

Specifying Cost Bounds in TIMES

Antti Lehtilä, VTT
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This document describes the facilities to specify various bounds on costs in the TIMES model, introduced in version 2.3.0. In TIMES, the total objective function is calculated from detailed annual payments related to investments, fixed O&M costs and variable costs, including taxes and subsidies on investments, operation, process flows or gross or net commodity production. However, setting bounds on the various cost components has not been possible until version 2.3.0.

New bound attributes

The following two attributes are available for specifying bounds on various types of cost components, by region and currency:

Attribute	Description
REG_BNDCST(r,y,item,cur,bd)	Regional bound on costs of type item in year y, specified in currency cur. Default interpolation: Values migrated to milestone years. User-defined interpolation: All options available.
REG_CUMCST(r,y1,y2,item,cur,bd)	Regional cumulative bound on costs of type item during the period from y1 to y2 (inclusive), specified in currency cur. Interpolation: Not available.

Note that the bounds specified by using the attribute REG_BNDCST always apply to milestone years only. However, the bounds specified by the attribute REG_CUMCST apply to any range of years, which need not be milestone years. Consequently, one can also define a bound on any single year by using the cumulative bound attribute with equal years ($y1=y2$).

The types of cost components that can be bounded include the following:

Cost type	Description
INV	investment costs (annuities)
INVTAX	investment taxes (annuities)
INVSUB	investment subsidies (annuities)
INVTAXSUB	investment taxes-subsidies (annuities)
IN Vall	= INV+INVTAXSUB (annuities)
FOM	fixed OM costs
FOMTAX	fixed operating taxes
FOMSUB	fixed operating subsidies

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Cost type	Description
FOMTAXSUB	fixed operating taxes-subsidies
FOMALL	= FOM+FOMTAXSUB
FIX	= INV+FOM
FIXTAX	= INVTAX+FOMTAX
FIXSUB	= INVSUB+FOMSUB
FIXTAXSUB	= FIXTAX-FIXSUB
FIXALL	= FIX+FIXTAXSUB
COMTAX	commodity taxes
COMSUB	commodity subsidies
COMTAXSUB	commodity taxes-subsidies
FLOTAX	process commodity flow taxes
FLOSUB	process commodity flow subsidies
FLOTAXSUB	process commodity flow taxes-subsidies
ALLTAX	= FIXTAX+COMTAX+FLOTAX
ALLSUB	= FIXSUB+COMSUB+FLOSUB
ALLTAXSUB	= ALLTAX-ALLSUB

All the cost components related to investments are expressed in terms of annualized capital costs, i.e. as annuities paid in the year(s) in question. These capital cost components thus include interest during both construction and payback time. Note also that in all combined cost aggregations subsidies are treated as negative costs, but when bounded alone they are treated as positive.

Example 1. Set an upper bound X on the total investment annuity payments in year 2005 (or milestone year of the period including 2005) in the region WEU:

`REG_BNDCST('WEU','2005','INV','CUR','UP') = X;`

Example 2. Set a fixed bound 0 on the net sum of total fixed taxes and subsidies (the amount of taxes subtracted by the amount of subsidies) paid within the period 2005–2025 in the region WEU:

`REG_CUMCST('WEU','2005','2025','FIXTAXSUB','CUR','FX') = EPS;`

Remark: These new attributes have been introduced in v.2.3.0, and may be subject to some refinements in subsequent versions, according to user experience.

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New UC Attributes for referring to investment annuities

TIMES allows now also incorporating into user constraints the total investment cost annuities related to any process and paid in given milestone years. This requires that a corresponding UC_ATTR is specified for the NCAP component of the user constraint. The new UC_ATTR attributes related to incorporating investment cost annuities into user constraints are the following:

Attribute	Description	Applicable UC components
INVCOST	Multiply by investment cost annuities; Implies CUMSUM.	NCAP
INVTAX	Multiply by investment tax annuities; Implies CUMSUM.	NCAP
INVSUB	Multiply by investment subsidy annuities; Implies CUMSUM.	NCAP
CUMSUM	Sum over all periods up to current period (or previous period if specified on the RHS of dynamic constraint).	All
SYNC	Synchronize the RHS and LHS sides in a component of dynamic constraint (i.e. use the same T index); Applicable to the RHS side only.	All (RHS side only)

