may only be defined in the special _GLOBAL region.**

Once Stochastic Items have been specified, Stochastic Data parameters may be specified.

Specification of Stochastic Data Parameters in ANSWER-TIMES

The TIMES Stochastic Programming Extension involves 20 Data Parameters, as follows:

Stochastic Programming Data Parameter	Description
S_CAP_BND	Bound on total installed capacity in a period - stochastic
S_CM_CONST	Climate module constants - stochastic
S_CM_MAXC	Maximum level of climate variable - stochastic
S_COM_CUMNET	Cumulative net bound on commodity (e.g. emissions) - stochastic
S_COM_CUMPRD	Cumulative limit on production of a commodity - stochastic
S_COM_PROJ	Multiplier for demand baseline projection - stochastic
S_DAM_COST	Marginal damage cost of emissions - stochastic
S_FLO_CUM	Cumulative limit on flow - stochastic
S_UC_RHS	RHS and type of user constraint - stochastic
S_UC_RHSR	RHS and type of user constraint by Region - stochastic
S_UC_RHSRT	RHS and type of user constraint by Region, Period - stochastic
S_UC_RHSRTS	RHS and type of user constraint by Region, Period, TimeSlice - stochastic
S_UC_RHST	RHS and type of user constraint by Period - stochastic
S_UC_RHSTS	RHS and type of user constraint by Period, TimeSlice - stochastic
S_UCOBJ	Weight of UC objective component in tradeoff analysis
SW_LAMBDA	Risk aversion coefficient - stochastic
SW_PROB	Total probability of stochastic scenario (2-stage stochastics)
SW_SPROB	Conditional probability of sub-state w at stage j, given its parents state
SW_START	Start year of stochastic stage j
SW_SUBS	Number of sub-states of the world for state w at stage j

Two of the above Stochastic Data parameters (S_CM_CONST and S_CM_MAXC) are Climate Data Parameters.

Stochastic Data Parameters may be specified on either the Stochastic tab, or on the Parameter tab.

<u>Stochastic Tab</u>
Using the bottom half of the Data Screen on the **Stochastic** tab to specify Stochastic Data Parameters (using the AddRow in either the TS and TID data spreads) is exactly similar to the operation on most other tabs – in nearly all ways.

There is just one small exception that the alert user may wonder about and that is illustrated in the following screen snapshot showing the Stochastic data parameters that are associated with the selected Stochastic Item SW4-001:

The display of Stochastic data parameter S_COM_PROJ whose region argument REG *differs* from the region _GLOBAL of selected Item SW4-001 in the Stochastic Items listview is the small exception. (On most other ANSWER tabs, only TS and TID data parameters whose region argument is the *same* as the region of the selected Item in the Items listview will be displayed.)

- As a matter of convenience Stochastic data parameters that have a region argument (such as S_COM_PROJ) *are* displayed on the Stochastic tab when their associated Stochastic Item is selected in the Items listview.

- In addition the operation of the AddRow for TS and TID data spreads is modified so that the AddRow Region combobox is populated with regions for Stochastic data parameters that have a region argument, and with just _GLOBAL for Stochastic data parameters that are "regionless" (do not have a region argument).

- Also when a Stochastic Item that has associated Stochastic data parameters with a region argument (such as S_COM_PROJ) is *copied*, the standard ANSWER Copy Item process is extended so that the Stochastic Item created by Copy Item also has the same associated Stochastic data parameters with a region argument.

- Finally when a Stochastic Item that has associated Stochastic data parameters with a region argument (such as S_COM_PROJ) is *deleted*, the standard ANSWER Delete Item process is extended so that the Stochastic data parameters with a region argument associated with this Stochastic Item are deleted.

