

Elastic supply cost curves in TIMES

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1 Specifications

A TIMES user has expressed that she would find it interesting to be able to have a gas and oil supply curve in the EU TIMES model to take into account the impact of demand changes on the supply when running scenarios. The user sees that something like the elastic demand case would be useful: The oil and gas price are exogenous in the reference case, and for the scenarios there would be an inverse supply curve of the type

$$\text{Price} = \text{PRICeref} * (\text{demandscenario/demandreference})^{**} \text{ELAS}$$

The curve should be linearised. *ELAS* could be 1.2 for gas and 0.3 for oil (elasticities derived from POLES, but TIAM could be used to have an idea about these supply elasticities).

2 Implementation

The TIMES Damage Cost facility has already for long been supporting elastic cost curves for the net amount of commodities produced, typically used for defining so-called damage costs for emission commodities.

As described in the documentation, the marginal Damage Cost is given by the following expression:

$$MC(EM) = MC_0 \cdot \frac{EM^\beta}{EM_0^\beta} \quad (1)$$

Consequently, the Damage Cost facility has already been using exactly the same marginal cost formulation as the proposal for the elastic supply costs. The implementation of the elastic supply cost curves can thus be conveniently made as an extension to the Damage Cost facility, by allowing the damage costs to be defined also on the total production of a commodity.

In addition, for the implementation the Damage Cost facility needs to be extended in such a way that the Baseline marginal costs and demands can be automatically transferred to policy scenarios in the form of time-dependent Base quantities to be applied in the Damage Cost formulation.

Note: The implementation of this feature is experimental, and may be subject to changes, depending on user experience.

3 Defining the elastic supply cost curves

3.1 User-defined attributes

3.1.1 DAM_ELAST(r,c,lim)

DAM_ELAST(r,c,'N') should always be specified by the user whenever the cost curve is to be applied to the total commodity production, instead of the net. Only the values 0 or -1 are meaningful. The value -1 indicates that the user also requests the Base price to be subtracted from the resulting Damage Cost curve, thereby shifting the curve downwards, while the value 0 indicates that the cost curve should not be shifted by any amount.

DAM_ELAST(r,c,'LO') and DAM_ELAST(r,c,'UP') should be used for defining the lower and upper elasticities of the elastic supply cost curve, in the same way as with Damage Costs in general.

3.1.2 DAM_STEP(r,c,lim)

DAM_STEP(r,c,lim) should be used for defining the amount of cost steps in the linearized formulation of the cost curve (see the documentation of Damage Costs). In addition, it also defines the range of cost for which the stepped curve is defined, unless DAM_VOC(r,c,'N') is specified (see below). If such a DAM_VOC parameter is not specified, the stepped demand range will be the full Base quantity in the lower direction, and in the upper direction the range will be determined by DAM_STEP(r,c,'UP'), assuming for each step the same step size as in the lower direction. Beyond the last cost step the marginal cost will always be constant.

3.1.3 DAM_VOC(r,c,lim)

DAM_VOC(r,c,'LO') or DAM_VOC(r,c,'UP') should not be used for the elastic supply costs curves, because they define period-independent lower and upper ranges for the cost curve, in absolute terms. However DAM_VOC(r,c,'N') can be used for defining the desired target size for the cost steps, as a fraction of the Base demand. Denoting by $DEM(r,t,c)$ the Base demands, the resulting stepped demand ranges (in the lower and upper direction) will thus be:

$$\text{MIN}(DEM(r,t,c), (DAM_STEP(r,c,'LO')+0.5) \cdot DAM_VOC(r,c,'N') \cdot DEM(r,t,c))$$

and

$$(DAM_STEP(r,c,'UP')+0.5) \cdot DAM_VOC(r,c,'N') \cdot DEM(r,t,c)$$

If the lower range is smaller than the Base demand, the marginal cost will be constant below the first step, and likewise, the marginal cost will always be constant above the last cost step.

