

Inter/Extrapolation of Input Parameters in TIMES

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1 Introduction

Time-dependent user input parameters are specified for specific years, the so-called *datayears* (**datayear**). These datayears do not have to coincide with the modelyears (**v** or **modelyear**) needed for the current run. Reasons for differences between these two sets are for example that the period definition for the model has been altered after having provided the initial set of input data leading to different milestone years (**t** or **milestoneyr**) or that statistical data are only available for certain years that do not match the **modelyears**. In order to avoid burdening the user with the cumbersome adjustment of the input data to the modelyears, an inter-/extrapolation routine is embedded in the TIMES model generator. The inter-/extrapolation routine distinguishes between a default inter-/extrapolation that is automatically applied to the input data and an enhanced user-controlled inter-/extrapolation that allows the user to specify inter-/extrapolation rules for each time-series explicitly. Independent of the default or user-controlled inter-/extrapolation options, TIMES inter-/extrapolates (using the standard algorithm) all cost parameters in the objective function to the individual years of the model as part of calculating the annual cost details.

2 Default inter/extrapolation

The standard default inter-/extrapolation method interpolates linearly between data points, while it extrapolates the first/last data point constantly backward/forward. The parameters given in Table 1 are by default **NOT** inter/extrapolated in this standard default method. All other parameters are by default both interpolated and extrapolated in the default method.

Table 1: Parameters not being inter/extrapolated by the standard default method.

Parameter	Justification	Alternative default method
ACT_BND	Bound may be intended at specific periods only	Migration
CAP_BND		
NCAP_BND		
FLO_FR		
FLO_SHAR		
STGOUT_BND		
STGIN_BND		
COM_BNDNET		
COM_BNDPRD		
COM_CUMNET		
COM_CUMPRD		
COM_CHRBND		
IRE_BND		
IRE_XBND		

Parameter	Justification	Alternative default method
UC_RHST	User constraint may be intended for specific periods only	Migration
UC_RHSRT		
UC_RHSRTS		
NCAP_AFM	Interpolation meaningless for these parameters (parameter value is a discrete number indicating which MULTI curve should be used).	Migration
NCAP_FOMM		
NCAP_FSUBM		
NCAP_FTAXM		
NCAP_AFX	Interpolation meaningless for these parameters (parameter value is a discrete number indicating which SHAPE curve should be used).	Migration
NCAP_FOMX		
NCAP_FSUBX		
NCAP_FTAXX		
COM_ELASTX		
FLO_FUNCX		
NCAP_PASTI	Parameter describes past investment for a single vintage year and is not interpolated.	None
NCAP_PASTY	Parameter describes number of years over which to distribute past investments.	None
COM_BLVAL	Blending parameters at the moment not interpolated	None
PEAKDA_BL		
COM_BPRICE	Base prices for elastic demands are obtained from baseline solution	None
CM_MAXCO2C	Bound may be intended at specific years only	None

As shown in Table 1, for bound and RHS parameters an alternative default method of interpolation/extrapolation is applied: migration. Migration means that data points are interpolated and extrapolated within each period but not across periods. This method thus migrates any data point specified for other than **milestoneyr** year to the corresponding **milestoneyr** year within the period, so that it will be effective in that period.

3 Enhanced user-controlled interpolation / extrapolation

The inter-/extrapolation facility provides maximum flexibility by allowing the user to control the interpolation of each time series separately. Many bounding constraints as well as market and product allocation constraints might be applicable either to only specific years or to the continuous time-span of the full time horizon, or to a subset thereof. The possibility of controlling interpolation on a time-series basis improves the independence between the years found in the primary database and the data actually used in the individual runs of a TIMES model. In this way the model is made more flexible with respect to running scenarios with arbitrary model years and period lengths, while using basically the very same input database.

The enhanced interpolation/extrapolation facility provides the user with options to control the interpolation and extrapolation of each individual time series (Table 2). The option 0 does not change the default behavior. The specific options that correspond to the default methods are 3 (the standard default) and 10 (alternative default method for bounds and RHS parameters).

Non-default interpolation/extrapolation can be requested for any parameter by providing an

additional instance of the parameter with an indicator in the YEAR index and a value corresponding to one of the integer-valued Option Codes (see Table 2 and example below). This control specification activates the interpolation/extrapolation rule for the time series, and is distinguished from actual time-series data by providing a special control label (“0”) in the YEAR index. The particular interpolation rule to apply is a function of the Option Code assigned to the control record for the parameter. Note that for log-linear interpolation the Option Code indicates the year from which the interpolation is switched from standard to log-linear mode. TIMES user shell(s) will provide mechanisms for imbedding the control label and setting the Option Code through easily understandable selections from a user-friendly drop-down list, making the specification simple and transparent to the user.

The enhanced interpolation/extrapolation facility provides the user with the following options to control the interpolation and extrapolation of each individual time series:

- Interpolation and extrapolation of data in the default way as predefined in TIMES. This option does not require any explicit action from the user.
- No interpolation or extrapolation of data (only valid for non-cost parameters).
- Interpolation between data points but no extrapolation (useful for many bounds). See option codes 1 and 11 in Table 2 below.
- Interpolation between data points entered, and filling-in all points outside the interpolation window with the EPS value. This is useful for e.g. the RHS of equality-type user constraints, or limitations on future investment in a particular instance of a technology, which should often have a continuous value of EPS to be effective. See option codes 2 and 12 in Table 2 below.
- Forced interpolation and extrapolation throughout the time horizon. Can be useful for parameters that are by default not interpolated. See option codes 3,4, and 5 as well as 14 and 15 in Table 2 below.
- Log-linear interpolation beyond a specified data year, and both forward and backward extrapolation outside the interpolation window. Log-linear interpolation is guided by relative coefficients of annual change instead of absolute data values.