<u>Parameter Tab</u>
The Parameter tab offers the convenience of being able to see all instances of Stochastic Data Parameters in the database (for the currently selected scenarios) and also provides a convenient way of adding these parameters for multiple Stochastic Items. On the Parameter tab, drop down the long combobox, and select the Stochastic Data Parameters setting:
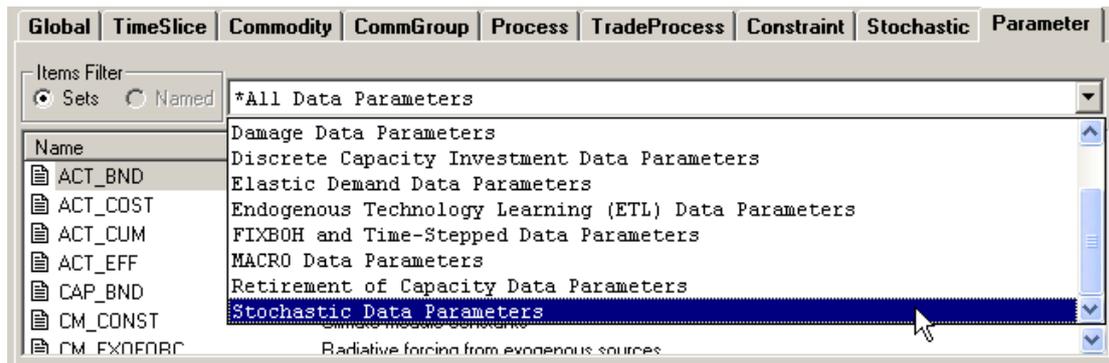
This provides the convenience of displaying just those Data Parameters that are specific to the TIMES Stochastic Extension:
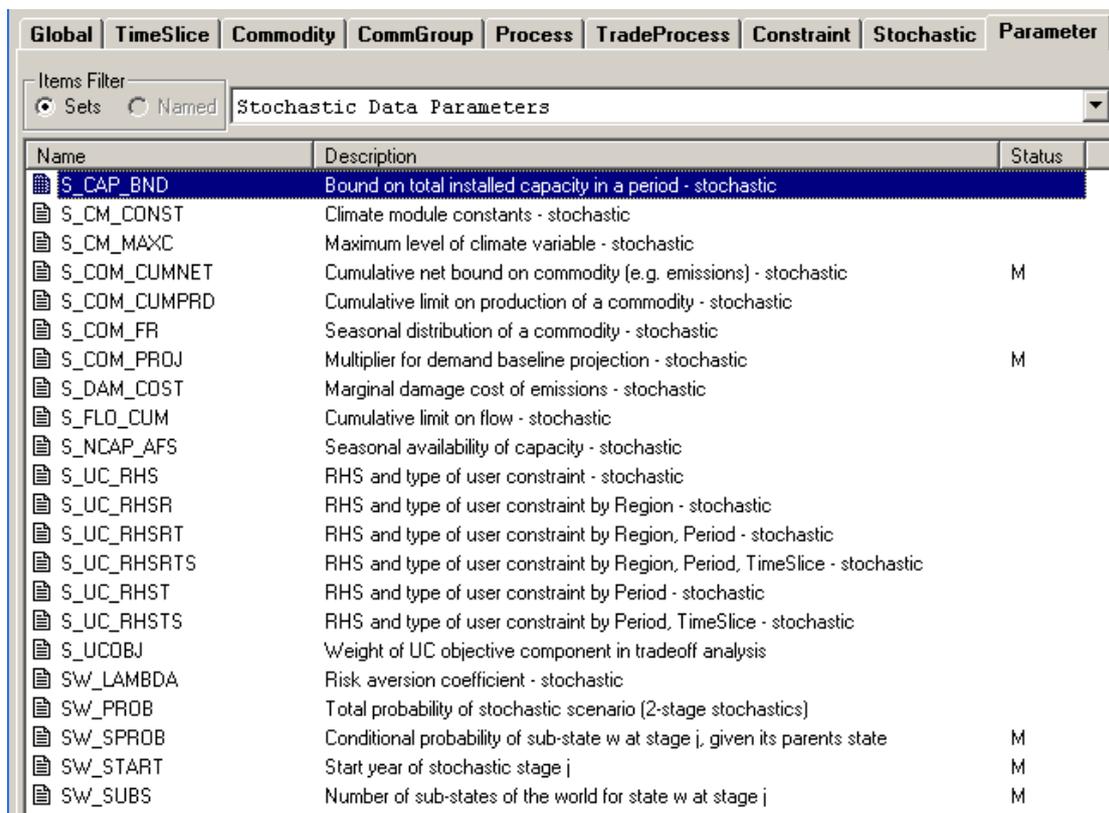
(To obtain the above display showing all Stochastic Parameters, the Parameter Items listview was selected and the right-mouse click menu option "Toggle Size" used.)