3.2 Automatic transfer of Baseline results

The Baseline results needed for defining the cost curve can be automatically transferred to a policy scenario via two internal attributes to be used as the time-dependent Base quantities and timeslice-dependent coefficients between the original timeslice-dependent commodity production and the timeslice-independent proxy for the total demand. Denoting by $MC_0(r, t, c, s)$ the Baseline prices of the commodity, the timeslice-independent proxy for the total demand is defined by the following formula:

$$DEM(r, t, c) = \sum_s VAR_COMPRD(r, t, c, s) \cdot MC_0(r, t, c, s)$$

The Base demand quantities to be used in the Damage Cost formulation are, of course, given by this very same formula, by substituting the Baseline solution values of $VAR_COMPRD(r, t, c, s)$ in the formula above. Consequently, the damage cost corresponding to the Base demand must also be normalized, and will thus always be automatically set to 1 for all periods.

The automatic transfer of results from the Baseline to a policy scenario will occur for a commodity c in region r , whenever all the following conditions hold in both the Baseline and the policy scenario:

1. $DAM_ELAST(r, c, 'N')$ is defined for the commodity in region r
2. $DAM_BQTY(r, c)$ is not defined for the commodity in region r
3. $DAM_COST(r, t, c, cur)$ is not defined for any (t, cur) in region r

In addition, the transfer only takes place when *elastic demands* are used in the policy scenario, because the data are transferred via the same GDX file as the Base prices of the elastic demands.

Elastic supply cost curves can also be defined manually, without the automatic transfer of Baseline results. In that case the cost curve should be defined exactly in the same way as for Damage Costs, the only difference being that the cost curve will be applied to the total commodity production instead of the net production. In addition, if desired, the curve can be shifted downwards by specifying $DAM_ELAST(r, c, 'N') = -1$, as described in Section 3.1.1.

3.3 Reporting of the costs

The annual costs related to the elastic supply cost curves defined by the Damage Cost attributes are reported in the $COST_DAM$ attribute. The objective function component representing these costs is reported separately as the 'DAS' component of REG_WOBJ , while the Damage Costs applied to the NET production are still reported as the 'DAM' component of REG_WOBJ , like before.

4 Illustrative Example

4.1 Unshifted elastic supply cost curve

Assume that we want to define an elastic supply cost curve for the crude oil commodity CRUDE in the region EU, with a lower elasticity of 0.63 and an upper elasticity of 0.70. Assume also that the Baseline demand is 10 units and the Baseline price is 9 currency units. In addition, we want to restrict the elastic cost range to 33% of the Base demand in the lower direction, and to 200% of the Base demand in the upper direction. Figure 1 illustrates the resulting elastic marginal cost curve.

