Project TCB18
Individual Benchmarking Report
TenneT - 187

ELECTRICITY TSO
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Contents

Acronyms

Table 0.1: Acronyms in the report.

Acronym	Definition
AE	Allocatively Efficient
CAPEX	CAPital EXpenditure
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
fte	full time equivalents
I	Indirect support services (activity)
IRS	Increasing Returns to Scale
L	LNG terminal services (activity)
M	Maintenance services (activity)
NDRS	Non-Decreasing Returns to Scale
O	Other (out-of-scope) services (activity)
OPEX	OPerating EXpenditure
P	Planning services (activity)
S	System operations (activity)
SC	Staff intensity (scaled)
SE	Scale Efficiency
SF	Energy storage services (activity)
SI	Staff intensity per NormGrid unit
T	Transport services (activity)
TCB18	(CEER) Transmission Cost Benchmarking project 2018
TO	Offshore transport services (activity)
TOTEX	TOTal EXpenditure
TSO	Transmission System Operator
UC	Unit cost (cost per NormGrid unit)
VRS	Variable Returns to Scale
X	Market facilitation services (activity)

Chapter 1

Results

The following material is a summary of results, descriptive data and sensitivity analyses for TenneT with code number 187 in the TCB18 benchmarking based on data processed 15.04.2019. This release is exclusively made to the authorized NRA and the information contained in this release is not reproduced as such in any other project report for TCB18. All underlying information in this release is subject to the confidentiality agreement of TCB18. This report with associated data files is part of the final deliverables for the TCB18 project. The contents of this report are strictly confidential.

The benchmarking model of the TCB18 project uses a total expenditure measure as input and the costs drivers listed in Table 2.6 below. In addition, it is a Data Envelopment Analysis (DEA) model which means that it determines the best practice among the TSOs and uses this as the standard for evaluating each of the firms in the sample.

DEA constructs a best practice frontier by departing from the actual observations and by imposing a minimal set of additional assumptions.

One assumption is that of *free disposability* which means that one can always provide the same services and use more costs and that one can always provide less services at given cost levels. In the base model, this is an entirely safe assumption, but it does allow us to identify more comparators for any given TSO.

Another assumption is that of *convexity*. It basically means that one can make weighted averages of the performance profiles of two or more TSOs. This is a more technical assumption widely used in economics.

The third assumption is that of *non-decreasing returns to scale* or as it is sometimes called, *(weakly) increasing returns to scale*. It means that if we increase the costs of any given TSO with some percent, we should also be able to increase the service output, the costs drivers, with at least the same percent. We can also formulate this as an assumption that it can be a disadvantage to be small, but not to be large. It is important that this assumption is not just imposed *ex ante*. The statistical analysis of alternative returns to scale models suggests that it actually is a reasonable assumption to make in the sample of electricity transmission operators in this study.

The best practice DEA model and the theory behind it are further explained in the main report and its accompanying appendices.

Using the base model, we have estimated the efficiency level of TenneT to be

71.5 %

The interpretation is that using best practice, the benchmarking model estimates that TenneT is able to provide the same services, i.e. keep the present levels of the cost drivers, at 71.5 % of the present total expenditure level. In other words, the model suggests a saving potential of 28.5 % or in absolute terms, a savings in total comparable expenditure of

92 MEUR

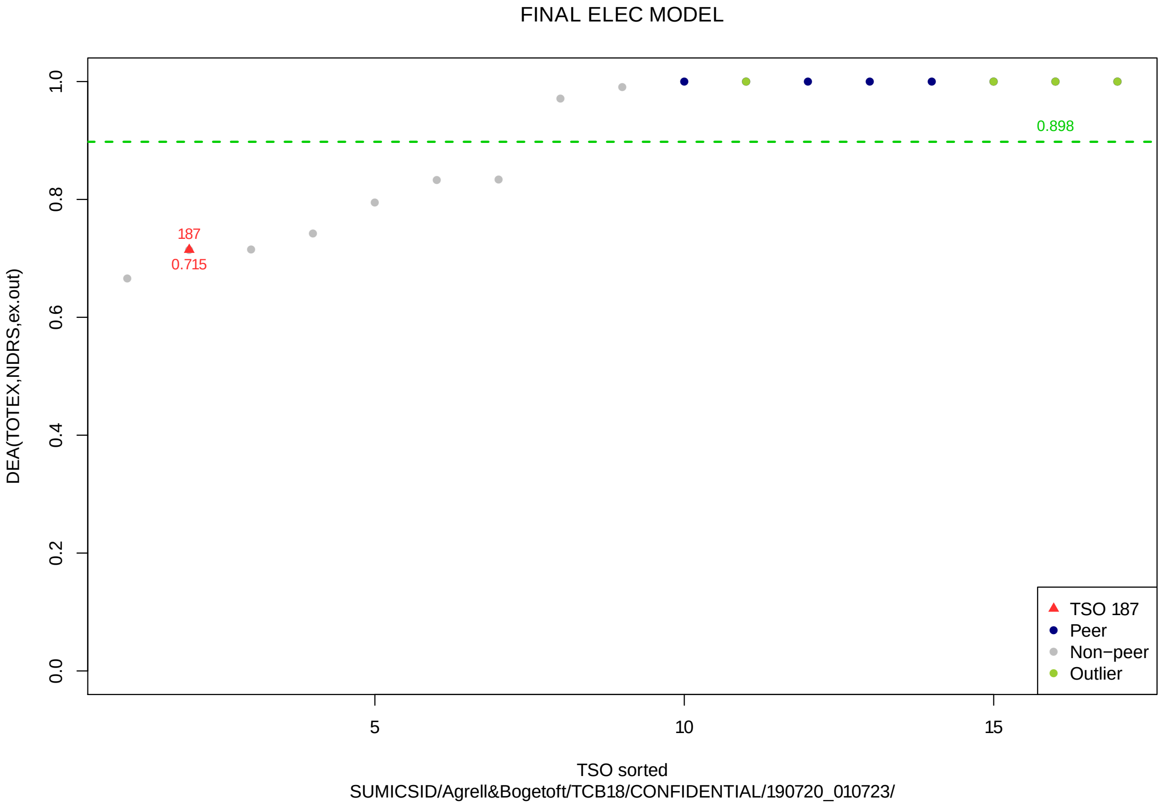

Figure 1.1: Final DEA cost efficiency results for electricity TSO in TCB18 .

The model considers both investment efficiency and operating efficiency under a given set of environmental conditions. The material in this report may provide elements to explore other differences than those explicitly included in the model, to understand the scores and the operating practice of the electricity transmission operators in Europe in 2017.

To evaluate the estimated efficiency of TenneT, it is always relevant to compare to the efficiencies of the other TSOs in the TCB18 project, see Figure 1.1. Structural comparability is assured by stringent activity decomposition, standardization of cost and asset reporting, harmonized capital costs and depreciations, elimination of country-specific costs related to taxes, land, buildings, and out-of-scope activities, correction for salary cost differences and national inflation as well as currency differences.

Table 1.1: Efficiency scores year 2017

	Mean eff	#outliers
All TSO	0.898	4
TenneT	0.715	0

Chapter 2

Data

The data collected in the TCB18 project is extremely rich and cannot be fully represented in a short summary. Hence, the reporting for each individual operator includes the following documents in addition to this report:

1. Asset sheet with Normgrid values.
2. Cost data sheet (Capex and Opex).

Below in Table 2.1, we provide an overview of the model data used and some descriptive statistics for the units.

Table 2.1: Detailed asset summary (usage share included) 2017

	Code	Units 2017	Units <1973	NGCapex	NGOpex	NGTotex
Overhead lines	10	700	359	101,347,675	12,558,995	113,906,670
Cables	20	639	90	59,838,831	1,081,679	60,920,510
Circuit ends	30	2,540	916	71,231,660	40,947,235	112,178,895
Transformers	40	130	31	7,887,815	960,560	8,848,375
Compensating devices	50	119	8	1,924,480	24,966	1,949,446
Series compensations	60	58	13	1,930,257	254,009	2,184,266
Control centers	70	3	0	220,341	152,979	373,320
Other installations	90	1	0	0	0	0
TOTAL				244,381,059	55,980,423	300,361,482

Table 2.2: Detailed asset summary (usage share included) 2016

	Code	Units 2016	Units <1973	NGCapex	NGOpex	NGTotex
Overhead lines	10	697	359	100,486,174	12,520,960	113,007,133
Cables	20	634	90	59,639,205	1,077,593	60,716,798
Circuit ends	30	2,489	916	69,040,162	39,961,061	109,001,223
Transformers	40	130	31	7,887,815	960,560	8,848,375
Compensating devices	50	119	8	1,924,480	24,966	1,949,446
Series compensations	60	58	13	1,930,257	254,009	2,184,266
Control centers	70	3	0	220,341	152,979	373,320
Other installations	90	1	0	0	0	0
TOTAL				241,128,434	54,952,127	296,080,562

Table 2.3: Detailed asset summary (usage share included) 2015

	Code	Units 2015	Units <1973	NGCapex	NGOpex	NGTotex
Overhead lines	10	687	359	100,296,529	12,499,148	112,795,677
Cables	20	608	90	56,411,953	1,025,052	57,437,005
Circuit ends	30	2,428	916	66,014,829	38,599,661	104,614,490
Transformers	40	128	31	7,670,373	946,407	8,616,780
Compensating devices	50	113	8	1,704,093	23,629	1,727,721
Series compensations	60	58	13	1,930,257	254,009	2,184,266
Control centers	70	3	0	220,341	152,979	373,320
Other installations	90	1	0	0	0	0
TOTAL				234,248,374	53,500,885	287,749,259

Table 2.4: Detailed asset summary (usage share included) 2014

	Code	Units 2014	Units <1973	NGCapex	NGOpex	NGTotex
Overhead lines	10	679	359	100,184,035	12,482,547	112,666,582
Cables	20	595	90	55,573,194	1,008,401	56,581,595
Circuit ends	30	2,283	916	60,335,348	36,043,895	96,379,243
Transformers	40	124	31	7,353,122	915,702	8,268,824
Compensating devices	50	113	8	1,704,093	23,629	1,727,721
Series compensations	60	57	13	1,909,456	251,605	2,161,061
Control centers	70	3	0	220,341	152,979	373,320
Other installations	90	1	0	0	0	0
TOTAL				227,279,590	50,878,757	278,158,347

Table 2.5: Detailed asset summary (usage share included) 2013

	Code	Units 2013	Units <1973	NGCapex	NGOpex	NGTotex
Overhead lines	10	655	359	99,428,672	12,407,992	111,836,664
Cables	20	568	90	50,483,130	935,573	51,418,703
Circuit ends	30	2,206	916	55,578,430	33,903,281	89,481,711
Transformers	40	123	31	7,193,178	907,496	8,100,674
Compensating devices	50	105	8	1,451,938	21,845	1,473,783
Series compensations	60	56	13	1,888,656	249,201	2,137,857
Control centers	70	3	0	220,341	152,979	373,320
Other installations	90	1	0	0	0	0
TOTAL				216,244,345	48,578,367	264,822,713

2.1 Capex-break

In the gas benchmarking, one operator was subject to the capex-break method described in the main report. However, the application was not made to prevent an infeasible target, but to avoid an absurd datapoint. In the particular case, using the official inflation metric for the entire investment stream would lead to a Capex value that exceeds the sum of all Capex in the sector, or 10,000 times higher than the actual regulatory asset base (RAB) for the operator! Obviously, the early inflation values in this country do not correspond to a realistic assessment of the network capital valuation. By using capex-break, a new value relatively close to the actual comparable value was calculated.

In the electricity benchmarking, no operator was subject to capex-break.

2.2 Capex-old

The assets prior to 1973 still operating at the reference year provide output in terms of NormGrid, but the investment stream is not reported. To compensate for this, the CapexBreak methodology above has been applied to calculate a corrective term with equal unit cost to the period 1973-2017. This means that the added Capex does not change the investment efficiency for the evaluated operator, it merely assures equal consideration of prior investments for operators with longer or shorter investment streams.

In the case of TenneT the CapexOld value is calculated to 20,692,619 EUR. The correction is capped to 11,497,440 EUR corresponding to the reported pre-1973 investment.

2.3 Model input and output

The single input (Totex) and the relevant outputs for the benchmarking model for TenneT are listed in Table 2.6 below. The exact calculation of the inputs and outputs is documented in the separate confidential spreadsheets provided for each TSO on the project platform.

Table 2.6: Model data year 2017

Type	Name	Value	Mean	TSO/mean
Input	dTotex.cb.hicpog_plici	321,242,361	290,928,519	1.10
Output	yNG_yArea	338,973,131	304,572,352	1.11
Output	yTransformers_power	39,990	44,303	0.90
Output	yLines.share_steel_angle_mesum	1,967	2,096	0.94

Chapter 3

Regression analysis

The robust regression results for the final model are presented below. The dependent variable is as before *dTotex.cb.hicpog_plici*. Regression results for alternative models and variants were presented at project workshops W4 and W5.

Table 3.1:

	Dependent variable:
	refmod[[rfm]]
yNG_yArea	0.302^{***}
	(0.047)
yTransformers_power	$4{,}196.088^{***}$
	(208.079)
yLines.share_steel_angle_mesum	$16{,}770.490^{***}$
	(2,986.596)
Observations	81
R^2	0.981
Adjusted R^2	0.980
Residual Std. Error	59,571,597.000 (df = 78)
Note:	*p<0.1; **p<0.05; ***p<0.01

Chapter 4

Sensitivity analysis

4.1 Scale efficiency

The productive efficiency depends on a multitude of factors, including the scale of operations. In DEA, the model can easily calculate these effects through the concept of different assumptions of returns to scale. In Figure 4.1 a reference set of four points is analyzed. Using constant returns to scale (CRS), only operator B is deemed cost efficient, located at the most productive scale (MPS). Thus $DEA_{CRS}(B) = 1$. The smaller operator A has a lower cost-efficiency than B, operating at an inefficient scale, $DEA_{CRS}(A) < 1$. However, as discussed above, a smaller scale may be imposed by a national border and/or a concession area, beyond the control of the operator. Thus, the frontier assumption of increasing returns to scale (IRS) or non-decreasing returns to scale (NDRS) illustrated by the red curve in 4.1 renders A fully efficient; $DEA_{IRS}(A) = 1$. Finally, an operator such as C that is CRS-inefficient but above optimal scale is also inefficient under IRS, but efficient under variable returns to scale (VRS), i.e. $DEA_{CRS}(C) = DEA_{IRS}(C) < 1$ and $DEA_{VRS}(C) = 1$. VRS is the weakest assumption available, it assumes both diseconomies of scale for small and large units. In network operations the diseconomies of size (e.g. congestion), are not considered relevant. However, the results allow the calculation of the economy of scale effect through the formula:

$$DEA_{SE}(k) = \frac{DEA_{CRS}(k)}{DEA_{VRS}(k)} \tag{4.1}$$

The actual scale efficiency results for the electricity transmission system operators in TCB18 are given in Table 4.1 and in Figure 4.2 below.

Table 4.1: Scale efficiency DEA(SE)

	Mean eff	#scale-efficient
All TSO	0.964	7
TenneT	0.959	0

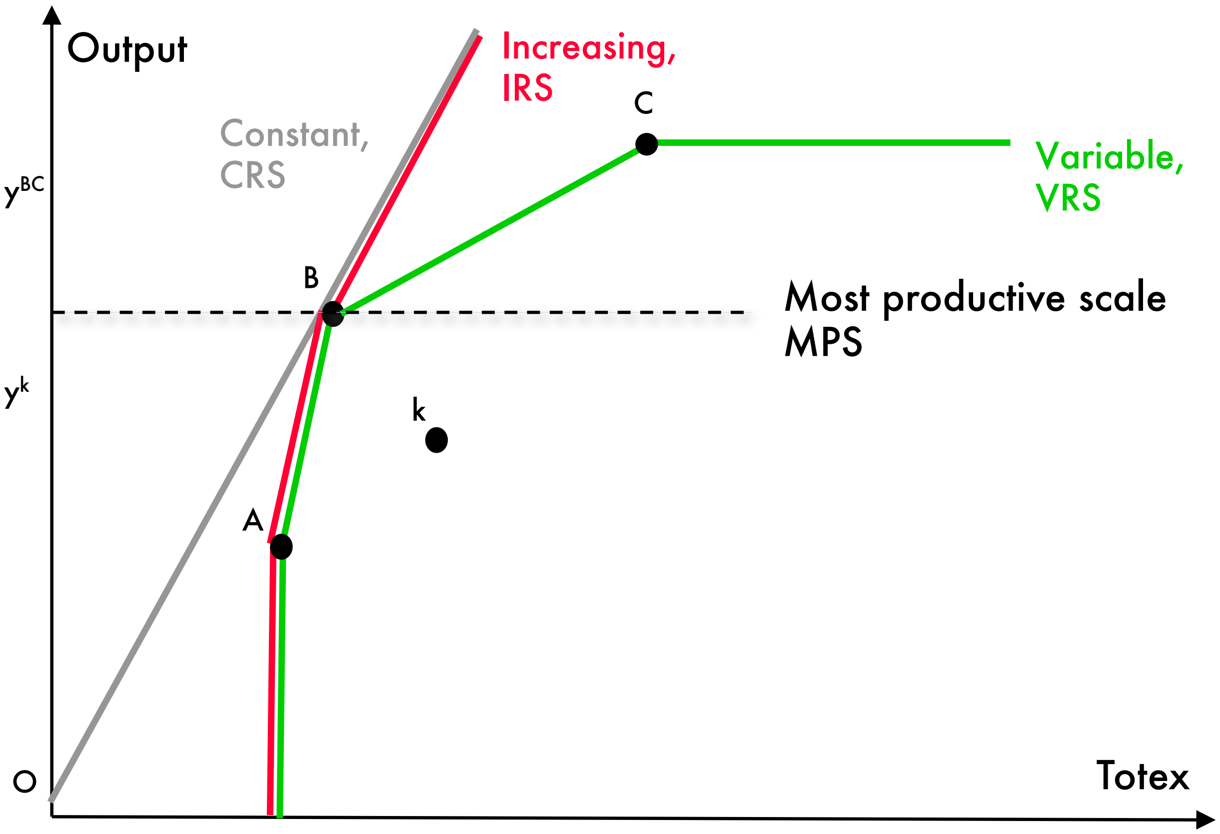

Figure 4.1: DEA frontiers CRS, IRS and VRS and scale efficiency (SE).