Use the AddRow facility to specify Stochastic Data Parameter instances as needed.

- For non-BASE scenario **STOC5STG** as the editable scenario, if you move to the Parameter tab, select the Stochastic Data Parameters setting and click on the

  Select All Items button, you will see displayed all of the Stochastic Data Parameter instances that are needed in ANSWER-TIMES to specify the (slightly modified) section 5.5 *TIMES-Stochastic.pdf* five-stage stochastic model. Here are the TS Stochastic Data Parameter instances:

	Scenario	Parameter		Region	Item1	Item2	TimeSlic	Item5	Stochastic	I/E	1990	2000	2010	2015	2020	2035	2050	2065	2080
M	STOC5STG	S_COM_PROJ	?	REG	-	TX	-	-	SW3-001	0				1.0700					
M	STOC5STG	S_COM_PROJ	?	REG	-	TX	-	-	SW3-002	0				0.9600					
M	STOC5STG	S_COM_PROJ	?	REG	-	TX	-	-	SW4-001	0				1.0500					
M	STOC5STG	S_COM_PROJ	?	REG	-	TX	-	-	SW4-002	0				0.9500					
M	STOC5STG	S_COM_PROJ	?	REG	-	TX	-	-	SW5-001	0				1.0400					
M	STOC5STG	S_COM_PROJ	?	REG	-	TX	-	-	SW5-002	0				0.9300					
Add	STOC5STG		▼	?															

TS data

and here are the TID Stochastic Data Parameter instances:

TID data

	Scenario	Parameter		Region	Item1	Com	Item3	Year	Limit	Stochastic	Value
M	STOC5STG	S_COM_CUMNET	?	REG	-	CO2	2010	2080	UP	SW2-001	550,000.0000
M	STOC5STG	S_COM_CUMNET	?	REG	-	CO2	2010	2080	UP	SW2-002	500,000.0000
M	STOC5STG	S_COM_CUMNET	?	REG	-	CO2	2010	2080	UP	SW2-003	450,000.0000
M	STOC5STG	SW_SPROB	?	_GLOBAL	-	-	-	-	-	SW2-001	0.3300
M	STOC5STG	SW_SPROB	?	_GLOBAL	-	-	-	-	-	SW2-002	0.3400
M	STOC5STG	SW_SPROB	?	_GLOBAL	-	-	-	-	-	SW3-001	0.6000
M	STOC5STG	SW_SPROB	?	_GLOBAL	-	-	-	-	-	SW4-001	0.5500
M	STOC5STG	SW_SPROB	?	_GLOBAL	-	-	-	-	-	SW4-012	0.7000
M	STOC5STG	SW_SPROB	?	_GLOBAL	-	-	-	-	-	SW5-001	0.5000
M	STOC5STG	SW_START	?	_GLOBAL	-	-	-	-	-	S2	2,010
M	STOC5STG	SW_START	?	_GLOBAL	-	-	-	-	-	S3	2,020
M	STOC5STG	SW_SUBS	?	_GLOBAL	-	-	-	-	-	SW1-001	3
M	STOC5STG	SW_SUBS	?	_GLOBAL	-	-	-	-	-	SW2-001	2
M	STOC5STG	SW_SUBS	?	_GLOBAL	-	-	-	-	-	SW3-001	2
M	STOC5STG	SW_SUBS	?	_GLOBAL	-	-	-	-	-	SW4-001	2
Add	STOC5STG		▼	?							

(As already noted at page 1, the stochastic example contained in non-BASE scenario **STOCH5STG** has the same event tree as the five-stage stochastic model specified in section 5.5 of *TIMES-Stochastic.pdf*, but uses TID parameter S_COM_CUMNET to specify cumulative bounds on emissions of CO2 from 2010 to 2080 in stage 2 for sub-states 1,2, 3, rather than using TS parameter S_CM_MAXCO2C.)

Carrying out a Stochastic Model Run in ANSWER-TIMES

The process of carrying out a Stochastic Model Run in ANSWER-TIMES is described below, using as an example the Stochastic Model Run involving the BASE scenario and non-BASE scenario **STOCH5STG** containing Stochastic model data. (ANSWER-MARKAL users who have carried out Stochastic Model Runs should note that the process is very similar to that used for Stochastic Model Runs in ANSWER-MARKAL.)