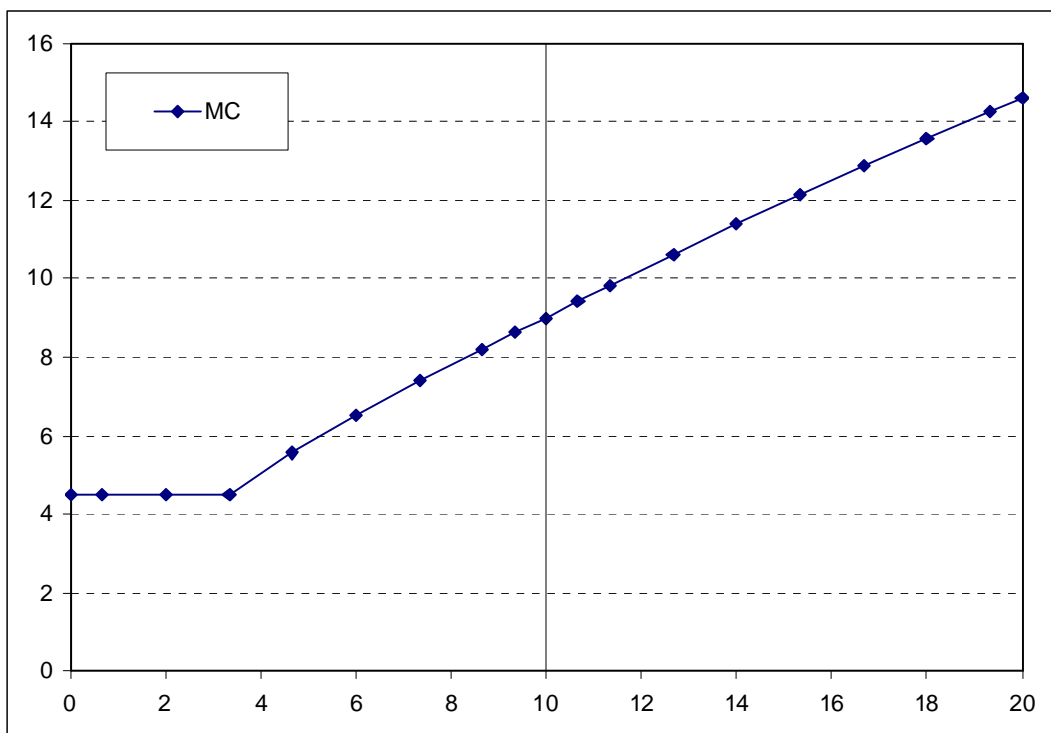


Figure 1. Desired elastic marginal cost curve.

The cumulative cost curve resulting from the marginal cost curve is illustrated in Figure 2, as a function of the demand.

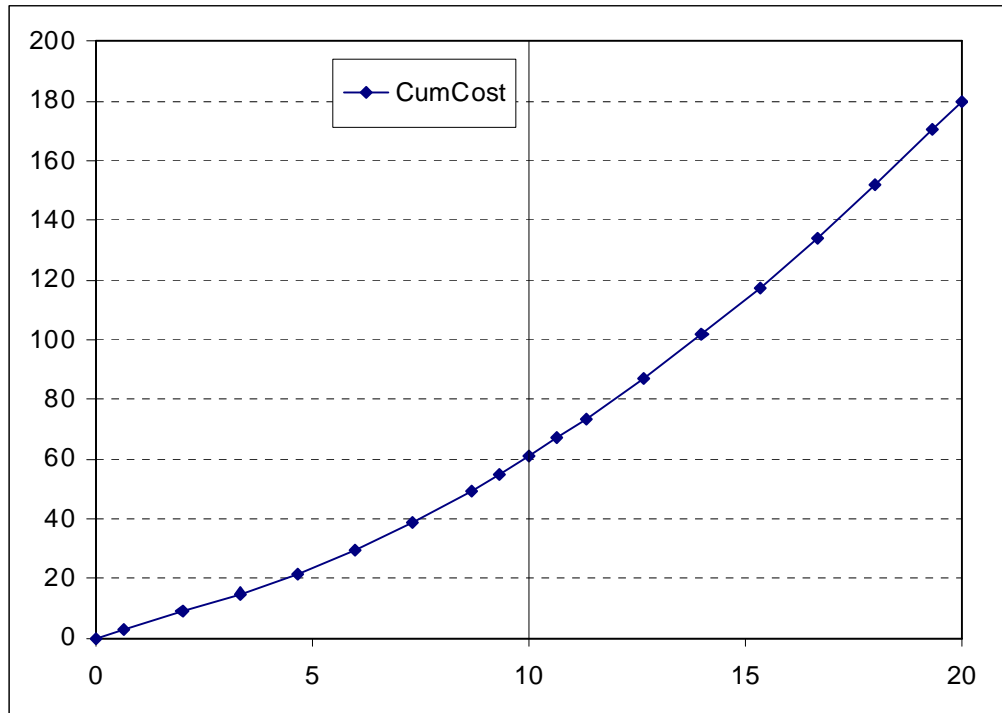


Figure 2. Cumulative cost curve resulting from the marginal cost curve of Figure 1.