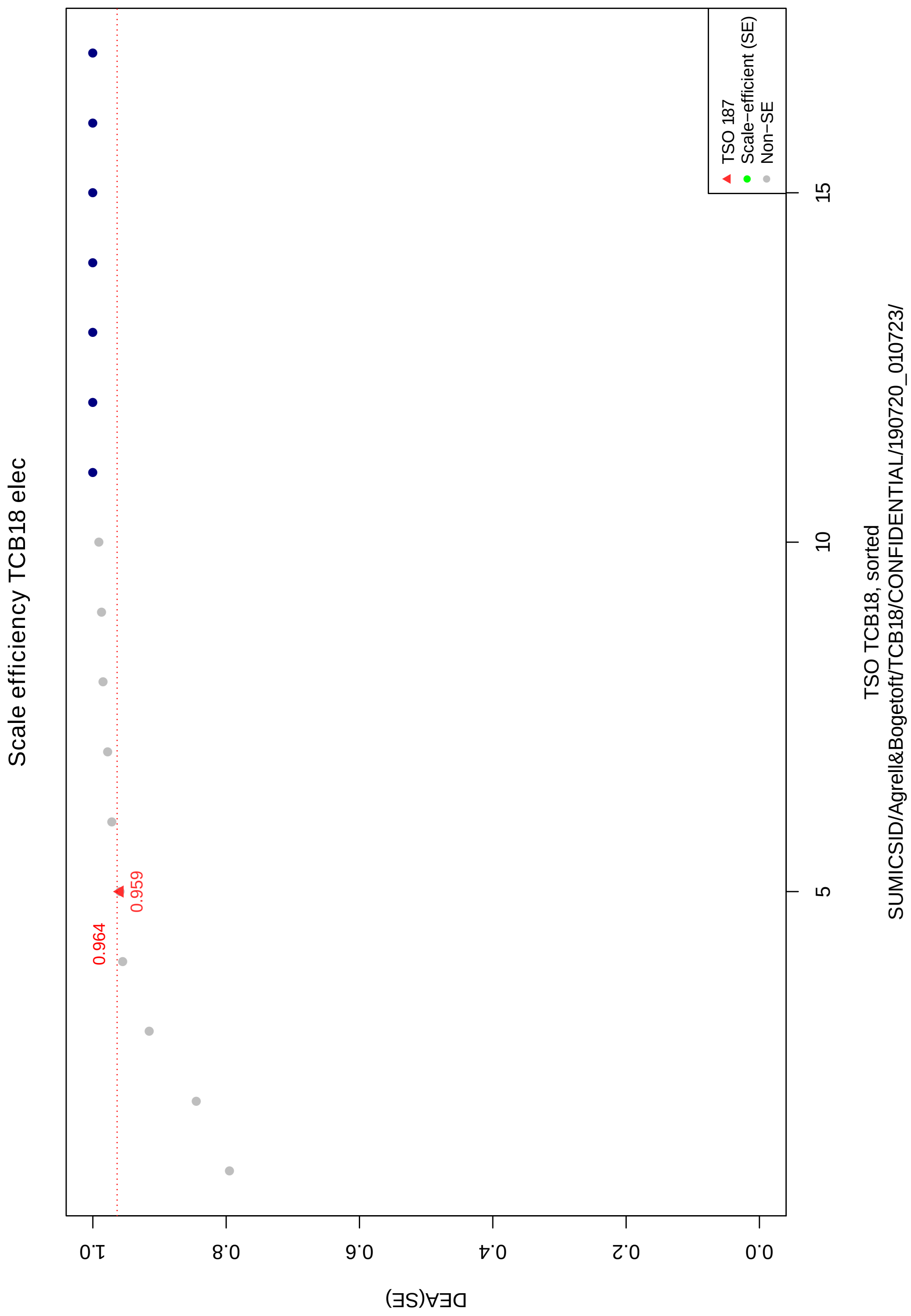

Figure 4.2: Scale efficiency, $DEA_{SE}(k)$.

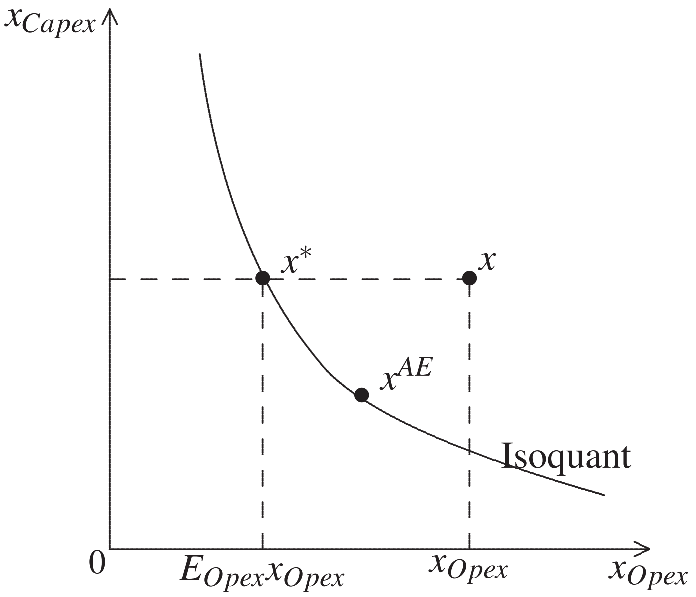

Figure 4.3: Opex efficiency E_{Opex} with fixed Capex.

4.2 Partial Opex-capex efficiency analyses

In regulatory benchmarking, it is common to focus on Totex efficiency. The question is whether TSOs can provide the same level of services with less Totex. To evaluate this, one needs a model with one input, Totex, and the usual cost drivers as outputs.

Now, Totex is the sum of Opex and Capex,

$$Totex = Opex + Capex$$

and one may therefore ask how much the TSOs could save on Opex (with fixed Capex) or on Capex (with fixed Opex). This is what we call Opex and Capex efficiency. To evaluate this, we need a model with two inputs (Opex and Capex) and the usual cost drivers.

Figure 4.3 illustrates the idea of Opex Efficiency where we project horizontally (on Opex) for a fixed level of Capex (vertical axis).

Capex efficiency is similar except that we project the observed Opex-Capex combination $x = (Opex, Capex)$ in the vertical direction for a fixed Opex level.

It follows from these definitions that all points on the input isoquant will be fully efficient from a partial Opex as well as a partial Capex perspective. This does not mean that all the points are fully Totex efficient however. In the illustration, the sum of Opex and Capex is only minimal at one point on the isoquant, namely x^{AE}.

In our analysis, we do not know the location of the isoquant. Instead we estimate the location using Data Envelopment Analysis. This means that the isoquant becomes piecewise linear like in Figure 4.4 below with corresponding values in Table 4.2.

It also means that there will typically be quite a large number of TSOs on the estimated frontier and in consequence a large number of TSOs that cannot save Opex given Capex and vice versa. However, this does not necessarily mean that they are all Totex efficient. Note in the numerical example that only TSO C is Totex efficient, as can easily be seen also from the table. Notwithstanding, TSOs A, B, C, and D are all fully Opex and Capex efficient.

To sum up, TSOs that are Opex- and Capex-efficient cannot save Opex for fixed Capex, nor Capex for fixed Opex. However, this does not imply that they cannot save on Totex. The reason is that the mix between Opex and Capex may not be optimal. A TSO like D in the numerical example can save a lot of Opex, but it requires a small increase in Capex.

Note that in Fig. 4.5-4.7 a single point in the graph may represent multiple operators with the same value, the graphs contain all participating operators.

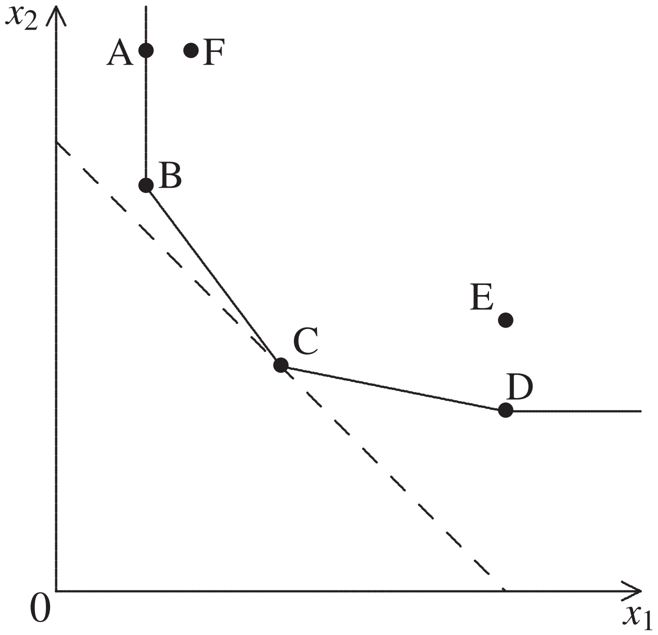

Figure 4.4: Partial Opex- and Capex-efficiency: numerical example.

Table 4.2: Partial opex-capex efficiency: numerical example.

TSO	Opex	Capex	Output	Totex
A	2	12	1	14
B	2	9	1	11
C	5	5	1	10
D	10	4	1	14
E	10	6	1	16
F	3	12	1	15

Table 4.3: Partial DEA scores year 2017

	DEA(Opex)	DEA(Capex)
All TSO	0.902	0.885
TenneT	0.529	0.433

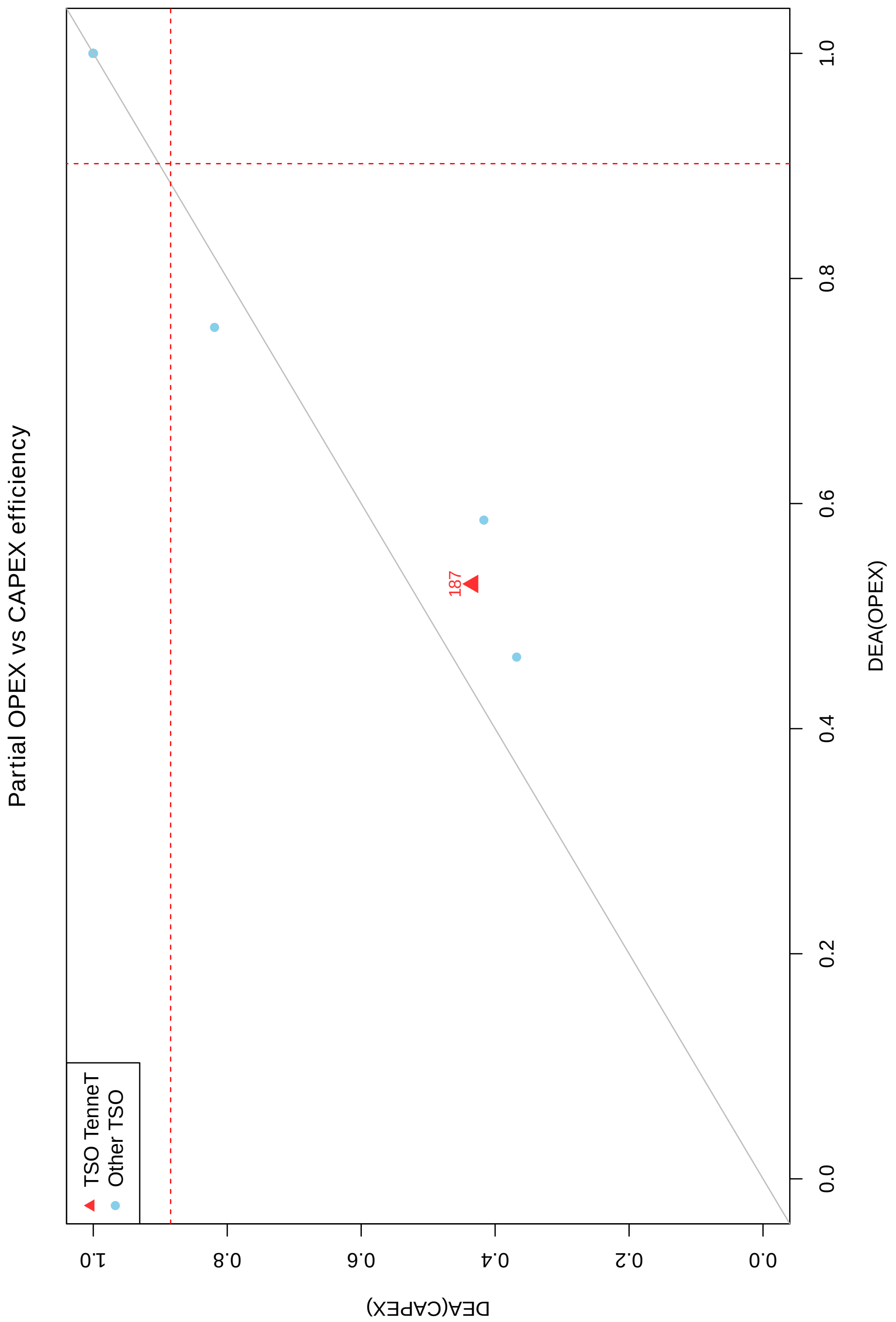

Figure 4.5: Partial OPEX and CAPEX efficiency in TCB18 (red dashed line=mean).

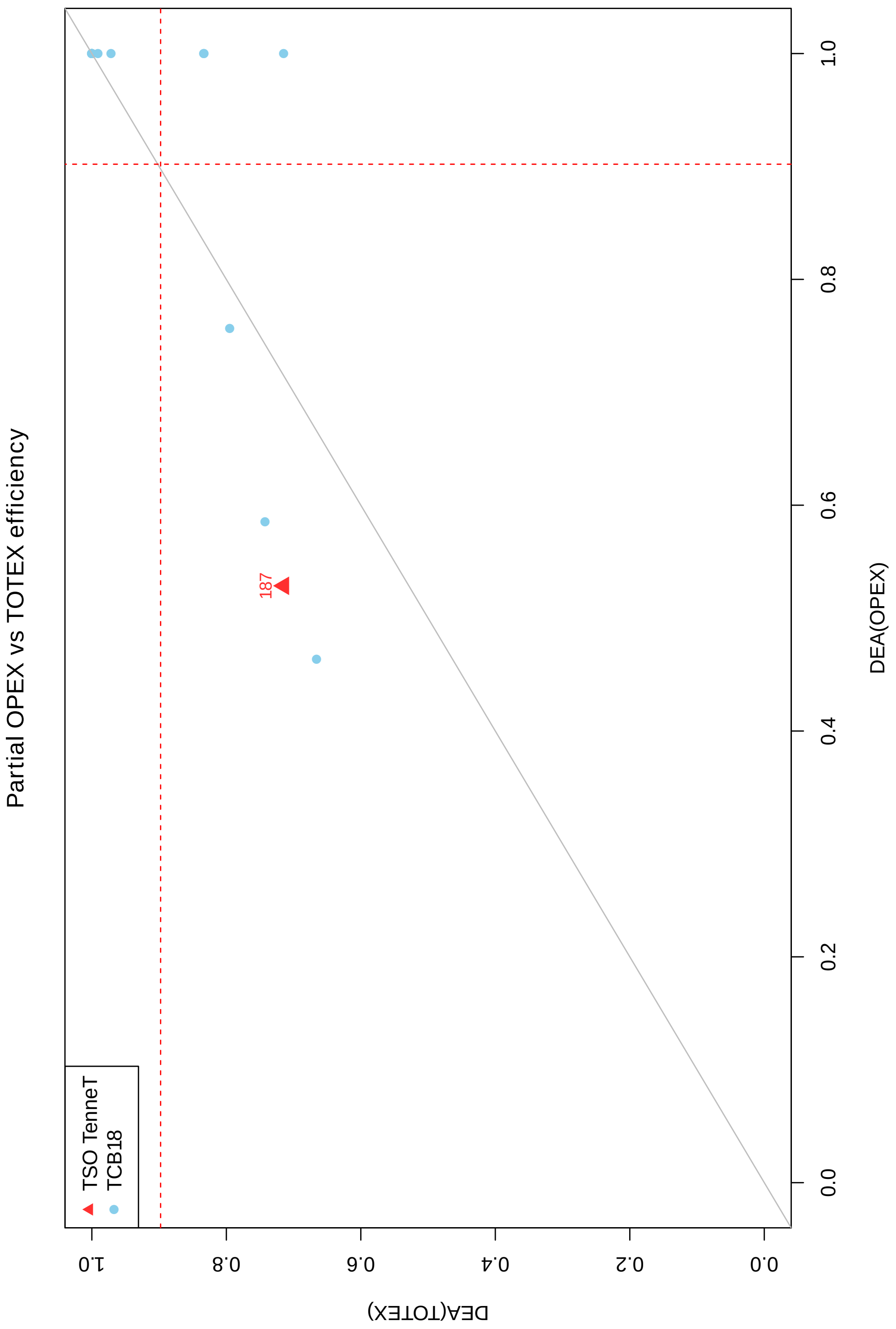

Figure 4.6: Partial OPEX vs TOTEX efficiency in TCB18 (red dashed line=mean).