- Click on the [Run Model…] button on the Home Screen to bring up the Run Model form. <u>If there is no online Run involving non-BASE scenario **STOCH5STG**</u> the top of the form will appear as follows, with the Run Name defaulting to STOC5STG and Model Variant defaulting to Standard TIMES:

Run Model

Model Run Details

Name: STOC5STG   [Change Run...]

Description: Stochastic Data for section 5.5 five-stage stochastic model in TIMES-Stochastic.pdf

Comment: Same event tree, but using parameter COM_CUMNET to specify cumulative bounds on emissions of CO2 from 2010 to 2080 in stage 2 for sub-states 1,2, 3, rather than using mitigation parameter

Model Variant: [Specify Model Variant...] Standard TIMES

[Specify Milestone Years]

Scenarios comprising this run:

Name	Description	Modified	
BASE	example4 demonstration database	2012/03/09 17:53	[Add...]
STOC5STG	Stochastic Data for section 5.5 five-sta...	2012/04/04 14:37	[Remove]
			[Up]

(To create the situation where there is no online Run involving non-BASE scenario **STOCH5STG**, exit the Run Model form, and in the Cases listview (bottom LHS of Home Screen) multi-select the Cases STOC5STG-001, STOC5STG-002, …, STOC5STG-024 and click on the [Delete…] button beneath the Cases listview, being sure to <u>uncheck</u> the ☐ Remember Case Definition(s) checkbox.)

- Change the Run Name to **STOC5STG-001**, by appending **-001**. (ANSWER-TIMES requires the Run Name for a Stochastic Run to end in **-001**. Other Run Names ending in **-001** such as S5STG-001 are allowable.)

- <u>To specify that a TIMES model run uses the Stochastic Extension</u>, click on the [Specify Model Variant…] button on the Run Model form, and then select the "Stochastic" option button. For Run **STOC5STG-001** this results in the following:


