A Note on Age Corrections in TCB18

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1 Question

In TCB18, the main output parameters are derived from techno-economic weighted sums of the network assets, in particular the NormGrid grid size proxy. The construction of this proxy is the subject of a technical report (Sumicsid, 2019-02-27, ver 1.3, Appendix F to the main final report) and several presentations at the project workshops, such as Workshops W3 (2018-10-10 and 2018-10-11), W4 (2018-11-27) and W5 (2019-04-04 and 2019-04-05). One of the principles behind the system is that the assets together form an active power system in a stable operational state, using harmonized techno-economic lifetimes for all assets. The valuation of the components and the investments is made through real annuities, meaning that the timing and the book value age of the asset does not affect the analysis. It is further assumed that the optimal maintenance is performed as to sustain the state of the equipment over the entire horizon, but not necessarily beyond.

Specific methods apply to significant rehabilitation of assets, developed in a method note (Sumicsid, 2017-12-19, Appendix D to the final report). In the TCB18 data collection, the occurrence of significant rehabilitations was judged very low, although some TSOs (including GTS) reported an implausible incidence of rehabilitation. After investigation of the implausible part of the submissions it was concluded that the occurrences of significant rehabilitations are rare and comparable across TSOs, removing the need for applying the method for significant rehabilitations. The age analysis reported in this note support this conclusion.

Although the age effects in the gas model were tested and the results presented at W5 (2019-04-05), the Dutch gas TSO GTS has raised concerns that the age effects still remain to be fully explored. The hypothesis (H1) claimed by the operator is that high asset age leads to higher costs and, by consequence to lower cost efficiency score for the same output. Another hypothesis (H2) is that the age effects are discontinuous and that the sample lacks data to statistically address the problem of GTS.

This note supplements the documentation of the analysis of age effects in gas as done in TCB18.

2 Testing H1

The age effect hypothesis H1 in TCB18 were tested during the project using robust regressions on mean asset age per operator (age_meany) and the mean asset for pipelines (age1y) scaled on the normalized grid (yNG) through a logarithmic formulation, with Totex as dependent variable. The results did not prove significant, as shown below.

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Call:
dTotex.cb.hicpog_plici ~ log(yNG) + log(age_meany) + log(age1y)

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)    -1.211e+09  1.280e+08  -9.454 6.83e-14 ***
log(yNG)        8.647e+07  7.725e+06  11.193  < 2e-16 ***
log(age_meany)  1.115e+08  3.044e+08   0.366    0.715
log(age1y)     -1.683e+08  3.064e+08  -0.549    0.585
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Robust residual standard error: 79250000
Multiple R-squared:  0.679,Adjusted R-squared:  0.6645
No outliers
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To deepen the investigation of the age relations in the TCB18/GAS data , we break up the observations in two asset categories: pipelines and compressors, corresponding to 98% of the mean NormGrid. A series of age indicators is presented in Table 1 to be tested against the scores.

Table 1 Age proxies , TCB18/GAS.

Parameter	Definition	Assettype
age_1	Average asset age (yrs)	Pipelines
age_3	Average asset age (yrs)	Compressors
agem	Mean asset age (yrs)	ALL
share_ngc_young10_1	Share of assets ≤ 10 years old	Pipelines
share_ngc_young10_3	Share of assets ≤ 10 years old	Compressors
share_ngc_young05_1	Share of assets ≤ 5 years old	Pipelines
share_ngc_young05_3	Share of assets ≤ 5 years old	Compressors
share_ngc_old_1	Share of overage assets	Pipelines
share_ngc_old_3	Share of overage assets	Compressors
sharem_young10	Mean share of assets ≤ 10 years old	ALL
sharem_young05	Mean share of assets ≤ 5 years old	ALL
sharem_old	Mean share of overage assets	ALL

Four hypotheses can be formulated, whereof (1) and (2) are corollaries of H1, (3) and (4) are supporting the opposite hypothesis (-H1):

1) If any combination of the parameters share_ng_old_Y are significant with negative coefficient(s), presence of older network assets has a negative influence on the DEA score.

2) If any combination of the parameters share_ngc_youngXX_Y and/or sharem_youngXX are significant with positive coefficients, younger network assets has a positive influence on the DEA score.