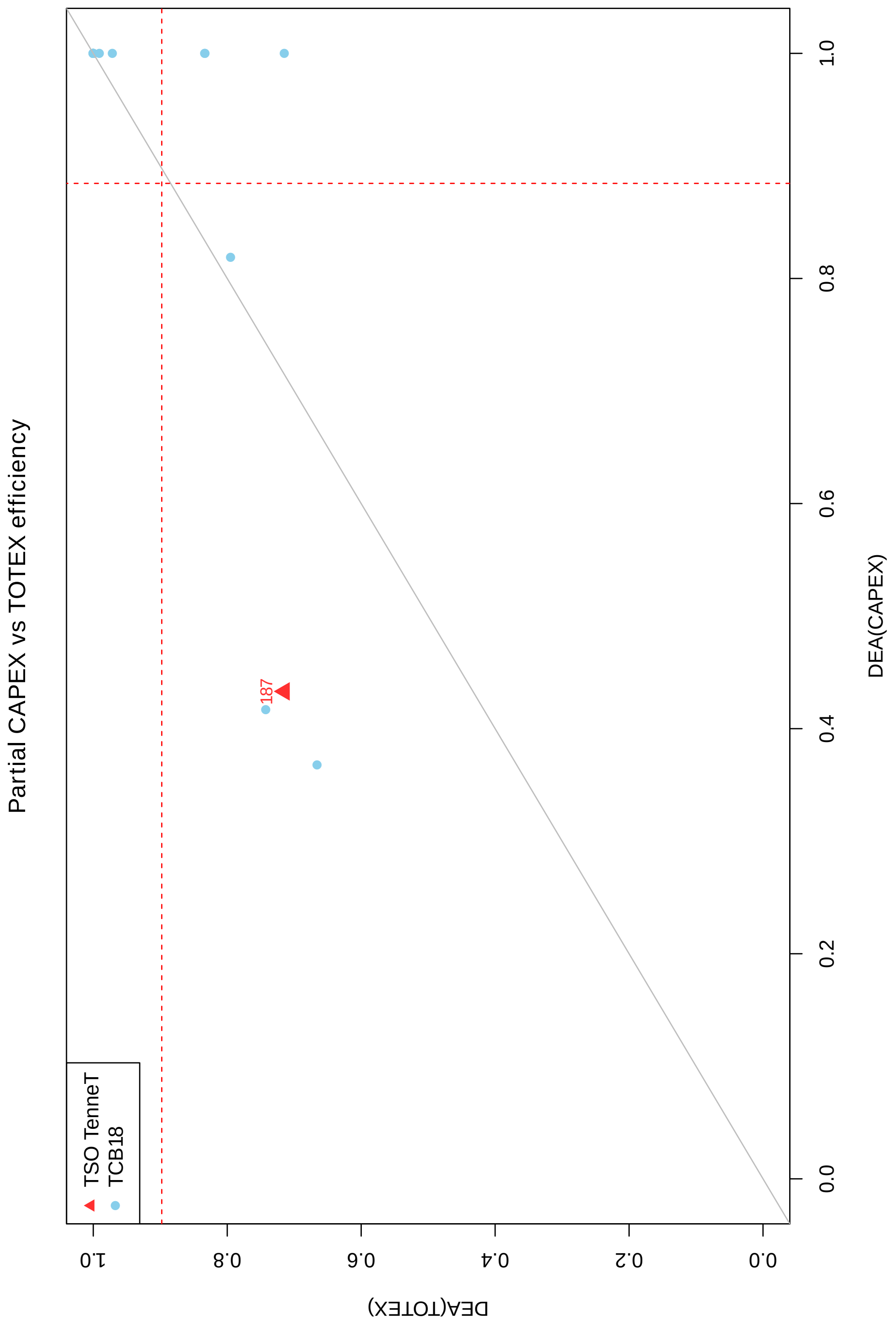

Figure 4.7: Partial CAPEX vs TOTEX efficiency in TCB18 (red dashed line=mean).

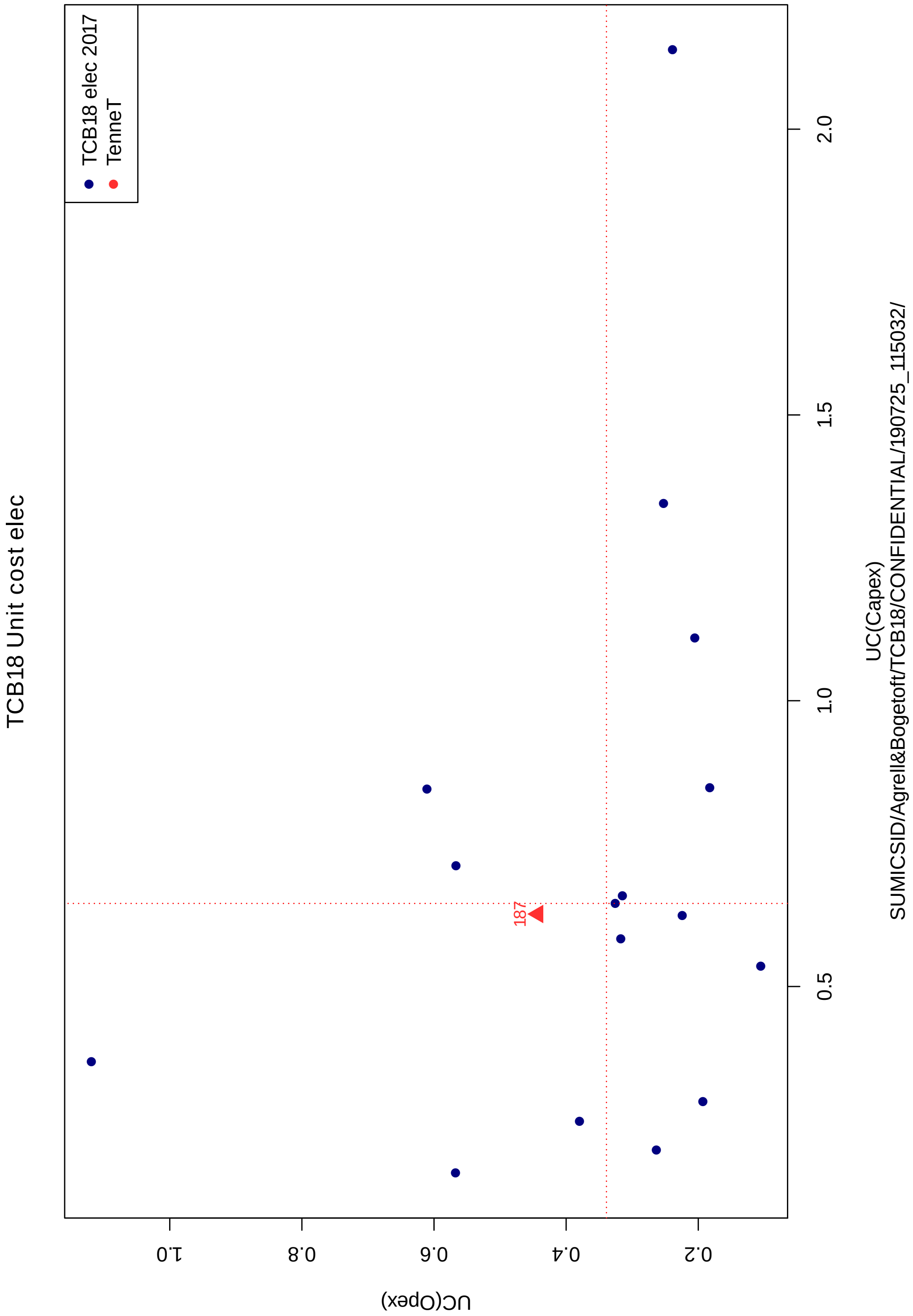

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Figure 4.8: Unit cost UC(Opex) vs UC(Capex).

4.3 Sensitivity analysis

The calculated cost functions are proportional to a number of parameters, e.g. the NormGrid weights. However, since a frontier benchmarking is an investigation into relative, not absolute, changes, the scales of the inputs and outputs are not important. The relevant evaluation in this context is whether a change in a technical parameter would lead to changes in the relative ranking or level of the benchmarked units. To investigate this aspect, the following model parameters have been varied and the resulting changes in the efficiency score for TenneT are illustrated in the following graphs

Tested parameters

1. Interest rate, Fig. 4.9
2. Normgrid weights: calibration between Opex and Capex parts, Fig. 4.10
3. Normgrid weights: calibration for transport assets, Fig. 4.11
4. Normgrid weights: calibration for compressor/transformer assets, Fig. 4.12
5. Age assumptions for standardized life time, Fig. 4.13
6. Salary corrections for capitalized labor in investments, Fig. 4.14

For the analyses 1-4, a specific parameter w is varied using a factor k from 20% (-80%) to 200% (+100%) multiplied with the base value for the parameter, w_0. All other parameters remain at their base value, used for the final run. The graph then shows the efficiency score $DEA(kw_0)$ and the mean efficiency in the dataset.

Analysis 5 in Fig. 4.13 looks at the impact on the score of the assumptions regarding the standardized life time per asset. For simplicity, we have reduced the simulation to two alternative cases, Age_{low} and Age_{high}, respectively with correspondingly about 10 years shorter and longer lifetimes. The exact parameters are reproduced in Table 4.4 below.

Table 4.4: Standard age variants (years)

	Age-Low	Base case	Age-High
Overhead lines	50	60	70
Cables	40	50	60
Circuit ends	35	45	55
Transformers	30	40	50
Compensating devices	30	40	50
Series compensations	30	40	50
Control centers	20	20	30
Other installations	20	20	30
Substations	30	40	50
Towers	30	40	50

Analysis 6 in Fig. 4.14 concerns the possible adjustment for local labor costs in the investment stream. Here, we simulate a part a of the total gross investment stream to be constituted of labor costs corrected using the $PLICI$ index used in the study. The labor part ranges from 0% (base case) to 25% of the full investment value.

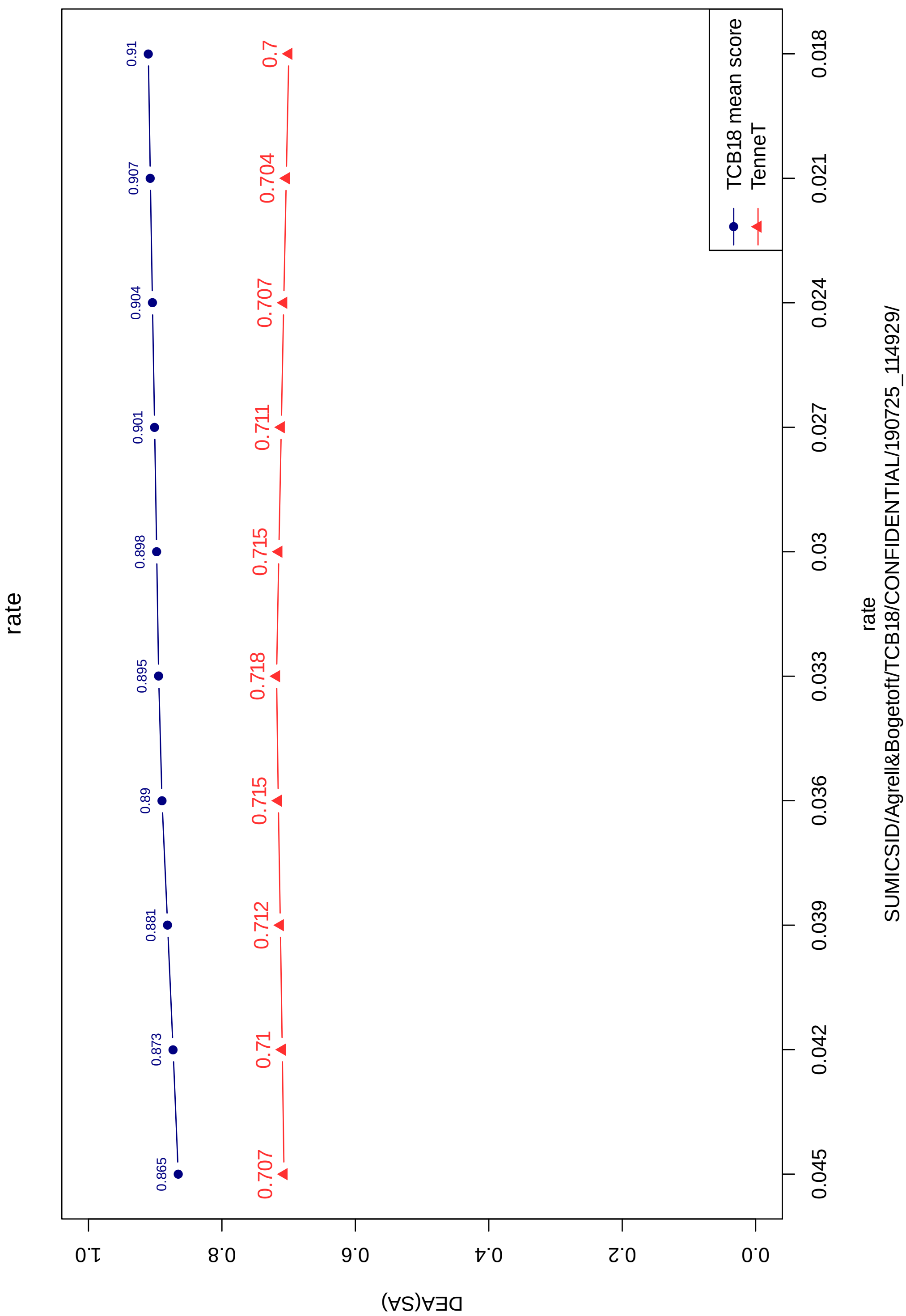


Figure 4.9: Average and operator-specific DEA-score as function of interest rate.

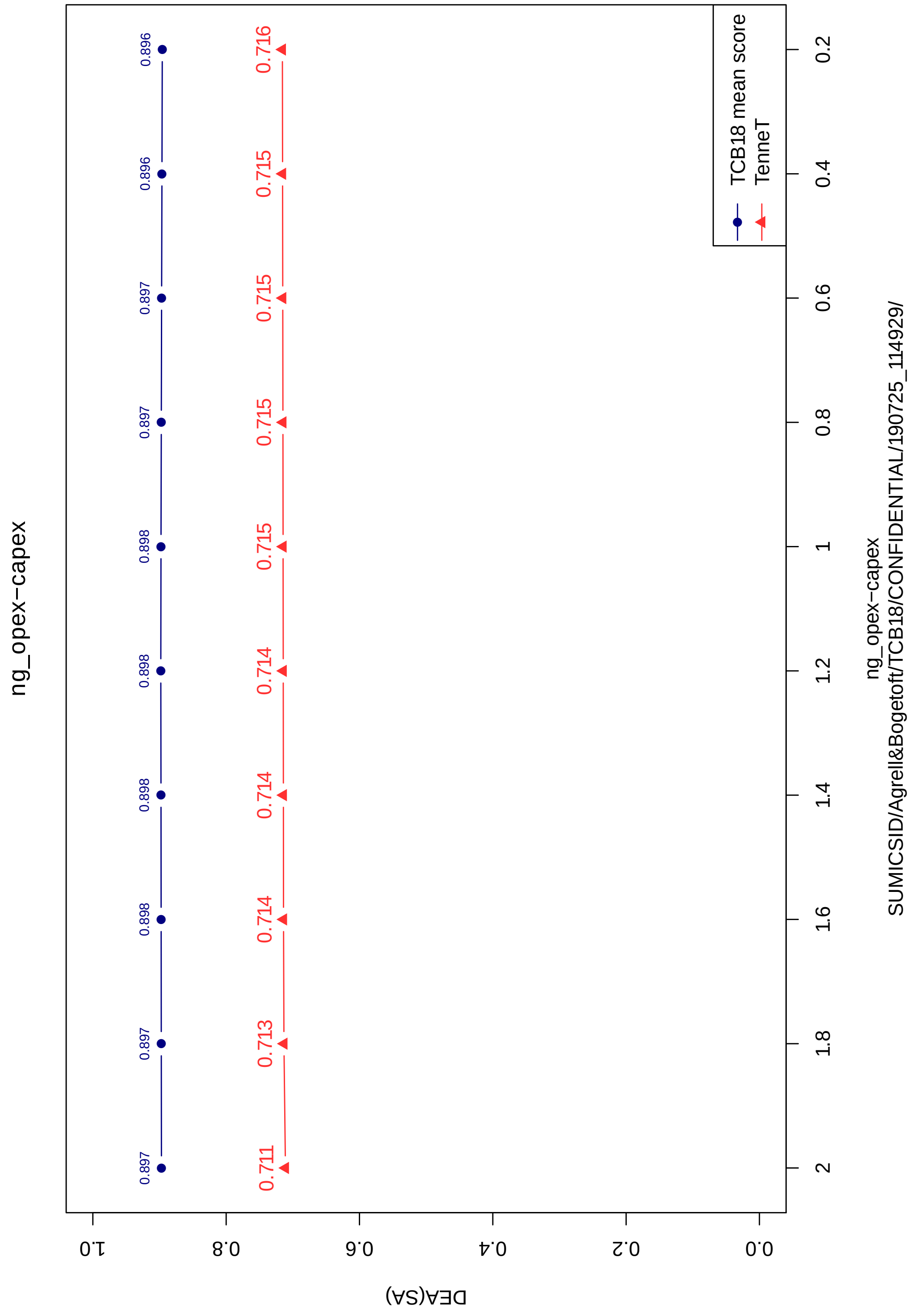


Figure 4.10: Average and operator-specific DEA-score as function of calibration NormGrid opex vs capex (-80pct, + 100pct)