- Click on the [OK] button on the Model Variant Specification form to return to the Run Model form, which will now appear as follows:
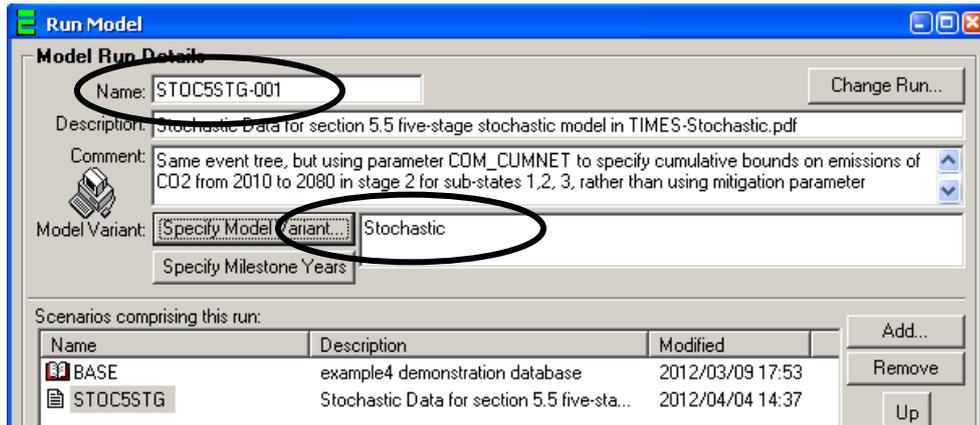
- Click on the [OK] button of the Run Model form to initiate the Stochastic Model Run. Assuming that the following checkbox settings were in place when you clicked on the [OK] button:
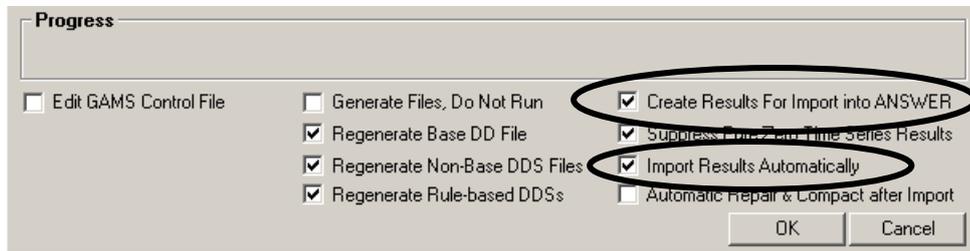
the Results Management section (bottom left-hand quadrant of the Home Screen) will appear as follows once the Stochastic Model Run has finished and Automatic Import of Results has occurred:
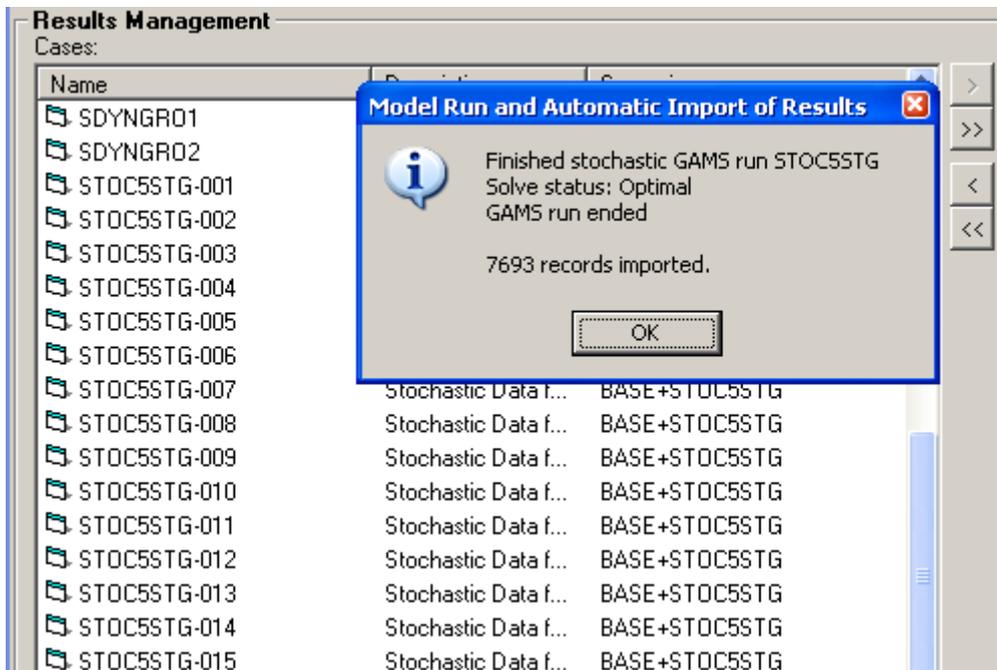
- Note that a separate ANSWER Case is created containing the Results for each State of the World in the event tree, so 24 Cases STOC5STG-001, STOC5STG-002, STOC5STG-003, …, STOC5STG-024 are created for this Stochastic Model Run. These Cases are created by appropriate processing of the *single* *.ANT file that the

ETSAP TIMES GAMS code creates. (The ETSAP MARKAL GAMS code creates a separate *.ANT file for each State of the World.)

Assorted Notes regarding the Stochastic Extension

1. The TIMES Stochastic Extension is available in conjunction with most of the other TIMES Model Extensions, but is not available with either MACRO or with Time-Stepped Solve.

2. For a Stochastic model run, ANSWER-TIMES ensures that the control variable **STAGES** is set to **YES** in the GEN file that controls the TIMES GAMS model run, by inserting:

    $SET STAGES 'YES'

    This can be seen by opening the file STOC5STG.GEN with a text editor.

3. It is suggested that all of the Stochastic Items that are needed to define a particular instance of an event tree (and the associated stochastic data parameters) should be created in a single non-BASE scenario. To define a different instance of an event tree create the Stochastic Items that are needed (and the associated stochastic data parameters) in a different non-BASE scenario.

    *   When carrying out a Stochastic Model Run, ensure that the appropriate non-BASE scenario specifying the event tree of interest is one of the selected non-BASE scenarios.

4. The "File, Export Scenario" and "File, Import Scenario" facilities have been modified to allow for the Export and Import of Stochastic Items and their associated stochastic data parameters. The "File, Export Scenario Data to Excel" and "File, Import Model Data from Excel" facilities have been similarly modified.