3) If any combination of the parameters share_ngc_youngXX_Y and/or sharem_youngXX are significant with negative coefficients, younger network assets has a negative influence on the DEA score.

4) If any combination of the parameters share_ng_old_Y are significant with positive coefficient(s), presence of older network assets has a positive influence on the DEA score.

We run a Tobit regression on the DEA-scores for the full panel dataset (excluding the 16 German TSO for which no age data are reported). Note that the sample is unbalanced as there are 40 observations with compressors and 54 with pipelines.

Table 2 Tobit regression, TCB18/GAS, panel data, *n* = 54/40.

Parameter	*n*	Coef	t-value	p-value
age_1	54	0.0007	0.1501	0.8806
age_3	40	0.0025	0.6289	0.5294
agem	54	0.0008	0.1669	0.8674
share_ngc_young10_1	54	0.1522	0.7341	0.4629
share_ngc_young10_3	40	**-0.2281***	**-1.9596**	0.0500
share_ngc_young05_1	54	-0.3564	-0.6231	0.5332
share_ngc_young05_3	40	**-0.3357*****	**-3.4158**	0.0006
sharem_young05	54	-0.5796	-1.5784	0.1145
sharem_young10	54	0.1667	0.7879	0.4308
share_ngc_old_1	54	-0.6904	-0.7646	0.4445
share_ngc_old_3	40	-0.0169	-0.1221	0.9028
sharem_old	54	-0.2393	-0.9249	0.3550

The parameters are used as independent variables in a Tobit regression on the DEA scores from TCB18. If any of the age proxies would be significant in explaining the DEA score an analysis should be made for the direction of the sign.

As seen from Table 2 there are only two proxies that are significant in the Tobit regression, as shown from the t-values and the associated p-values. The associated OLS output is provided below. The results for the 5-year panel in Table 2 are valid also in a cross section analysis for 2017.

The two significant parameters indicate that prevalence of younger compressors (in particular not more than five years old) is correlated with a lower DEA-score in the full sample. We can therefore not reject hypothesis (3) above.

Thus, the result suggest that there would be a disadvantage for the operators with new investments in compressors, a variant of the opposite hypothesis (-H1).

However, the position of GTS in the sample (cf. Figure 1 below) is such that the result do not provide any relevant proof of any cost-increase or bias with respect to age in the benchmarking, i.e (H1). If anything, it suggests that GTS might have an advantage through older assets.