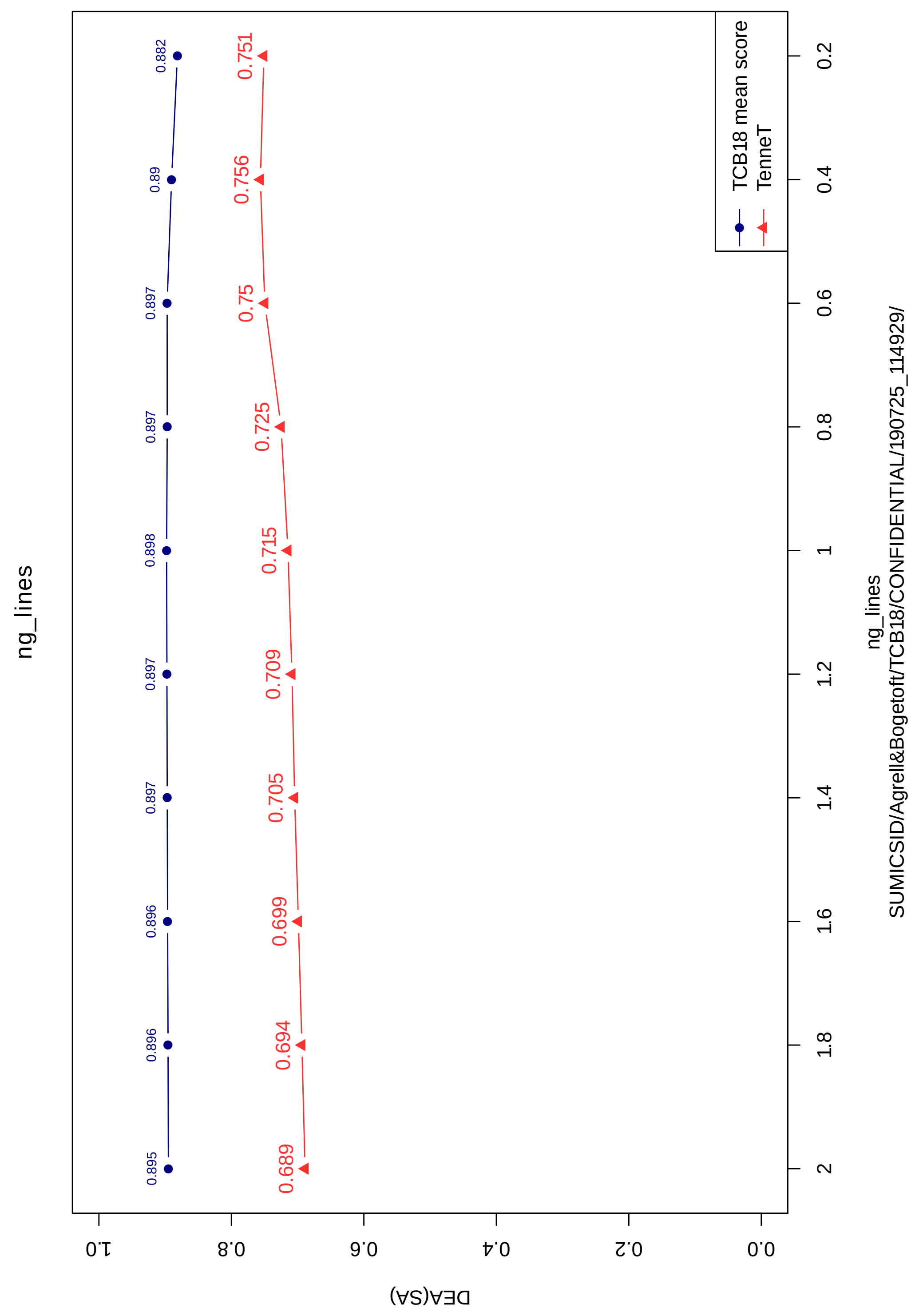


Figure 4.11: Average and operator-specific DEA-score as function of calibration NormGrid for lines (-80pct, + 100pct)

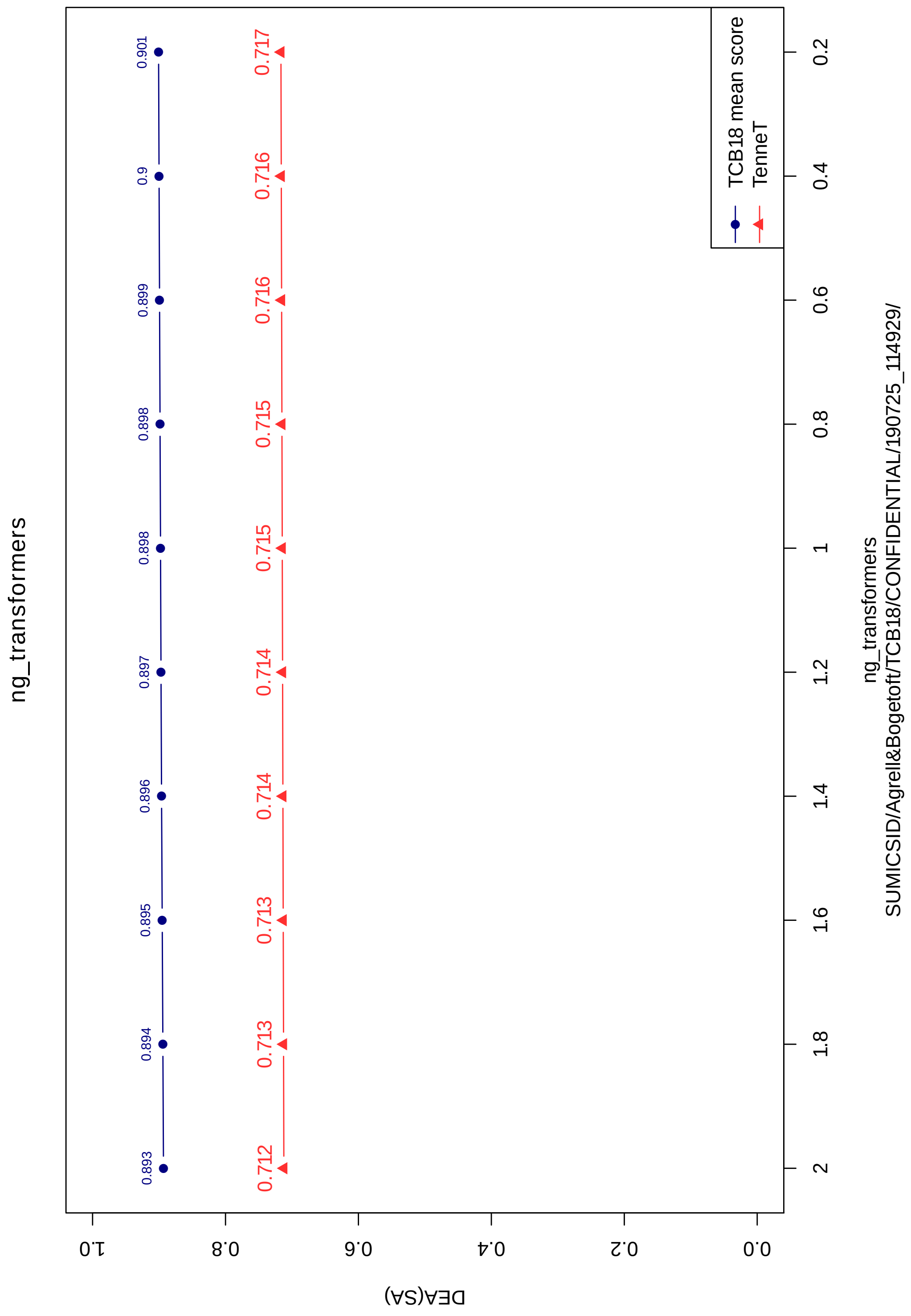


Figure 4.12: Average and operator-specific DEA-score as function of calibration NormGrid for transformers (-80pct, + 100pct)

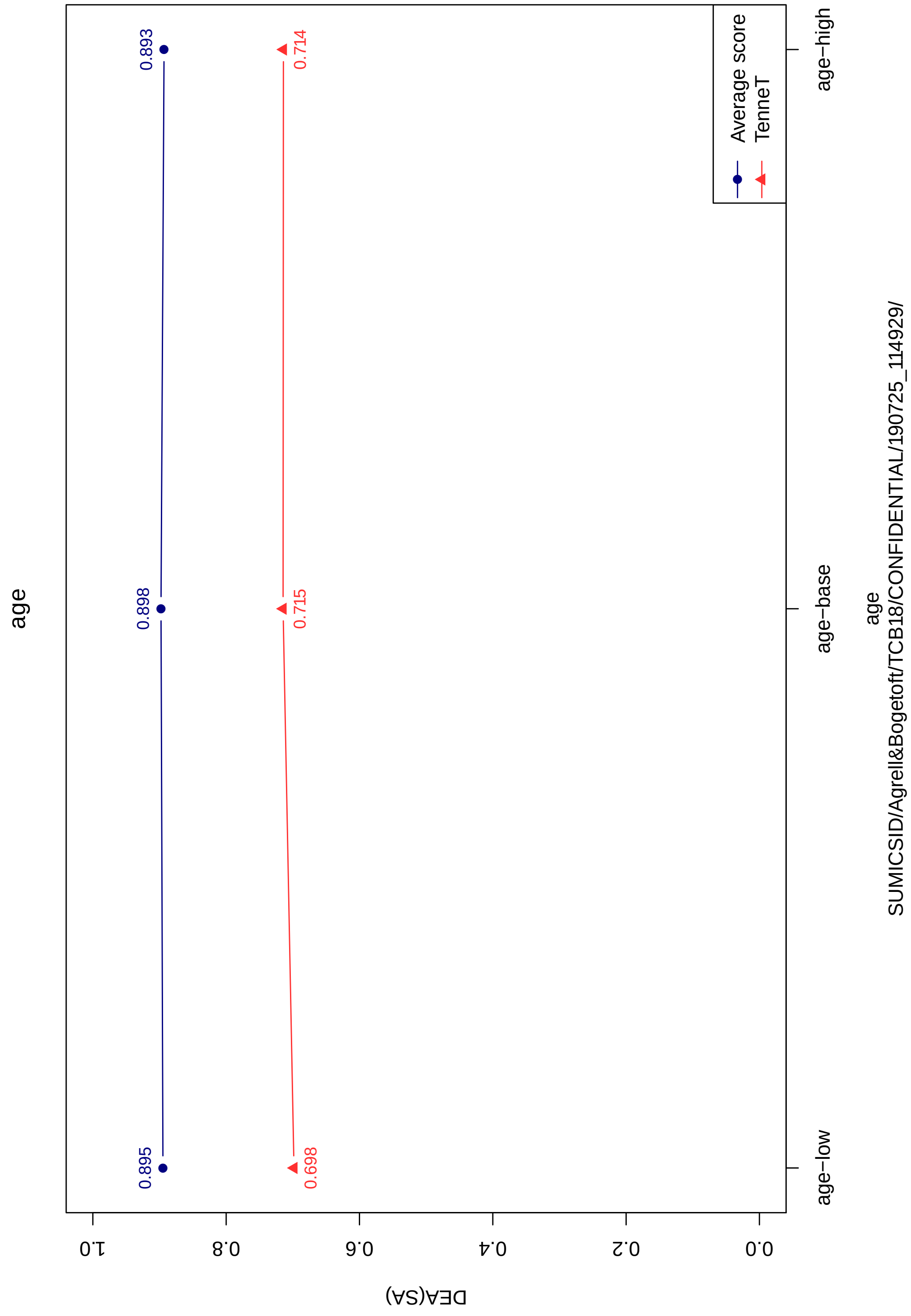


Figure 4.13: Average and operator-specific DEA-score as function of standard lifetimes (age-low = shorter lives, age-base = base case, age-high = longer lives)

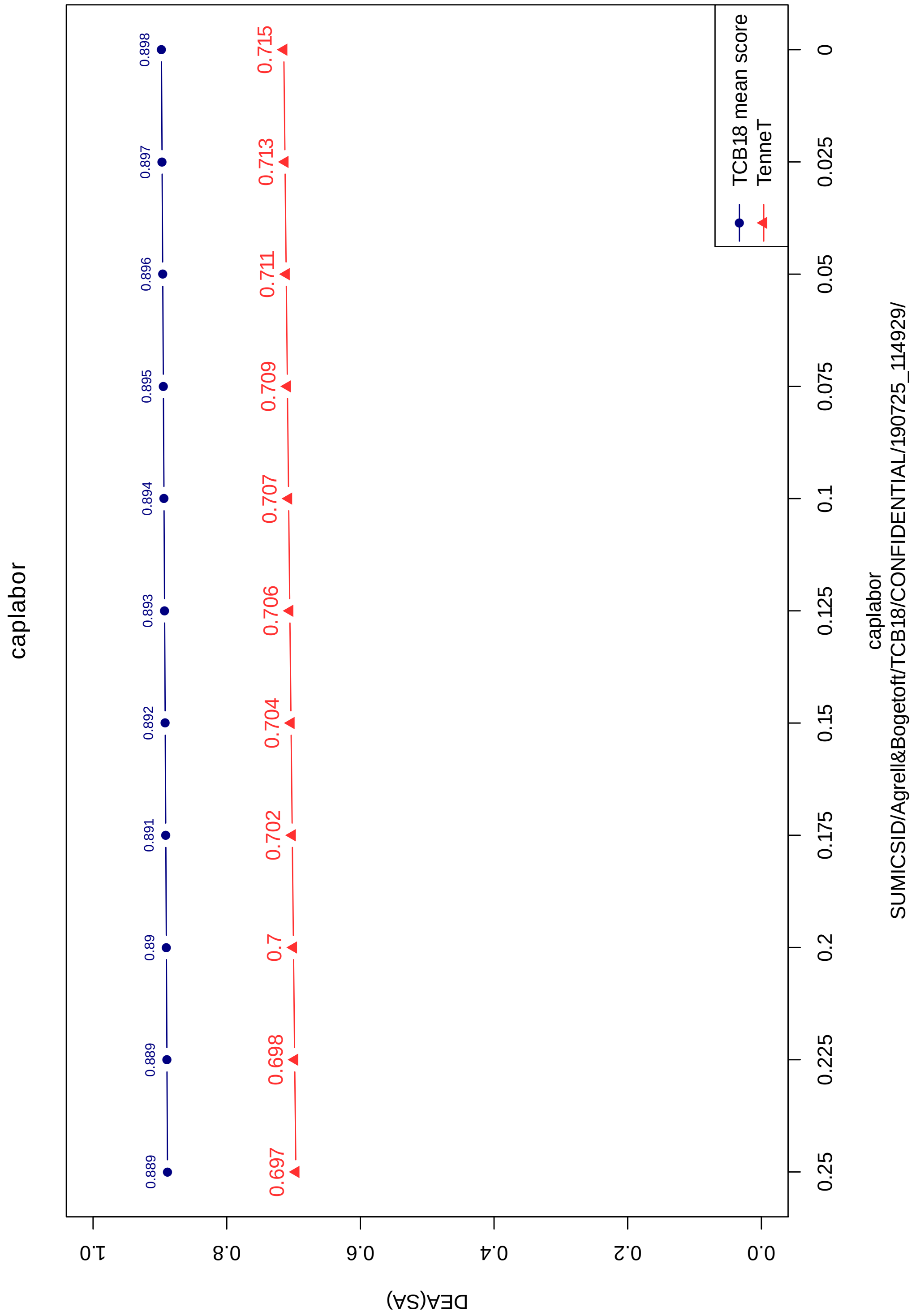


Figure 4.14: Average and operator-specific DEA-score as function of share of investments adjusted for local labor costs (0pct = base case to 25pct).

4.4 Profile

The specific profile of TenneT compared to the other operators in TCB18 is illustrated in Figures 4.15 and 4.16:

- The relative gridsize in Fig. 4.15 depicts the NormGrid sizes of the reference set, scaled such that the mean is set to 100. This analysis gives an impression of the scale differences in the benchmarking.
- The output profile in Fig. 4.16 gives a graphical image of the magnitude of the inputs and outputs for TenneT in red compared to the range of those in TCB18. A value of 100 here corresponds to the highest in the sample, a value of 0 is the smallest, respectively. The median values are indicated in blue.

The routing complexity is analyzed in 4.17 below. TenneT is marked with a red triangle and the share of angular towers below.The figure graphs the circuit length tower on the vertical axis, potentially indicating either a technical choice of smaller towers or topographical challenges (slope, subsoil quality, other obstacles).On the horizontal axis we plot the share of angular towers to the total number of towers. This indicates the routing complexity in terms of landuse and infrastructure obstacles. The output variable yLines.share-steel-angle-mesum is plotted in 4.18 below with TenneT marked as a red triangle. This figure can be compared to the gridsize figure in 4.15, illustrating how routing complexity affects the output variable.

4.5 Age

The age profile of the European operators in comparison to TenneT is illustrated in the Figures 4.19 and 4.20 below.

In Figure 4.19 the ages for all assets in the electricity dataset have been processed as a confidence interval, the yellow box marks the mean in bold black, the box edges are 25% and 75% quartiles and the outer whiskers are limits for one standard deviation up or down, respectively. The mean ages for the assets per type for TenneT are indicated with a red triangle and a (rounded) number. A circle to the left or right of the confidence interval box indicates an outlier.

In Figure 4.20 we investigate the prevalence of very old (pre-1973) assets that are still used in 2017. The average share of capital for different asset types (symbols) is graphed on the horizontal axis. The share of capital for pre-1973 assets is given on the vertical axis. The respective asset ages for TenneTare depicted using red symbols, the blue symbols depict the mean age and shares, respectively, in the TCB18 project. If the red symbols are located north-east on the corresponding blue symbol, it means that your assets are both relatively older and also that the asset type represents a higher importance than for the mean operator.