This elastic cost curve could be defined in TIMES by specifying the following parameters:

```

PARAMETER DAM_ELAST /
EU.CRUDE.N      0
EU.CRUDE.LO    0.63
EU.CRUDE.UP    0.70 /;

PARAMETER DAM_STEP /
EU.CRUDE.LO    5
EU.CRUDE.UP    7 /;

PARAMETER DAM_VOC /
EU.CRUDE.N     0.1333 /;

```

The DAM_VOC parameter defines the desired step size, which is here 0.1333 times the Base demand (i.e. 1.333 units of demand), so that the mid-point of the first step occurs at 33% of the Base demand ($10 \cdot (1 - 5 \cdot 0.1333) = 3.33$).

If these parameters are specified both in the Baseline scenario and in a policy scenario, the Base demand (and the corresponding the Base price) of the supply cost curve will be automatically transferred from the Baseline solution to the policy scenario, where the cost curve will subsequently be applied.

4.2 Shifted elastic supply cost curve

Here we use the same assumptions as above, but in this case the curve should be shifted downwards by the Base price amount. The corresponding shifted marginal cost curve is illustrated in Figure 3, and the cumulative cost curve in Figure 4.

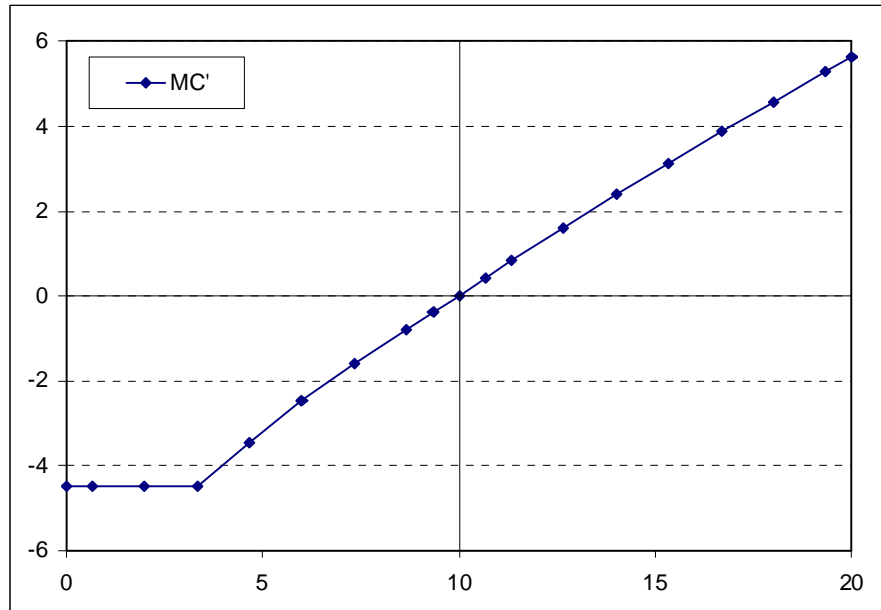


Figure 3. Shifted marginal cost curve corresponding to the marginal cost curve of Figure 1.