The hypothesis H1 that older transmission assets would bias or decrease the cost efficiency score in TCB18 cannot be supported.

```
Call:
vglm(res.ref.super ~ share_ngc_young05_3, family = tobit(Lower = 0),
    na.action = na.omit)

Pearson residuals:
                Min      1Q  Median     3Q   Max
mu          -1.2586 -0.6571 -0.4687 0.9449 2.382
loglink(sd) -0.7299 -0.4764 -0.2687 0.2459 3.417

Coefficients:
                       Estimate Std. Error z value Pr(>|z|)
(Intercept):1           0.75174    0.05913  12.712  < 2e-16 ***
(Intercept):2          -1.42904    0.11309 -12.637  < 2e-16 ***
share_ngc_young05_3    -0.33574    0.09829  -3.416 0.000636 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Log-likelihood: 0.4042 on 77 degrees of freedom

No Hauck-Donner effect found in any of the estimates
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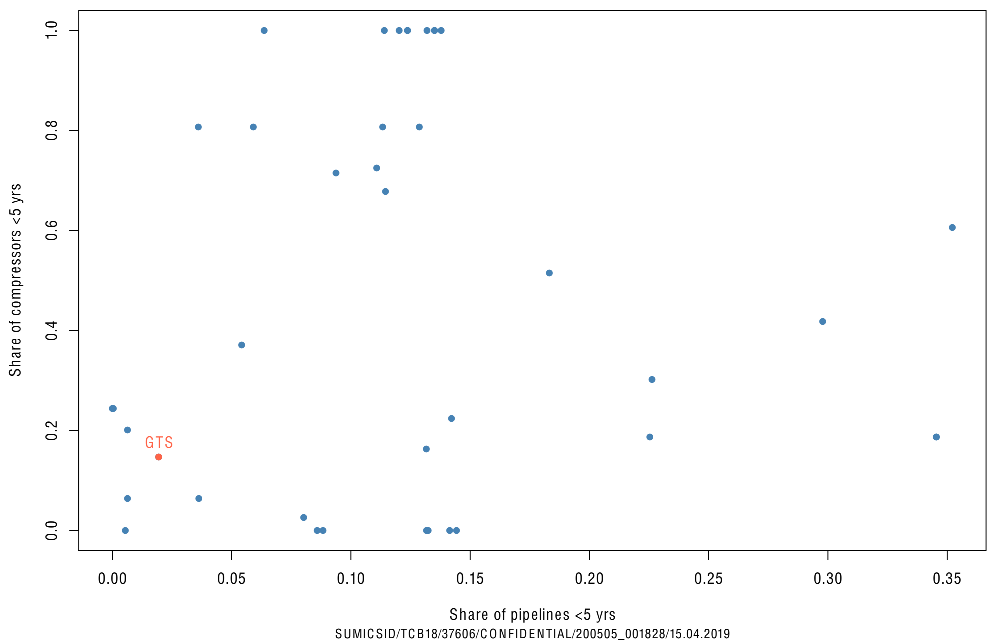

Figure 1 Parameters share of young (<5 yrs) compressors and pipelines, (TCB18/GAS, excl DE).

3 Test H2

The distribution of mean asset ages in the TCB18/GAS sample, excluding the German operators, is provided in Figure 2 below. GTS has the highest mean asset age with 46.7 years compared to the mean (27.1 years). It is also true that a 95% confidence interval for the mean age (20.7 – 33.6 years) does not include the GTS observation. On the other hand, the spread of the distribution is relatively smooth and linear with 4 of 13 observations likewise above the mean confidence interval. We also note the presence of two of GTS peers at 32.5 and 34 years, well above the mean. Notwithstanding the cost impact, it cannot be concluded that the sample lacks observations with high age or that GTS would be compared to a subsample with radically different age profile for the assets.

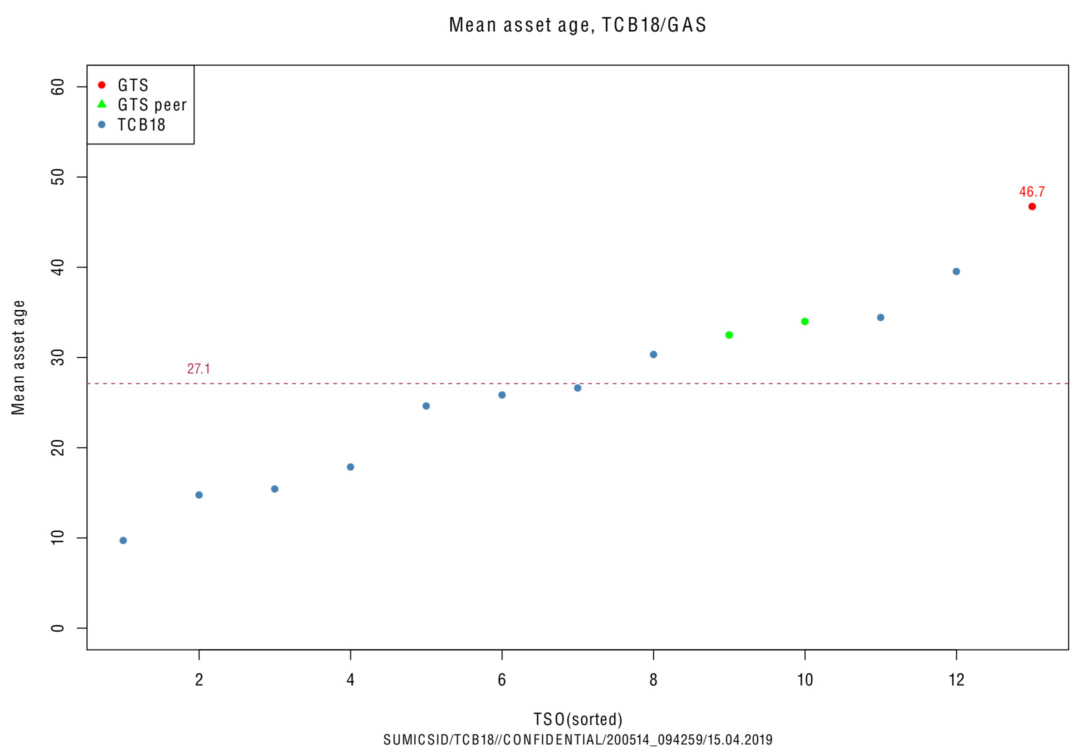

Figure 2 Mean asset age (TCB18/GAS, excl DE), 2017.