4.6 Cost analysis

In this section we analyze the staff profile, the functional costs and the overhead allocation share for TenneT compared to the electricity operators in TCB18. The cost analysis is purely informative and does not intervene as such in the benchmarking. In Fig.4.21 the mean staff intensity SI_f for all operators is presented using the NormGrid per activity f:

$$SI_f = mean_k\{\frac{Staff_{fk}}{NormGrid_k}\} \tag{4.2}$$

where $Staff_{fk}$ is the staff count (fte) for activity f for operator k and $NormGrid_k$ is the sum of the NormGrid for operator k in the corresponding year. This intensity is then used to obtain a size-adjusted comparator for the mean staff in the sample, SC_{fk}, scaled to the size of TenneT, i.e. $k = 187$ here:

$$SC_{f,187} = SI_f NormGrid_{187} \tag{4.3}$$

In Fig 4.22 the allocation key for indirect expenditure (I) is based on total expenditure per activity excluding energy and depreciation, i.e. the graph can also be interpreted as the relative shares of expenditure by function. In Fig 4.23 we graph the actual allocation of indirect expenditure to the benchmarked activities T,M,P per operator, along with the mean allocation in the sample.

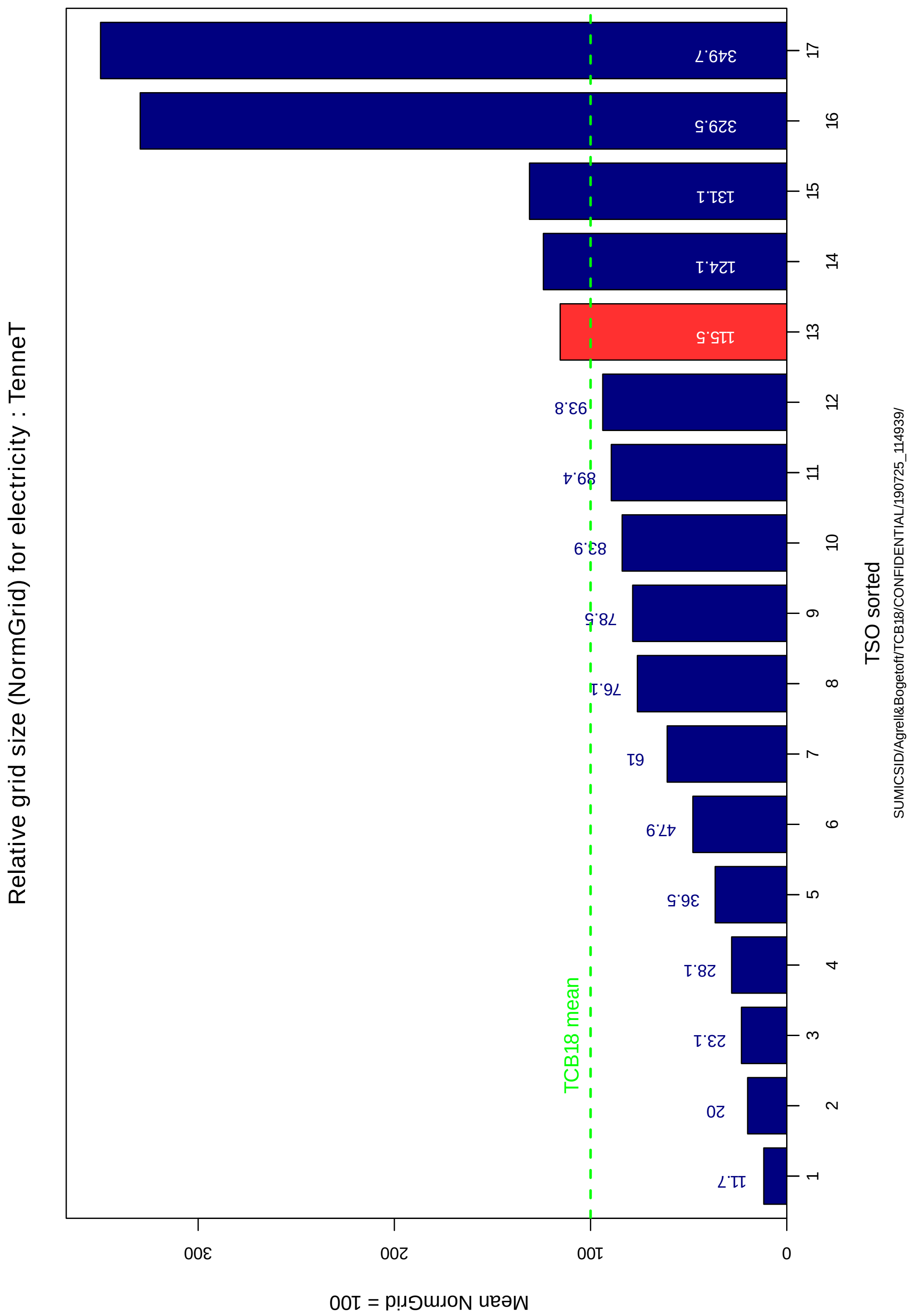


Figure 4.15: Relative gridsize in TCB18, (100=mean level in 2017).

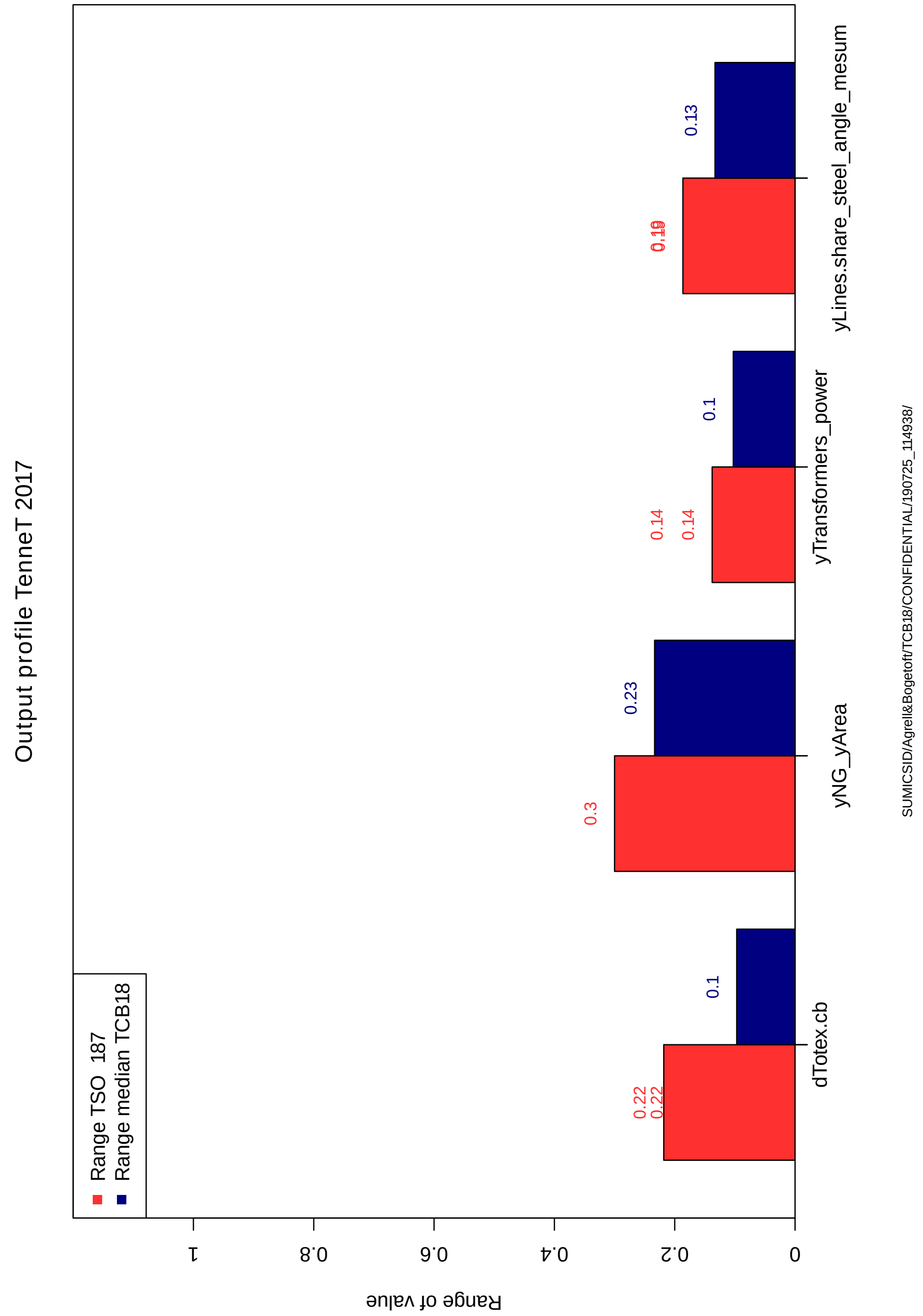
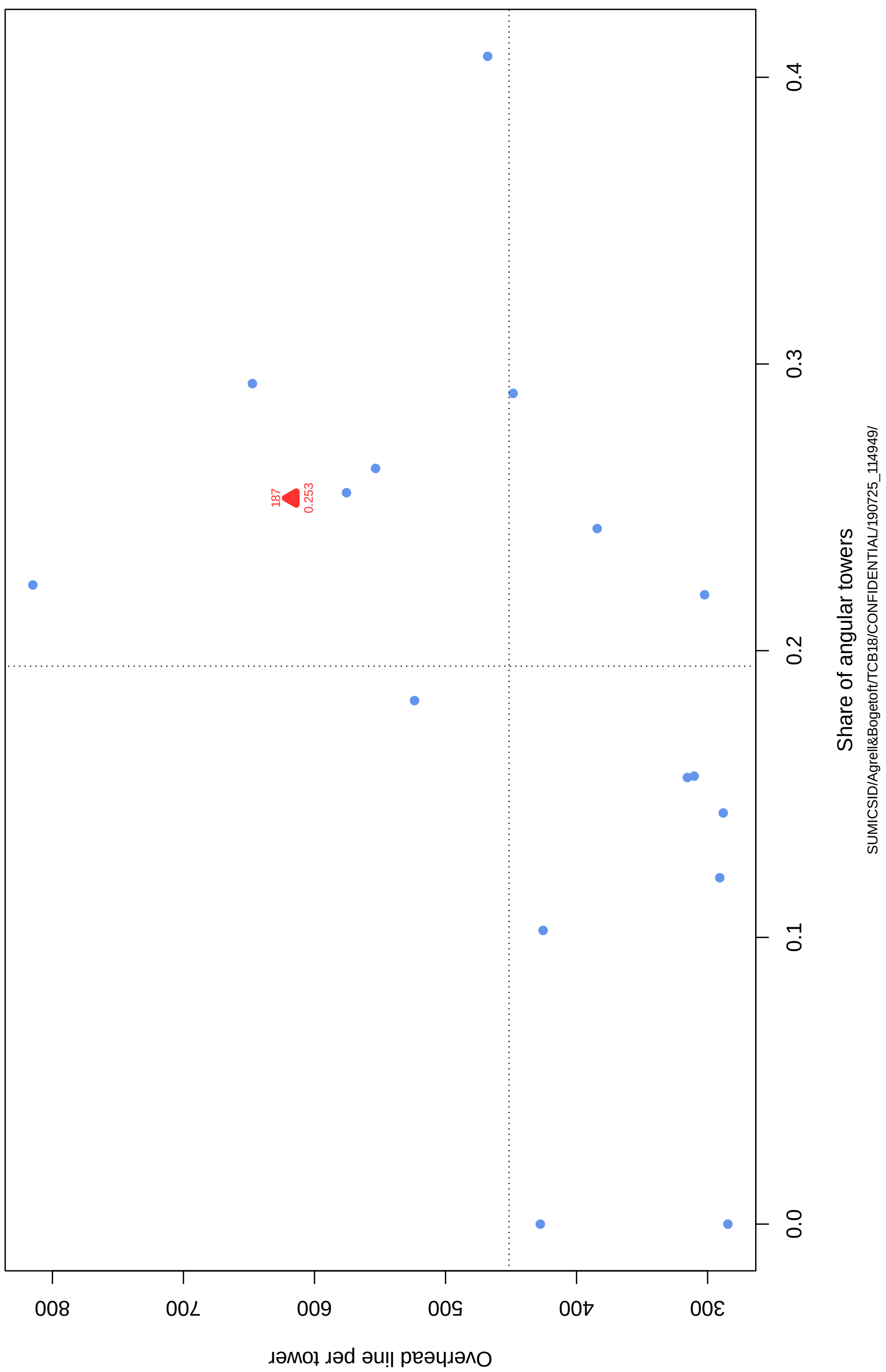


Figure 4.16: Inputs and outputs compared to median range in TCB18 (0.0 = minimum, 1.0 = maximum).



SUMICSID/Agrell&Bogetoft/TCB18/CONFIDENTIAL/190725_114949/

Figure 4.17: Linelength per tower and share of angular towers 2017.

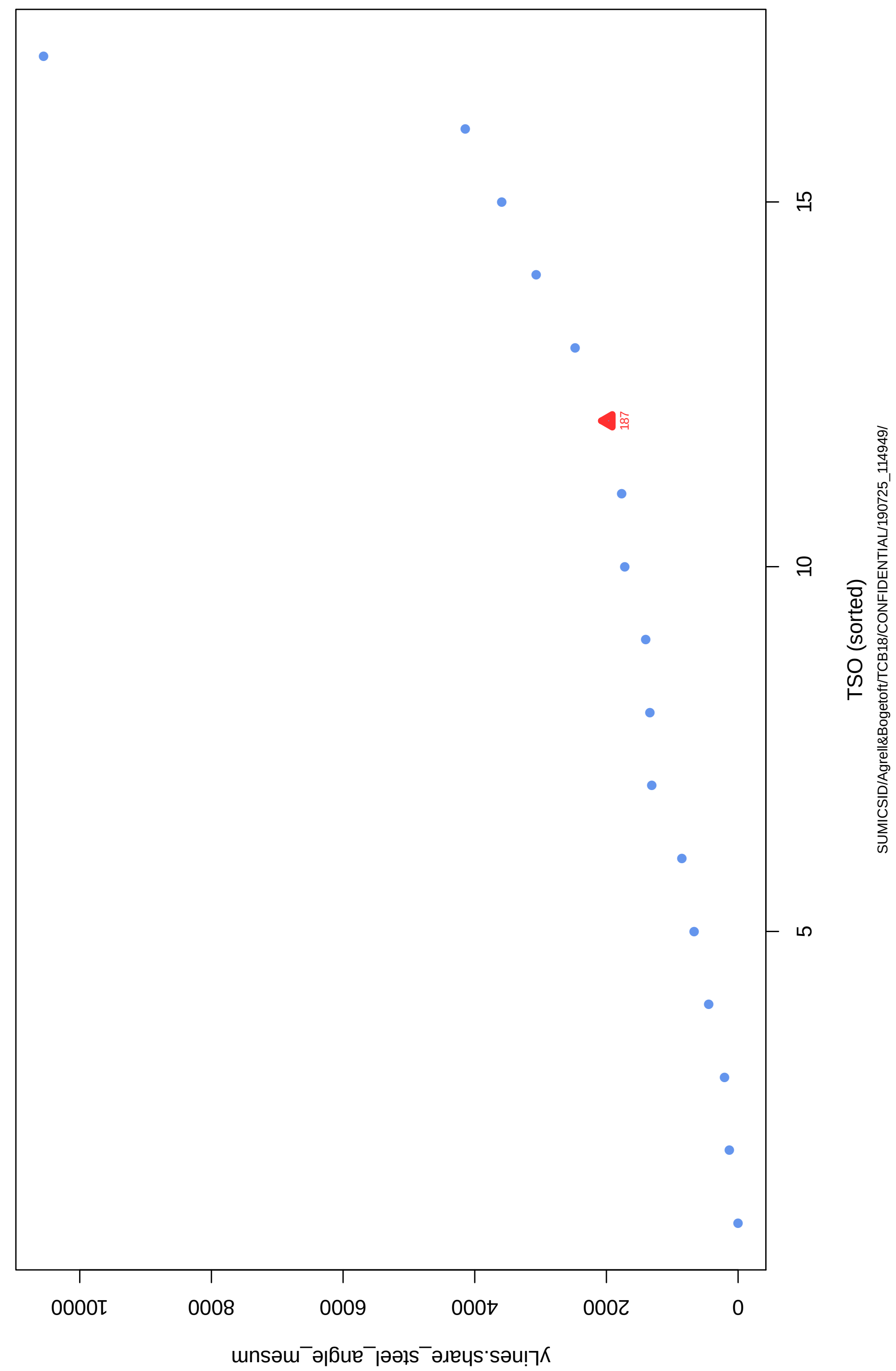


Figure 4.18: Output yLinesShareSteelAngleMesum, sorted in absolute value.