Table 2. Option Codes for the control of data interpolation

Action	Option code	Applies to
Default interpolation/extrapolation (see above)	0 (or none)	All
No interpolation/extrapolation	< 0	All
Interpolation but no extrapolation	1	All
Interpolation, but extrapolation with EPS	2	All
Full interpolation and extrapolation	3	All
Interpolation and backward extrapolation	4	All
Interpolation and forward extrapolation	5	All
Migrated interpolation/extrapolation within periods	10	Bounds, RHS
Interpolation migrated at end-points, no extrapolation	11	Bounds, RHS
Interpolation migrated at ends, extrapolation with EPS	12	Bounds, RHS
Interpolation migrated at end, backward extrapolation	14	Bounds, RHS
Interpolation migrated at start, forward extrapolation	15	Bounds, RHS
Log-linear interpolation beyond YEAR	YEAR (≥ 1000)	All

Example:

Three normal data points in a FLO_SHAR data series:

```
FLO_SHAR('REG','1995','PRC1','COAL','IN_PRC1','ANNUAL','UP') = 0.25;  
FLO_SHAR('REG','2010','PRC1','COAL','IN_PRC1','ANNUAL','UP') = 0.12;  
FLO_SHAR('REG','2020','PRC1','COAL','IN_PRC1','ANNUAL','UP') = 0.05;
```

FLO_SHAR is by default NOT interpolated or extrapolated in TIMES. A forced interpolation/extrapolation control option for this data series would be:

```
FLO_SHAR('REG','0','PRC1','COAL','IN_PRC1','ANNUAL','UP') = 3;
```

LOG-LINEAR interpolation means that the values in the data series are interpreted as coefficients of annual change beyond a given YEAR. The YEAR can be any year, including **modelyears**. The user only has to take care that the data values in her data series correspond to the interpretation she gives to them when using the log-linear option. For simplicity, however, the first data point is always interpreted as an absolute value, because log-linear interpolation requires at least one absolute data point to start with.

Example:

```
FLO_SHAR('REG','0','PRC1','COAL','IN_PRC1','ANNUAL','UP') = 2005;
```

This parameter specifies a log-linear control option, with 2005 as the value for the threshold YEAR of log-linear interpolation. The option specifies that all data points up to the year 2005 should be interpreted normally (as absolute data values), but all values beyond that year should be interpreted as coefficients of annual change. By using this interpretation, TIMES will then apply full interpolation and extrapolation to the whole of the data series. It is the responsibility of the user to ensure that the first data point and all data points up to (and including) the year 2005 truly represent absolute values of the parameter, and all subsequent data points truly represent coefficients of annual change. Using the data of the example above, the first data point beyond 2005 is found for the year 2010, and it has the value of 0.12. The interpretation thus requires that the maximum flow share of COAL in the commodity group IN_PRC1 is actually meant to increase by as much as 12% per annum between the years 1995 and 2010, and by 5% per annum between 2010 and 2020.

Applicability:

Apart from the migrating options 10–15, all the other enhanced interpolation options described above are available for all TIMES parameters, excluding the integer-valued parameters for SHAPE and MULTI indexes (see Table 1). The migrating options are available for all bound and RHS parameters, which are listed in Table 1 above (excluding CM_MAXCO2C, for which migration is of no use because the parameter is effective for any given year). Note that because option 10 is the default method for bound and RHS parameters, and it is not available for other parameters, there is no need to ever use this option explicitly. It is mentioned in Table 2 for completeness only.

An exception to the general applicability is the parameter CM_HISTORY, which will be always densely interpolated to ensure proper model calibration.

4 Interpolation of cost parameters

As a general rule, all cost parameters in TIMES are densely interpolated and extrapolated. This means that the parameters will have a value for every single year within the range of years they apply, and the changes in costs over years will thus be accurately taken into account in the objective function. The user can use the interpolation options 1–5 for even cost parameters. Whenever an option is specified for a cost parameter, it will be first sparsely interpolated/extrapolated according to the user option over the union of **modelyear** and **datayear**, and any remaining empty data points are filled with the EPS value. The EPS values will ensure that despite the subsequent dense interpolation the effect of user option will be preserved to the extent possible. However, one should note that due to dense interpolation, the effects of the user options will inevitably be smoothed.

5 Extrapolation of SHAPE indexes

Although SHAPE indexes are not interpolated or extrapolated by default, options for the extrapolation of SHAPE index parameters have been also implemented. The extrapolation can be done either only inside the data points provided by the user, or both inside and outside those data points. Inside the data points, the SHAPE index specified for any **datayear** is extrapolated to all **modelyear** between that **datayear** and the following **datayear** for which the SHAPE index is specified.

Table 3. Option Codes for the extrapolation of SHAPE indexes.

Action	Option code
No extrapolation, but migrate (default)	≤ 0 (or none)
Extrapolation between data points only	1
Extrapolation between and outside data points	2
Extrapolation between data points only, migration at ends	11

Example: The user has specified the following two SHAPE indexes and a control option for extrapolation:

```
NCAP_AFX('REG', '0', 'PRC1') = 1;  
NCAP_AFX('REG', '1995', 'PRC1') = 12;  
NCAP_AFX('REG', '2010', 'PRC1') = 13;
```

In this case, all **modelyears** between 1995 and 2010 will get the shape index 12. No extrapolation is done for **modelyears** beyond 2010 or before 1995.

The extrapolation options are currently available for the following SHAPE parameters, which define the index of the SHAPE curve that should be applied to the corresponding parameter:

- NCAP_AFX,
- NCAP_FOMX,
- NCAP_FSUBX,
- NCAP_FTAXX,
- COM_ELASTX,
- FLO_FUNCX.