Naturally, given that GTS exhibits the maximum age, the hypothesis that the age effect is discontinuous, occurring exactly between GTS and the next highest observation cannot be rejected. However, to be meaningful, this claim should also be corroborated with techno-economic arguments related to the nature of the assets and their state. The technical gas experts in TCB18 have provided techno-economic lifetimes, subject to the consultation to all NRAs and TSOs in TC18 without remarks in this regard. The techno-economic life time is defined as the expected age of replacement for each asset, up until which the asset will provide full functionality in the power system compared to a new asset. Passed the life time, the increase in expected maintenance cost is higher than the combined cost of capex and opex for a replacement. The potentially discontinuous part of the curve is therefore situated beyond the stipulated asset lifetimes in the consensus of both our experts and the project participants. This is consistent with the system-failure theory for energy infrastructure, e.g. Brown and Willis (2006) according to which the share of extremely old (overage) assets would be a predictor of system reliability (and overall system cost including corrective maintenance and outage).

To investigate this aspect, we graph the distribution for overage pipelines (Figure 3) and compressors (Figure 4) in the TCB18 sample. As seen, GTS is no longer the extreme point although higher than the mean. The sample thus includes observations with higher and lower share of overage assets. The direct peers have younger pipeline networks, but one of the direct peers have a similar age profile for the compressors.

The hypothesis H2 that the sample lacks comparison data for high age observations or that GTS would be compared to operators with radically younger networks cannot be confirmed.

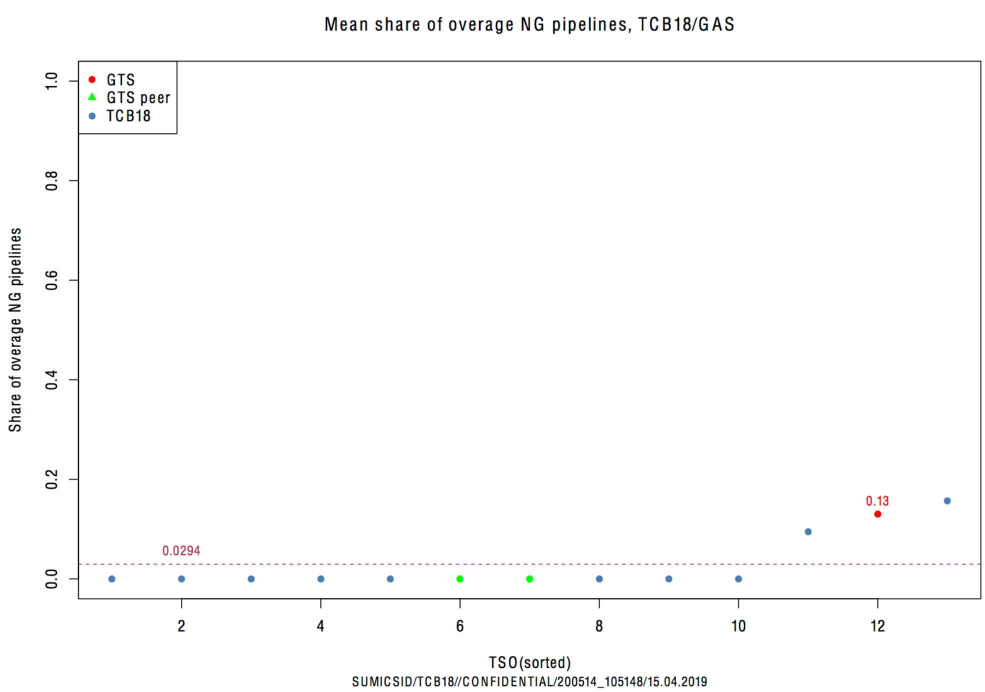

Figure 3 Share of overage (>60 year) pipelines, (TCB18/GAS excl DE, 2017).

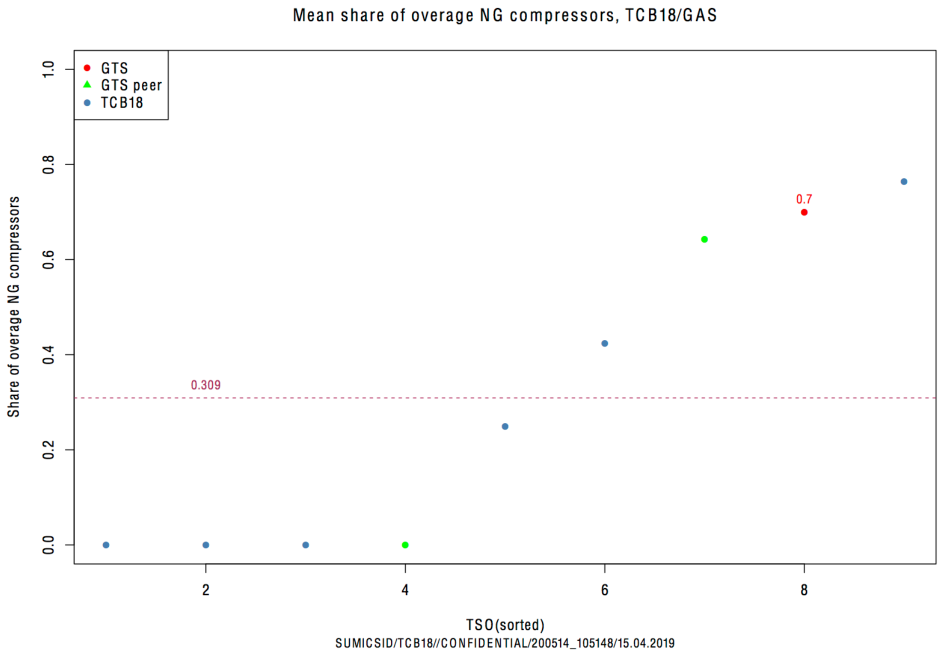

Figure 4 Share of overage (>30 years) compressors (TCB18/GAS excl DE, 2017).

4 Conclusions

We have investigated the question of whether the asset age could have an impact on the efficiency assessment, creating an unfair disadvantage for operators with older grids. Using proxies for age in a Tobit regression on the DEA scores, we have been able to determine that:

The DEA-scores in TCB18 for gas transmission are not sensitive to high asset age. A higher share of newer compressors (5 or 10 years), may lead to a lower DEA-score.

Since GTS has comparatively old assets, the findings do not corroborate the hypothesis justifying any adjustment of the DEA score.

Concerning the hypothesis that GTS would be a unique case in the data and/or that the cost function were to be discontinuous around the age of the GTS asset base, the analysis provides some objective elements:

1. For the mean asset age, the distribution of observations is relatively smooth.

2. For the share of overage assets (pipelines and compressors), GTS is not the maximum observation.

3. At least some of the direct peers for GTS have mean asset ages higher than average and a share of overage compressors that is comparable to that of GTS.

We can therefore conclude that the sample includes a mix of older and younger networks, with the exception of overage pipelines for which only three operators have non-zero observations.

However, given the definition and meaning of the techno-economic life time as the expected age for replacement, as well as the general results for the neutrality of the scores with respect to age within the interval, it is not clear how an ad hoc correction for an overage asset base could be defended on economic arguments. If indeed the marginal maintenance cost is increasing (which is not shown here) beyond the cost of replacement for the asset base, the hypothetical impact on the cost efficiency assessments should rightly be negative. Similar arguments can be made for any infrastructure or equipment (office computers, cars).

5 References

ACER (2015) ACER Report on Unit Investment Cost Indicators and Corresponding Reference Values for Electricity and Gas Infrastructure. Final report. https://www.acer.europa.eu

Brown, R. E. and H. L. Willis (2006) The economics of aging infrastructure, *IEEE Power and Energy Magazine*, **4**(3), pp. 36-43.

Sumicsid (2019) *Norm Grid Development, TCB18 Technical Report*. Version V1.3. 2019-02-27.