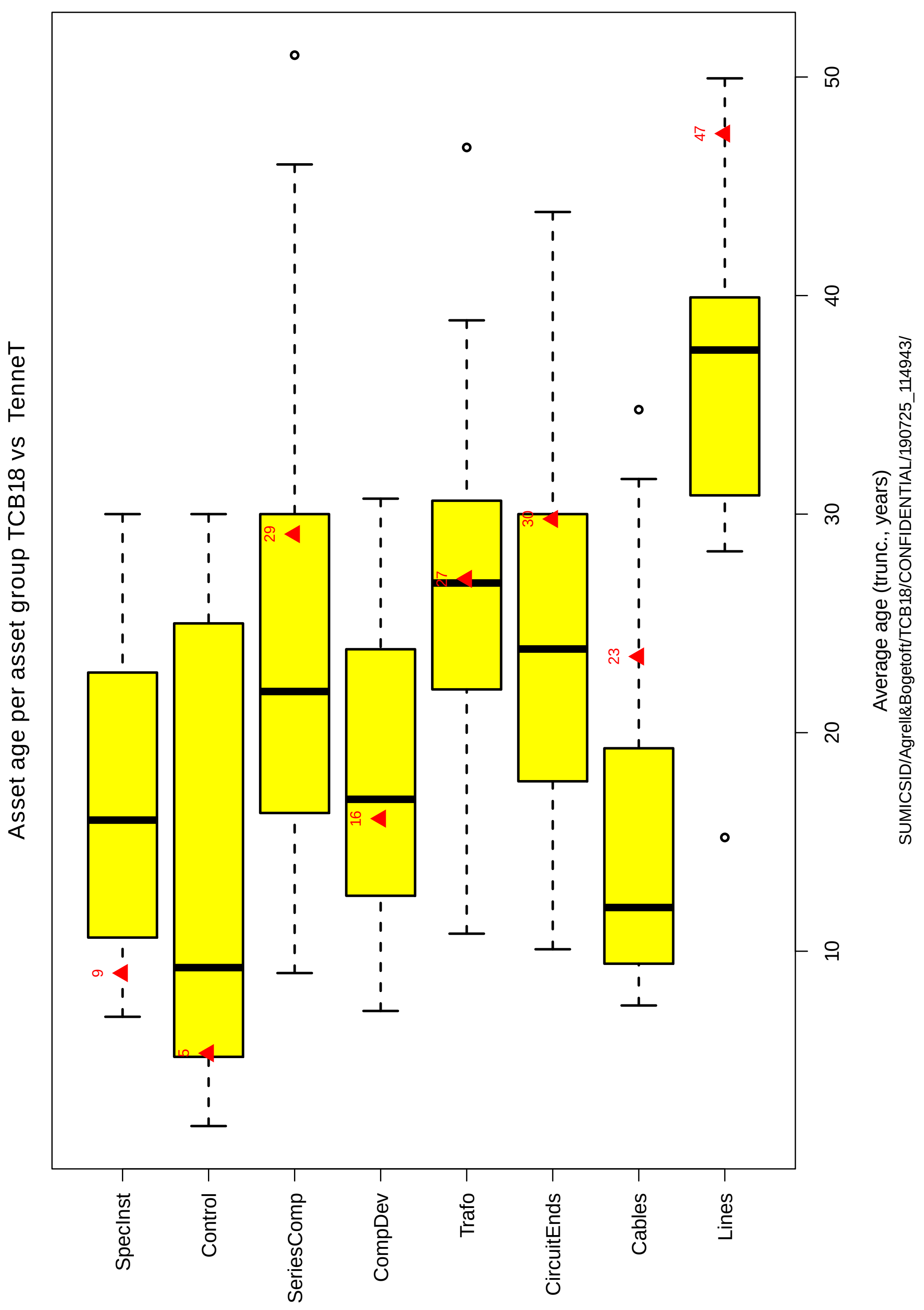


Figure 4.19: Asset ages (confidence interval) for all TCB18 and mean age for a specific operator.

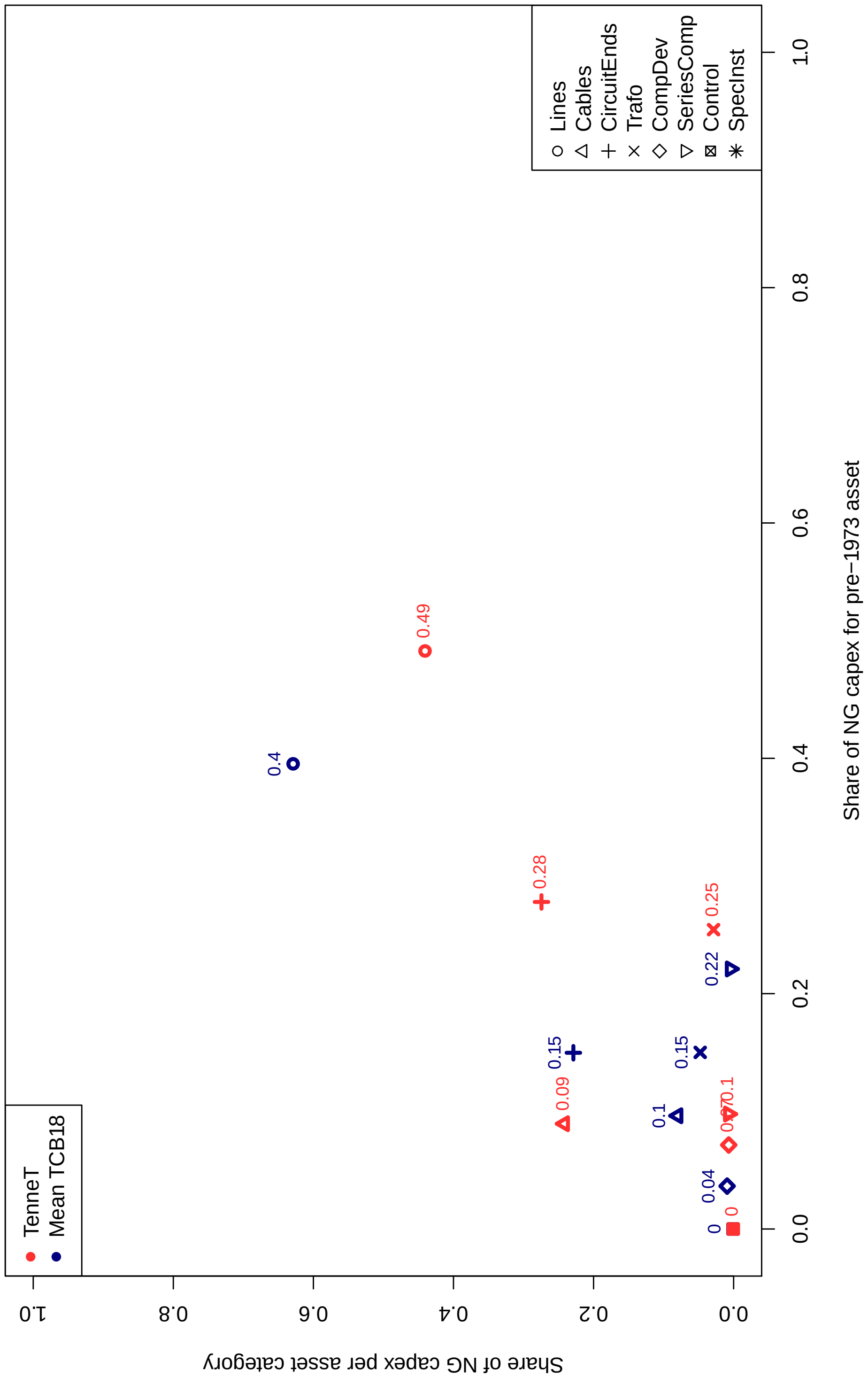


Figure 4.20: Share of total capital and share for old assets per asset category.

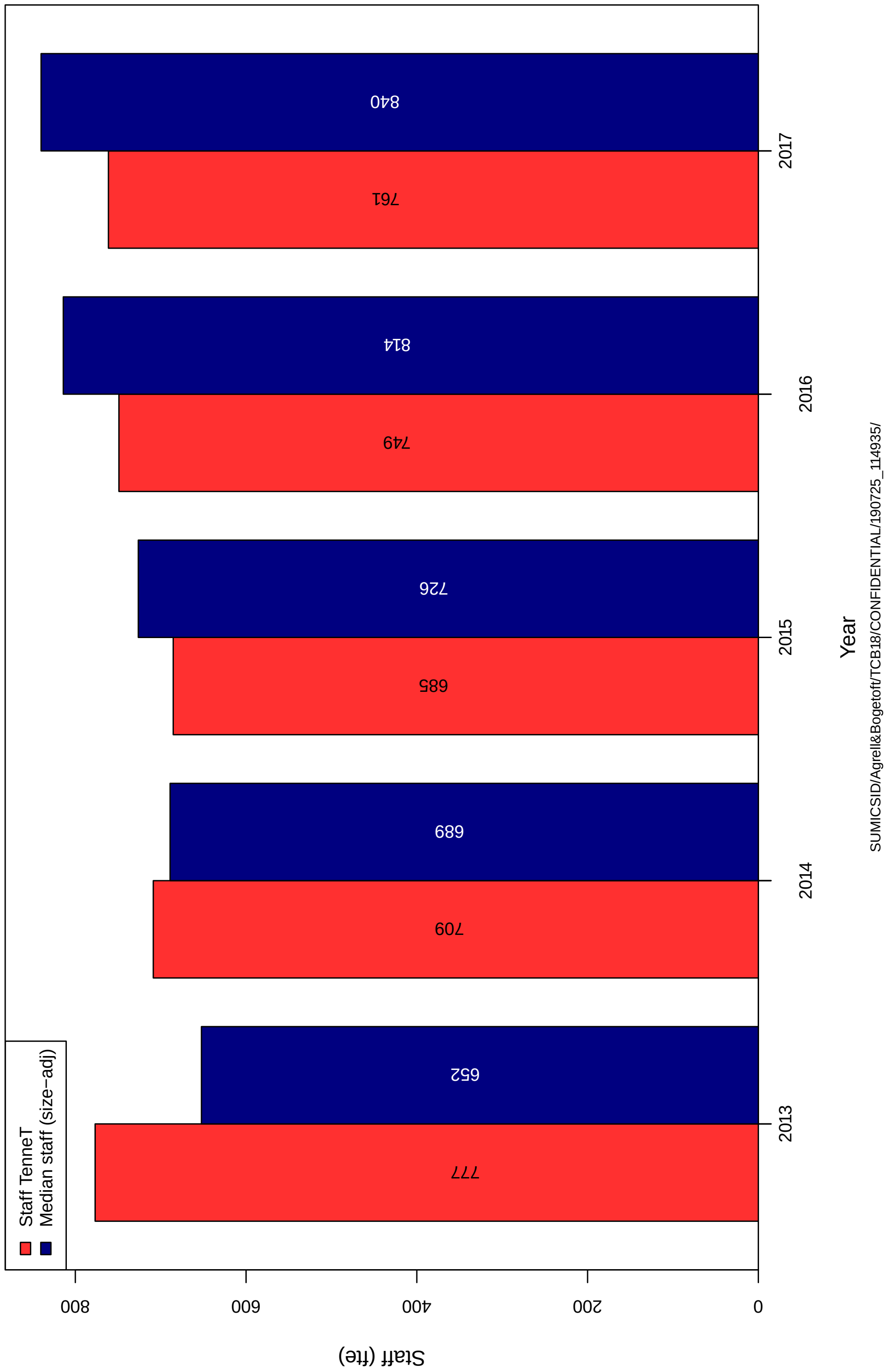


Figure 4.21: Actual staff (fte) compared to size-adjusted level for a median operator in TCB18.

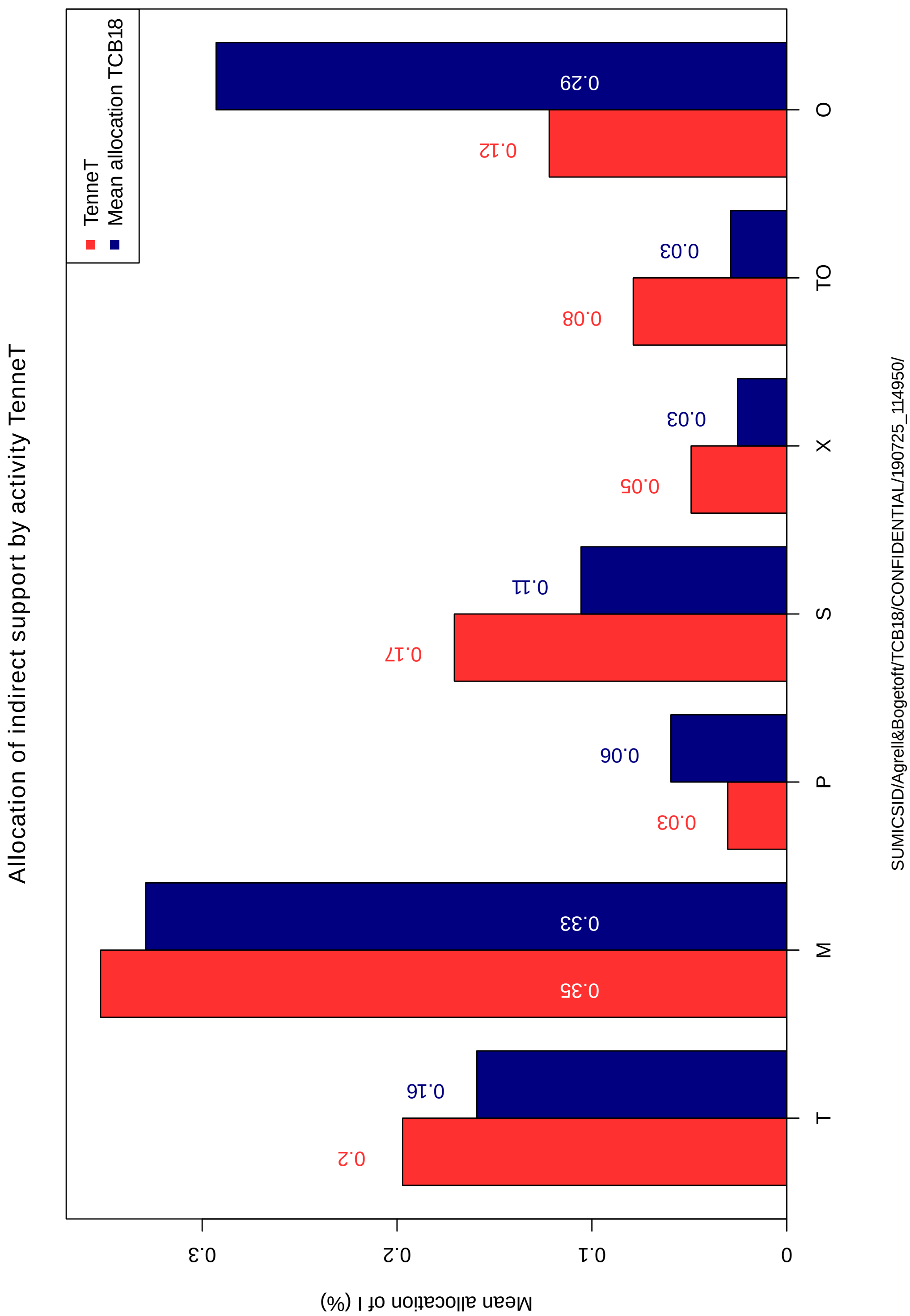


Figure 4.22: Allocation of overhead by function, mean and by operator, 2017.

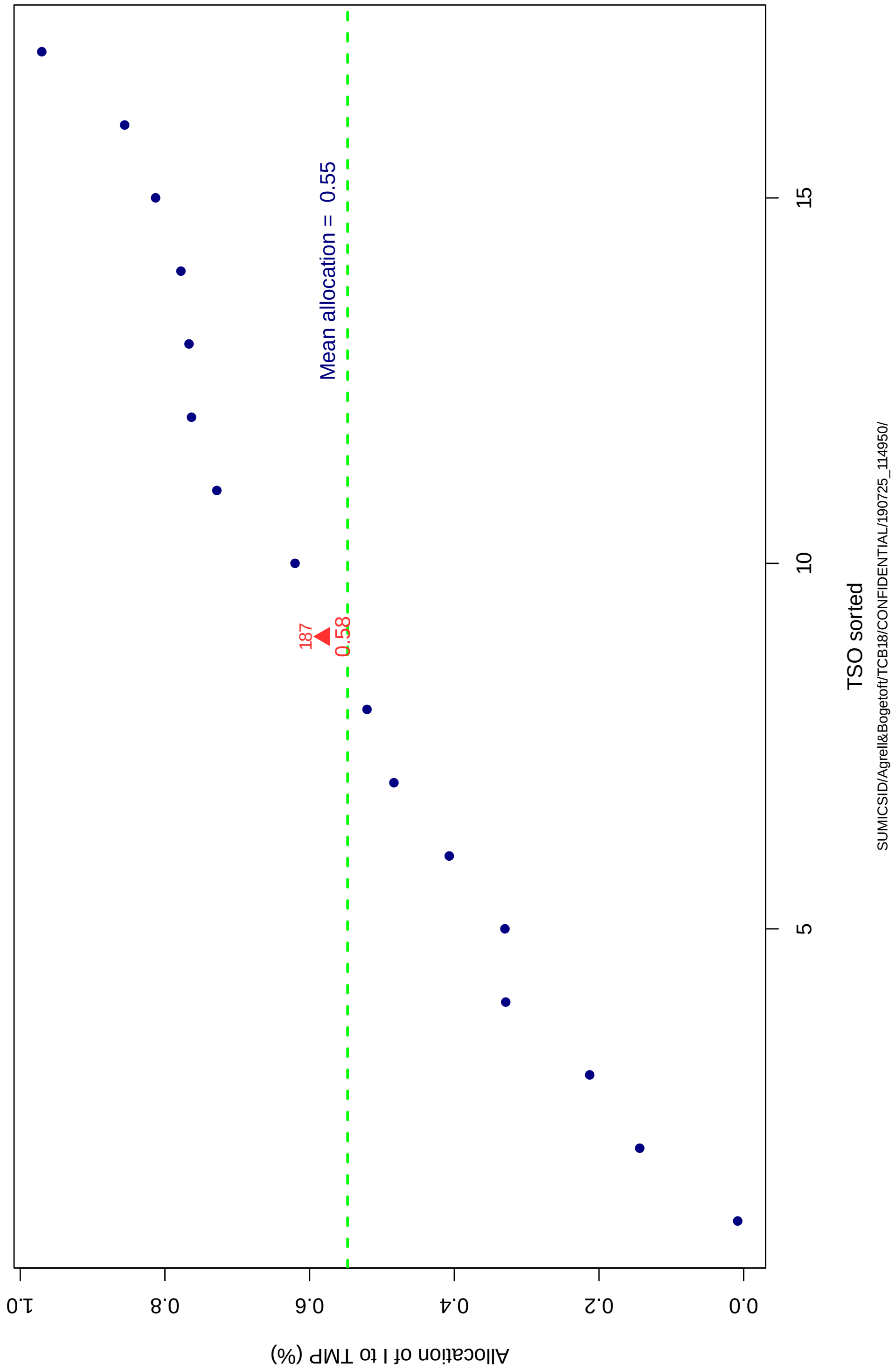


Figure 4.23: Overhead allocation (per cent) to TMP activities in TCB18.