As indicated in the table, all the three new UC_ATTR attributes INVCOST, INVTAX and INVSUB, which can be specified on the NCAP components, automatically imply also the attribute CUMSUM for the same component. The CUMSUM attribute means that the NCAP component for any milestone T year consists of the cumulative sum of the new capacities installed up to the year T. And, when combined with e.g. the INVCOST attribute, the resulting NCAP component represents the cumulative sum of capital cost annuities related to all new capacities installed up to the year T, and paid in year T. The SYNC attribute can be additionally used in dynamic constraints to synchronize the RHS milestone year to be the same as the LHS year. The user can also specify several of the cost attributes (INVCOST, INVTAX, INVSUB), which results in the summing of the cost types. Subsidies are always treated as negative.

Referring to Example 1 above (and assuming only one currency), an equivalent way of specifying an upper bound X for the total investment annuity payments in the WEU region in year 2005 would be to make the following UC specifications:

```
SET UC_N / INVBND /;  
UC_NCAP('INVBND', 'LHS', 'WEU', '2005', 'PRC') = 1;  
UC_ATTR('WEU', 'INVBND', 'LHS', 'NCAP', 'INVCOST') = YES;  
UC_RHSRTS('WEU', 'INVBND', '2005', 'ANNUAL', 'UP') = X;
```

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In the *INVBND* UC example above, the set PRC refers to all processes.

Example 3. In the WEU region, the total amount of subsidies on wind power investments should be limited to a maximum of 5% of all investments in the power sector between 2005 and 2030. This can be formulated as follows:

```
SET UC_N / WINDSUBS /;
UC_ATTR('WEU','WINDSUBS','LHS','NCAP','INVSUB') = YES;
UC_ATTR('WEU','WINDSUBS','RHS','NCAP','INVCOST') = YES;
UC_ATTR('WEU','WINDSUBS','RHS','NCAP','SYNC') = YES;
UC_NCAP('WINDSUBS','LHS','WEU',T,WINDPRC) = -1;
UC_NCAP('WINDSUBS','RHS','WEU',T,ELCPRC) = .05;
UC_RHSRTS('WEU','WINDSUBS','0',ANNUAL,'UP') = 1;
UC_RHSRTS('WEU','WINDSUBS','2005',ANNUAL,'UP') = EPS;
UC_RHSRTS('WEU','WINDSUBS','2030',ANNUAL,'UP') = EPS;
```

Remark 1: In this example, both the LHS and RHS sides are needed to formulate the constraint. Using any attribute on the RHS (e.g. INVCOST) will automatically imply that the constraint is dynamic, but we want both sides to refer to the same milestone years. Therefore, it is necessary to use also the SYNC attribute for the NCAP component on the RHS side.

Remark 2: In the above, the sets WINDPRC and ELCPRC denote sets of wind power technologies and all electricity production technologies, respectively. In VEDA-FE you should be able to use the various filters for the UC_NCAP parameters, to define these sets in an implicit way.

Example 4. In the WEU region, the growth in total investment costs should be limited to a maximum of 3% per annum. As a seed for the growth, the investment costs can be in 2005 at most 9000 million. This can be formulated as follows:

```
SET UC_N / INVGROW /;
UC_ATTR('WEU','INVGROW','LHS','NCAP','INVCOST') = YES;
UC_ATTR('WEU','INVGROW','RHS','NCAP','INVCOST') = YES;
UC_ATTR('WEU','INVGROW','RHS','NCAP','GROWTH') = YES;
UC_NCAP('INVGROW','LHS','WEU',T,PRC) = 1;
UC_NCAP('INVGROW','RHS','WEU',T,PRC) = 1.03;
UC_RHSRTS('WEU','INVGROW','0',ANNUAL,'UP') = 12;
UC_RHSRTS('WEU','INVGROW','2005',ANNUAL,'UP') = 9000;
```

Remark 1: Using any attribute on the RHS (e.g. GROWTH) will automatically imply that the constraint is dynamic, and that is exactly what is wanted here.

Remark 2: In the above, the interpolation option 12 is used to set the seed to zero in all periods other than the one including 2005.