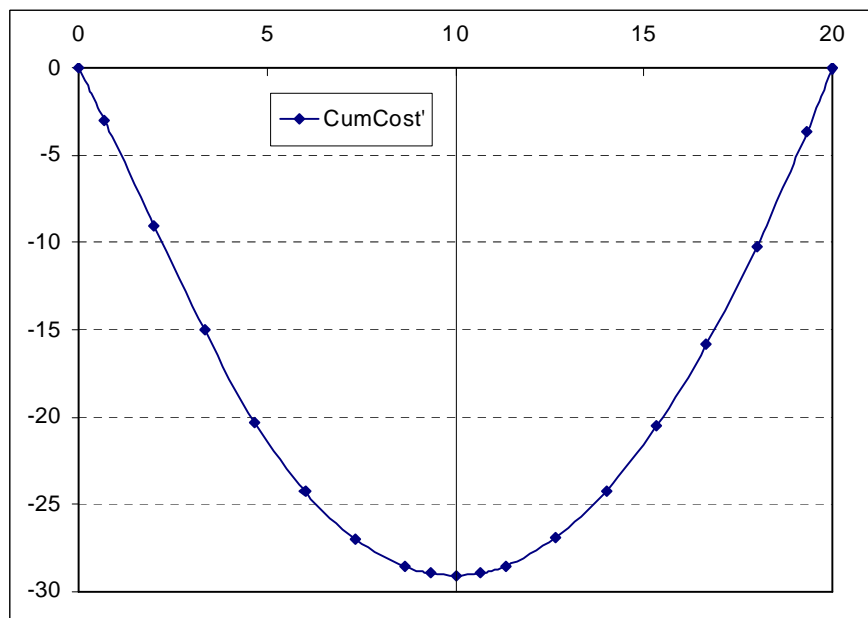


Figure 4. Cumulative cost curve resulting from the shifted marginal cost curve of Figure 3.

Because it is also desirable that, when using the shifted elastic supply cost curve, the value of the original objective function will be fully reproduced at the Base demand, the cumulative cost curve should additionally be shifted upwards by an amount that brings the minimum costs to zero at the Base demand, as shown in Figure 5. Note: *This second cost shift is only a constant term in the objective, and will thus not affect the solution.*

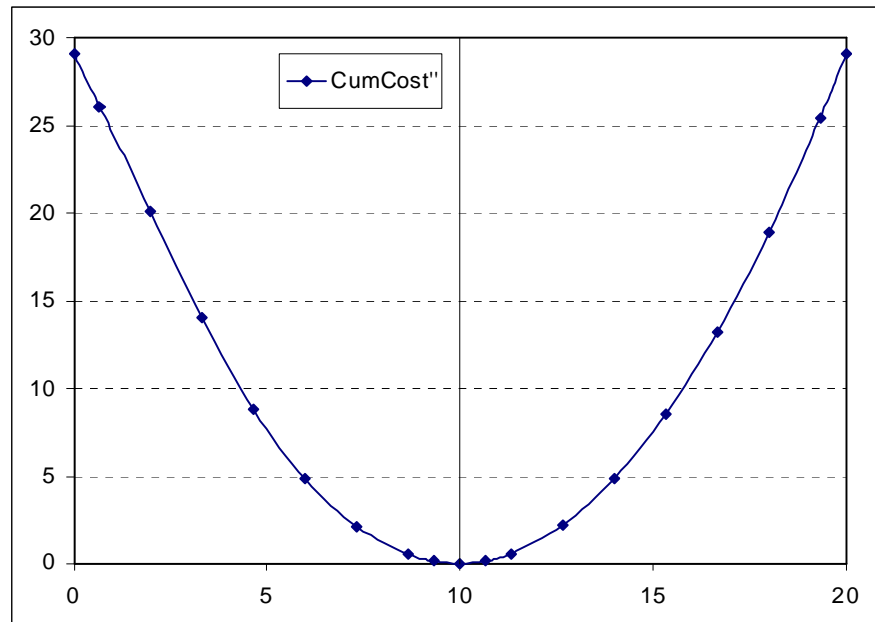


Figure 5. Cumulative cost curve shifted to have a minimum of zero.

This shifted elastic cost curve could be defined in TIMES by specifying the following parameters:

```

PARAMETER DAM_ELAST /
EU.CRUDE.N      -1
EU.CRUDE.LO     0.63
EU.CRUDE.UP     0.70 /;

PARAMETER DAM_STEP /
EU.CRUDE.LO     5
EU.CRUDE.UP     7 /;

PARAMETER DAM_VOC /
EU.CRUDE.N      0.1333 /;

```

Again, if these parameters are specified both in the Baseline scenario and in a policy scenario, the Base demand (and the corresponding the Base price) of the supply cost curve will be automatically transferred from the Baseline solution to the policy scenario, where the cost curve will subsequently be applied. If nothing else is changed, *the resulting value of the objective function will thus be the same as in the Baseline.*