Chapter 5

Second-stage analysis

In order to investigate whether some potentially relevant variables have been omitted in the final model specification, a so-called second stage analysis has been performed. The idea of the second stage analysis is to investigate if some of the remaining variation in performance can be explained by any of the unused cost drivers. This is routinely done by regressing the efficiency scores on these variables in turn. The second-stage regression is concretely regressing an omitted factor, ψ against the DEA-score, i.e.

$$DEA_{NDRS} = \beta_0 + \beta_1 \psi + \epsilon \tag{5.1}$$

The result of such an exercise is given in Table 5.1 below. A small value of the p-statistics or equivalent a high t-value would indicate that the parameter ψ is interesting. *maxImpact* indicates the coefficient value β_1 multiplied with the maximum range for the variable concerned, $\max(\psi) - \min(\psi)$.

As seen from Table 5.1, no parameter is significant at the 5% or 1% levels, indicating that the dimensions herein are considered in the model and do not merit specific post-run corrections.

Table 5.1: Second-stage analysis, final model electricity

Parameter	t-value	p-value	maxImpact	Sign-5%	Sign-1%
yNG	-0.298	0.770	-0.034		
yNG_zSlope	-0.167	0.870	-0.020		
yNG_zLandhumidity	-0.327	0.748	-0.037		
yNG_zGravel	-0.314	0.758	-0.035		
yNG_yLines.share_totex_angle.vsum_lmrob_corr	-0.201	0.843	-0.023		
yNG_yLines.share_circuit_angle.vsum_lmrob_corr	-0.248	0.807	-0.029		
yNG_yAreaShare.forest_lmrob_corr	-0.341	0.738	-0.038		
yNG_yShare.area.wetland.tot_lmrob_corr	-0.330	0.746	-0.038		
yNG_yShare.area.urban.tot_lmrob_corr	-0.368	0.718	-0.042		
yNG_yShare.area.infrastructure.tot_lmrob_corr	-0.370	0.717	-0.041		
yNG_yShare.area.cropland.tot_lmrob_corr	-0.386	0.705	-0.045		
yNG_yShare.area.woodland.tot_lmrob_corr	-0.319	0.754	-0.036		
yNG_yShare.area.grassland.tot_lmrob_corr	-0.275	0.787	-0.032		
yNG_yShare.area.shrubland.tot_lmrob_corr	-0.316	0.757	-0.036		
yNG_yShare.area.wasteland.tot_lmrob_corr	-0.402	0.694	-0.046		
yNG_zHumidity.wwpi_lmrob_corr	-0.477	0.640	-0.054		
yNG_zRugged_lmrob_corr	-0.310	0.761	-0.035		
yNG_zGravel_S_mean_lmrob_corr	-0.277	0.786	-0.032		
yNG_zGravel_T_mean_lmrob_corr	-0.282	0.782	-0.033		
yNG_yClimate.icing_lmrob_corr	-0.238	0.815	-0.027		
yNG_yClimate.heat_lmrob_corr	-0.396	0.698	-0.046		
yNG_zDensity.railways_lmrob_corr	-0.321	0.753	-0.036		
yLines_ehv	-0.827	0.421	-0.099		
yLines_hv	0.855	0.406	0.114		
yTowers_angular	-0.126	0.901	-0.017		
yTowers_angulars	-0.184	0.857	-0.026		
yTowers_steel	-0.530	0.604	-0.072		
yLines.share_totex_angle.vsum	0.083	0.935	0.010		
yLines.share_circuit_angle.vsum	0.385	0.706	0.054		
age1y	-0.228	0.822	-0.033		
age_meany	-0.120	0.906	-0.017		
dist_coast	0.853	0.407	0.080		
near_coast	-0.842	0.413	-0.071		

Chapter 6

Cost development

In this chapter the dynamic cost development for TenneT compared to that for the electricity operators in TCB18 is analyzed, first by activity, then by cost type for the benchmarked activities T,M,P. The graph for the general development, both in terms of grid growth (NormGrid) and in terms of expenditure, are drawn with dashed lines. The line for TenneT is drawn as a solid line if the costs are reported for several years, otherwise the graphs are only providing mean information.
In the activity cost graphs, a solid green line is indicating the base line of one (no change in expenditure). All cost data are adjusted for inflation using 2017 as base year, the analysis thus concerns real cost development.

This information is useful to consider specific sources of efficiency and in-efficiency compared to the comparators, considering the earlier analyses for profile, age and sensitivity.

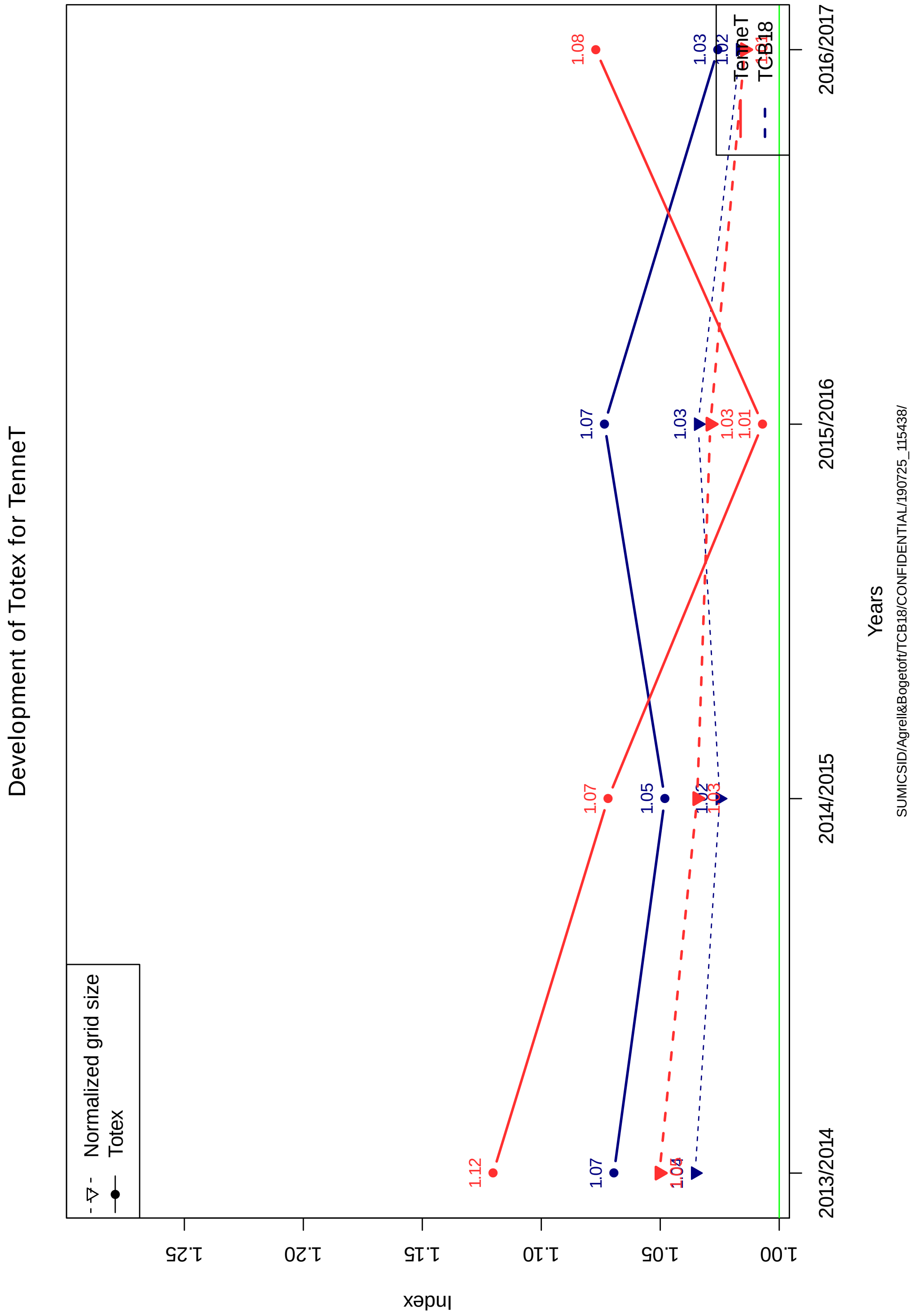


Figure 6.1: Totex development (TMP)

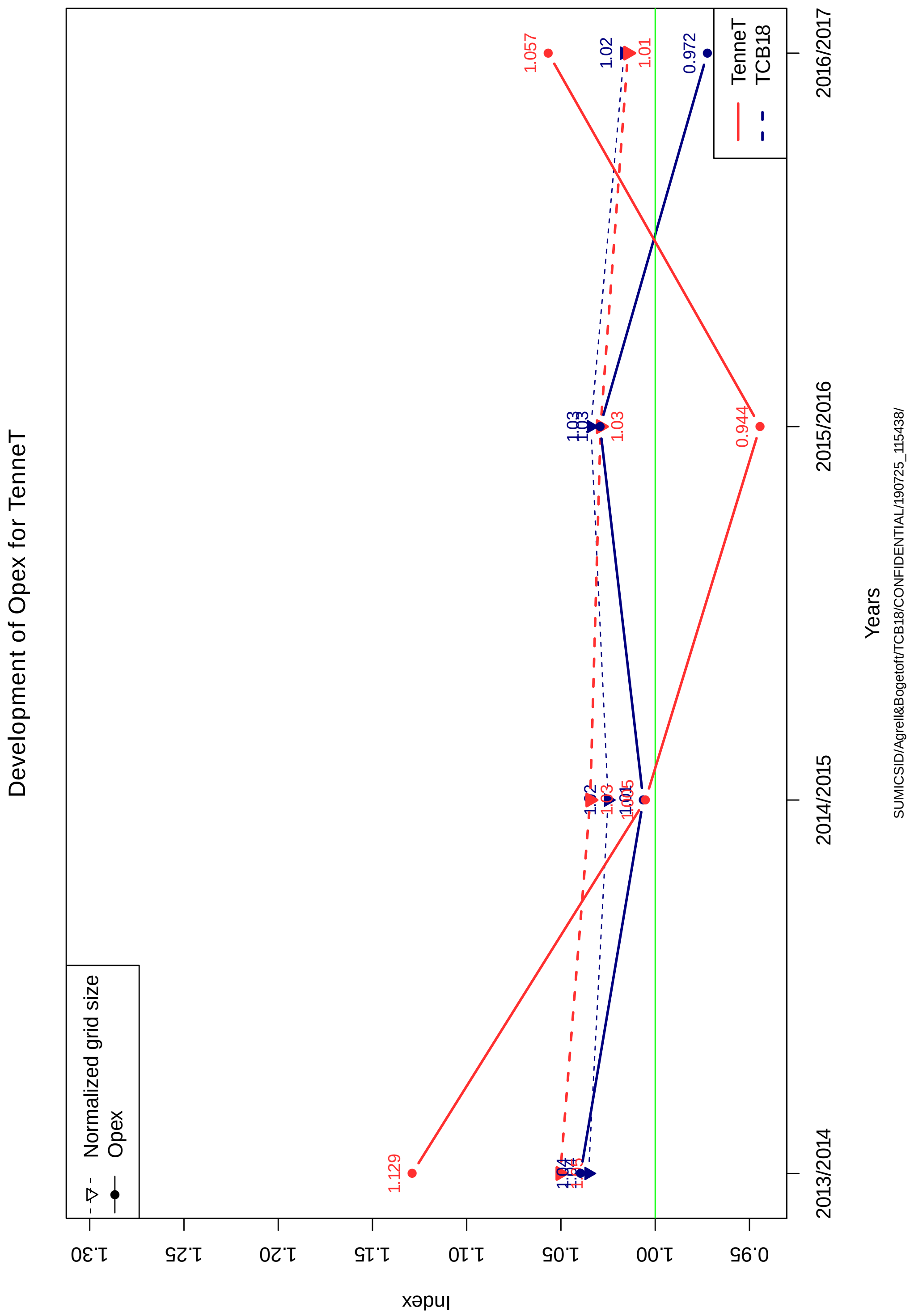


Figure 6.2: Opex development (TMP)

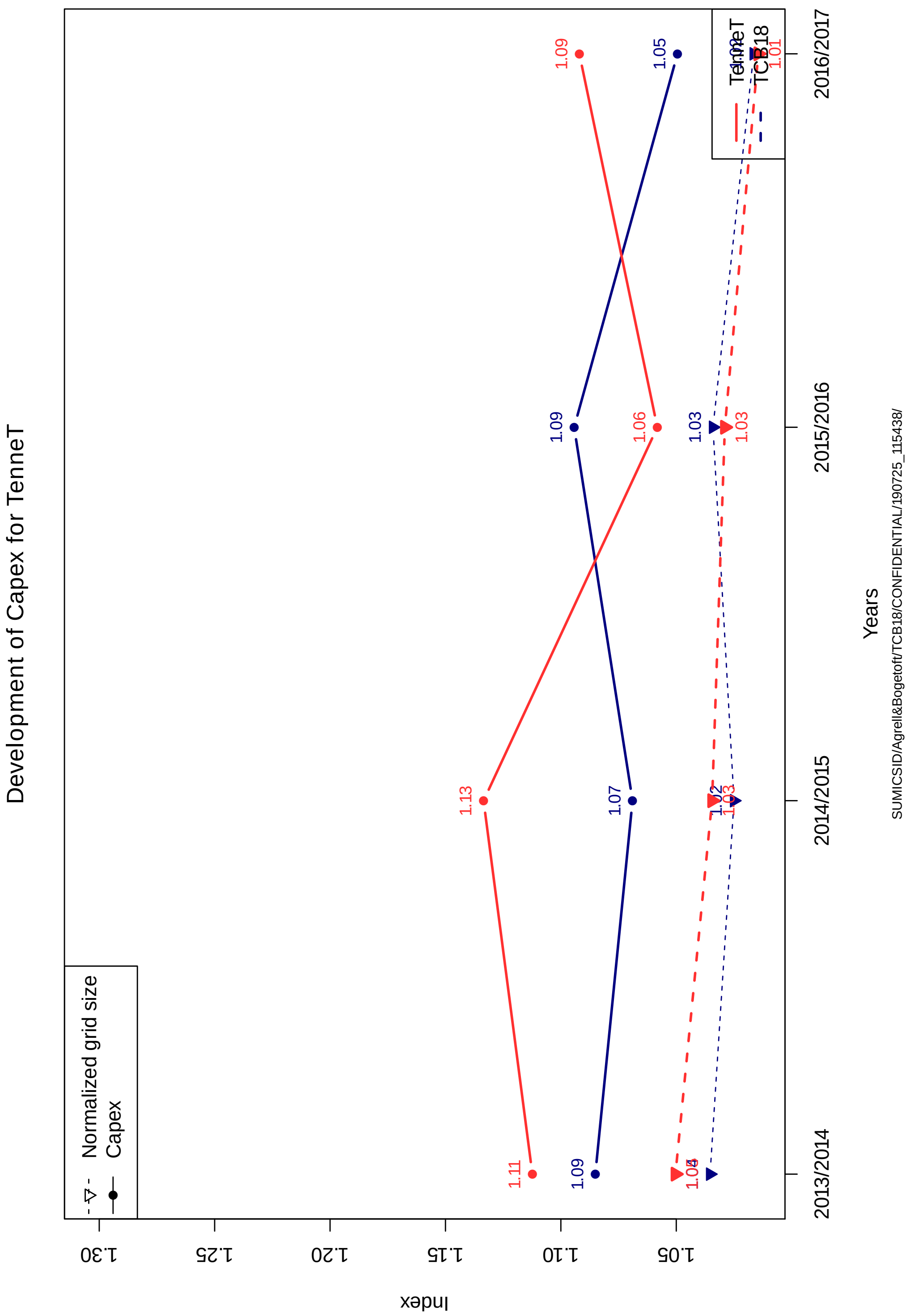


Figure 6.3: Capex development

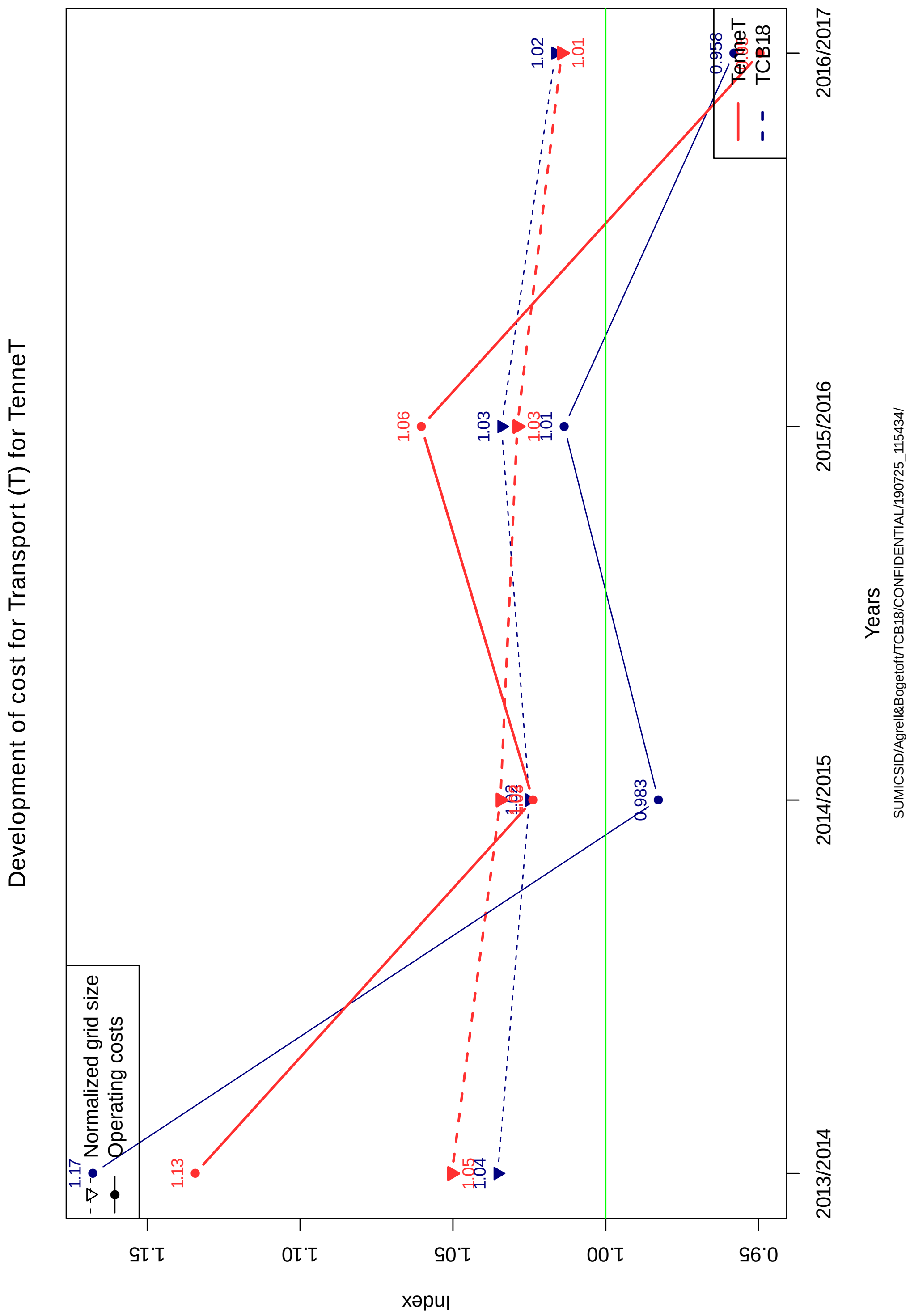


Figure 6.4: Cost development transport (T) vs grid growth.

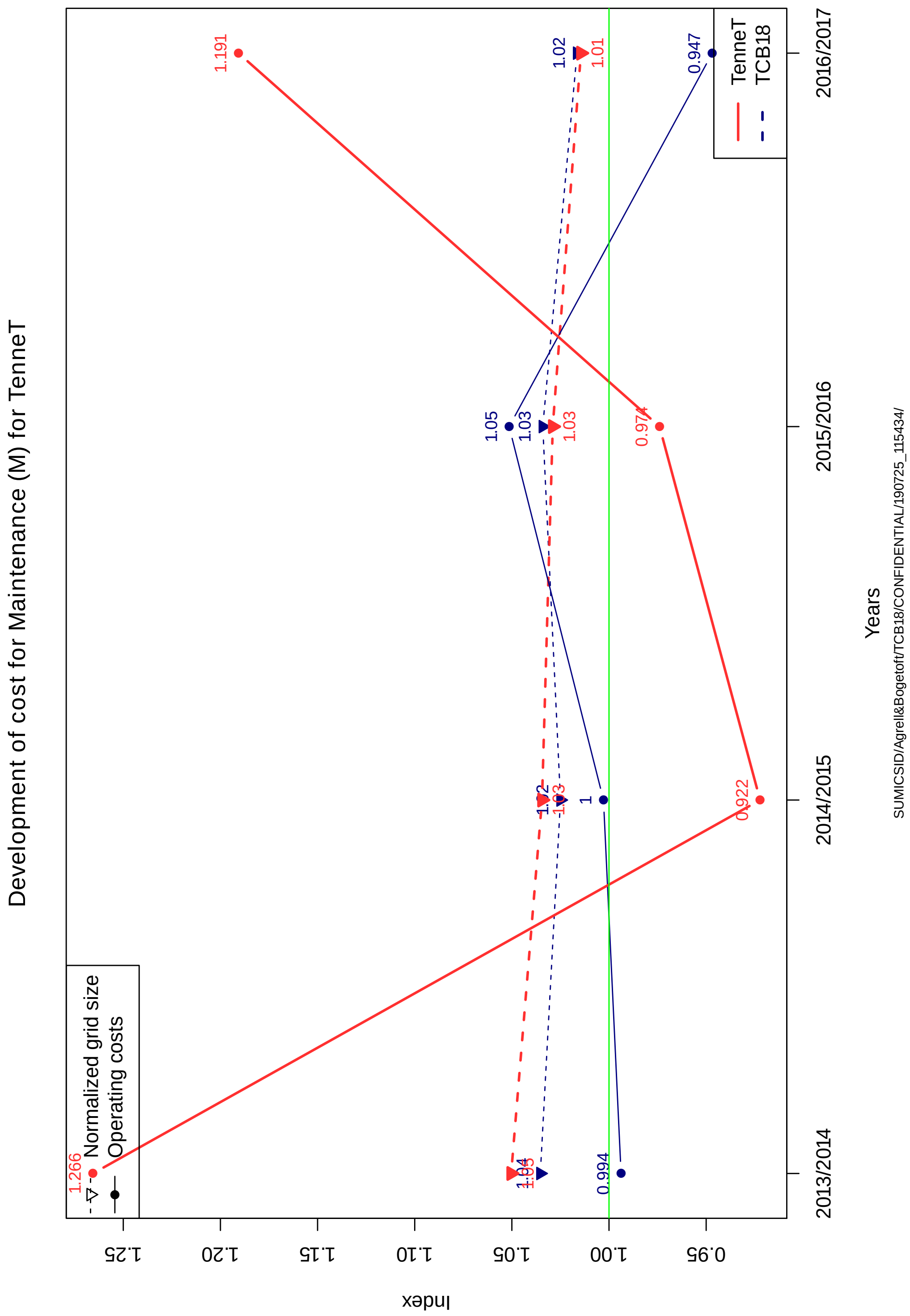


Figure 6.5: Cost development maintenance (M) vs grid growth.

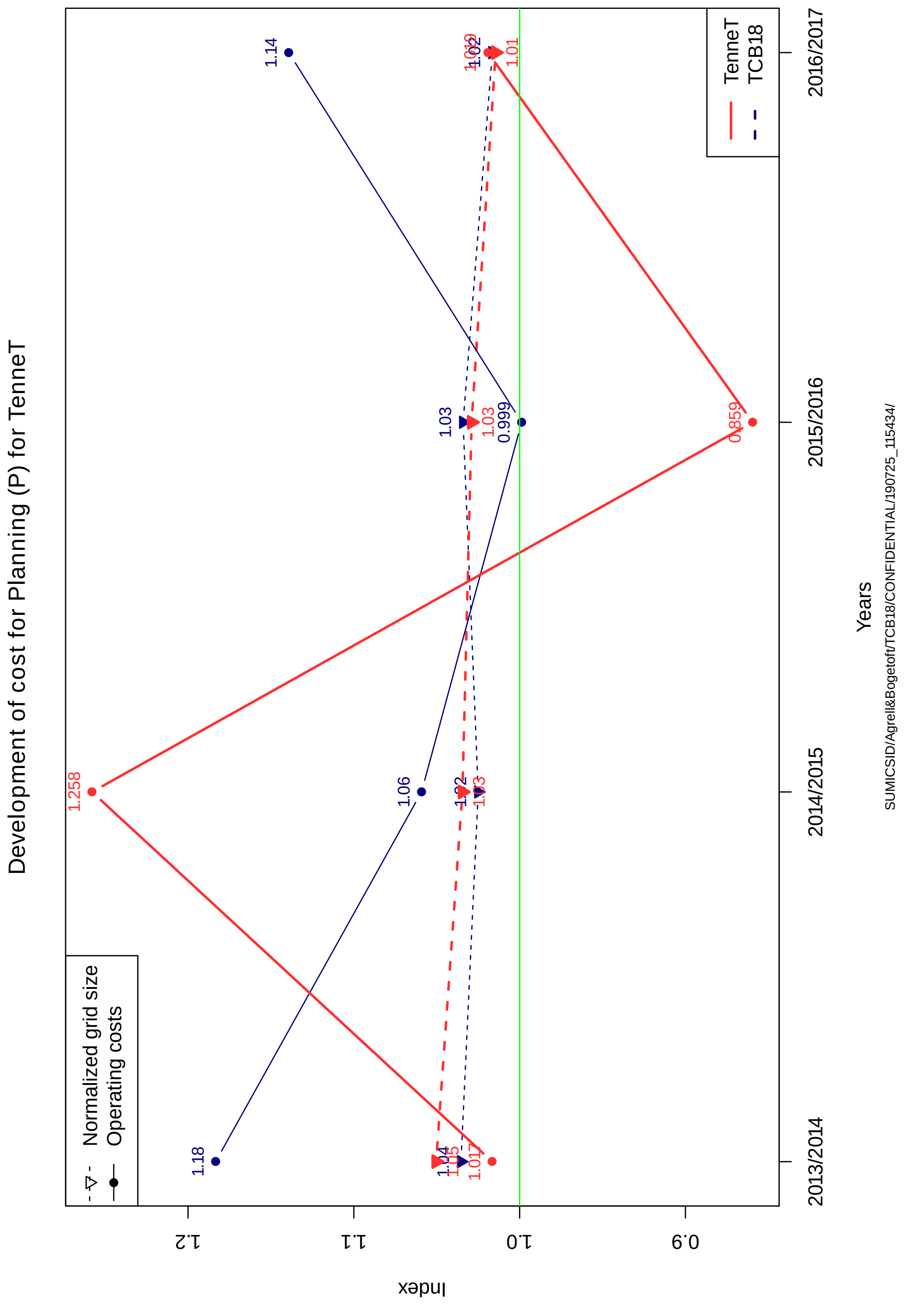


Figure 6.6: Cost development planning (P) vs grid growth.

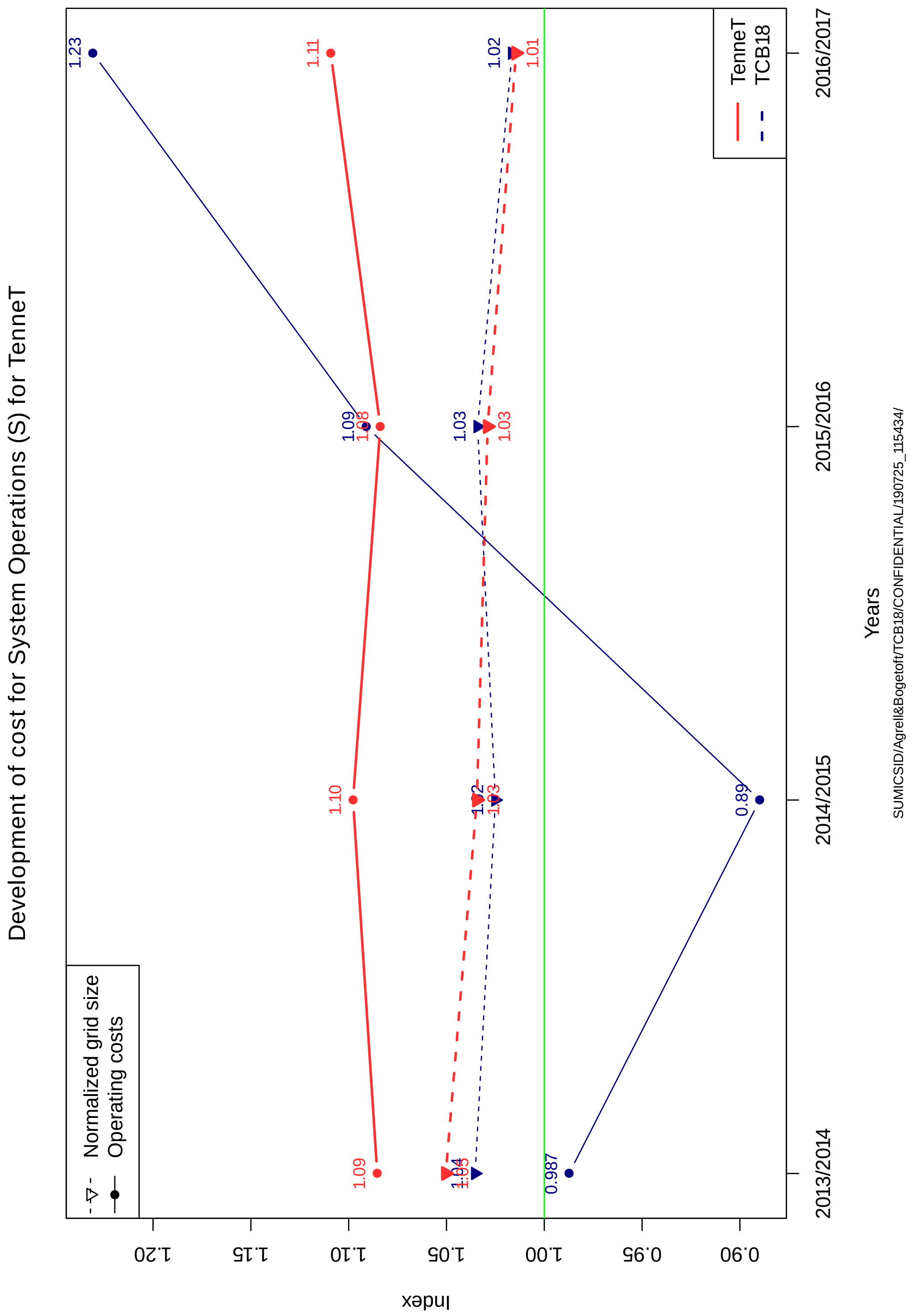


Figure 6.7: Cost development system operations (S) vs grid growth.

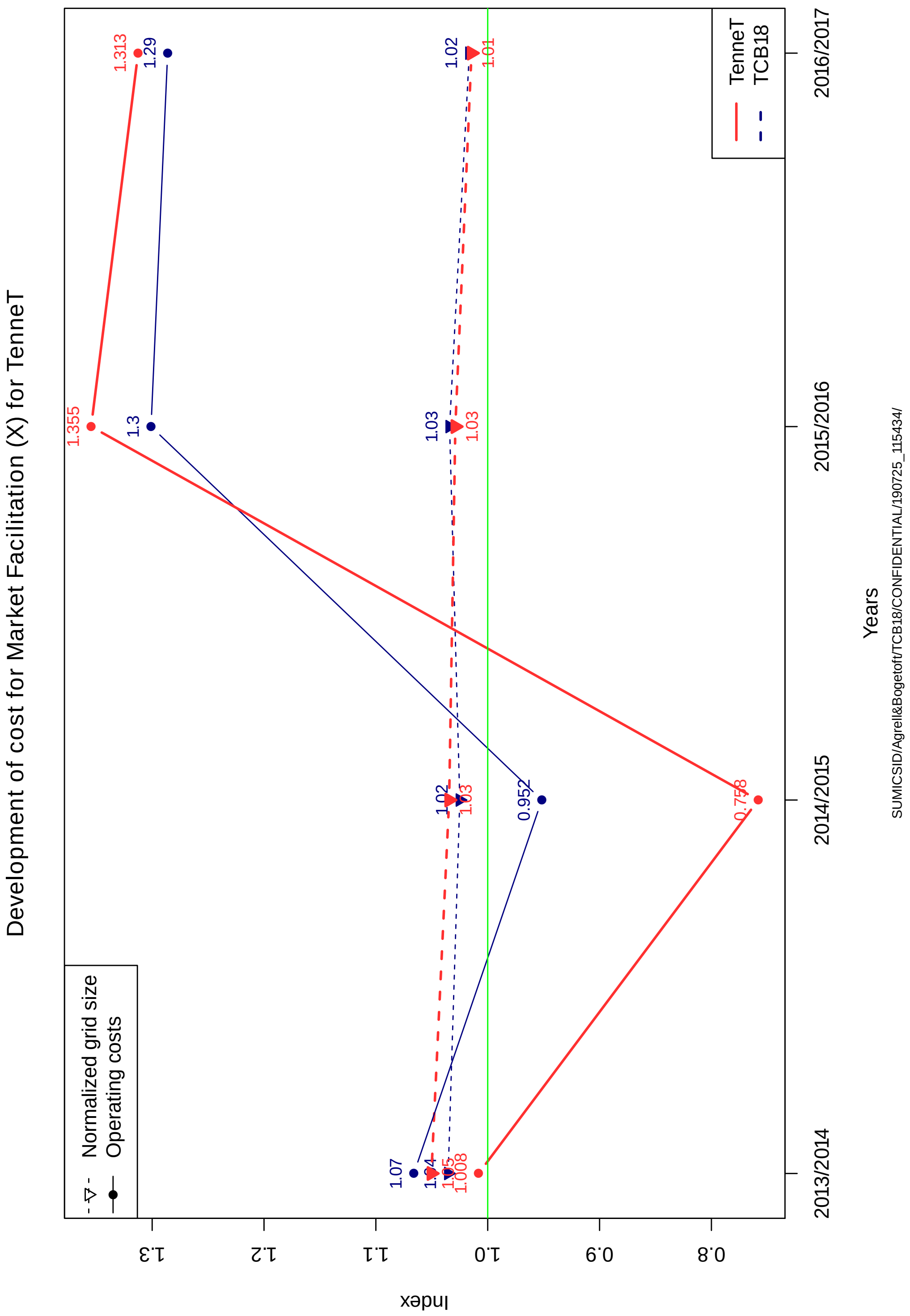


Figure 6.8: Cost development market facilitation (X) vs grid growth.

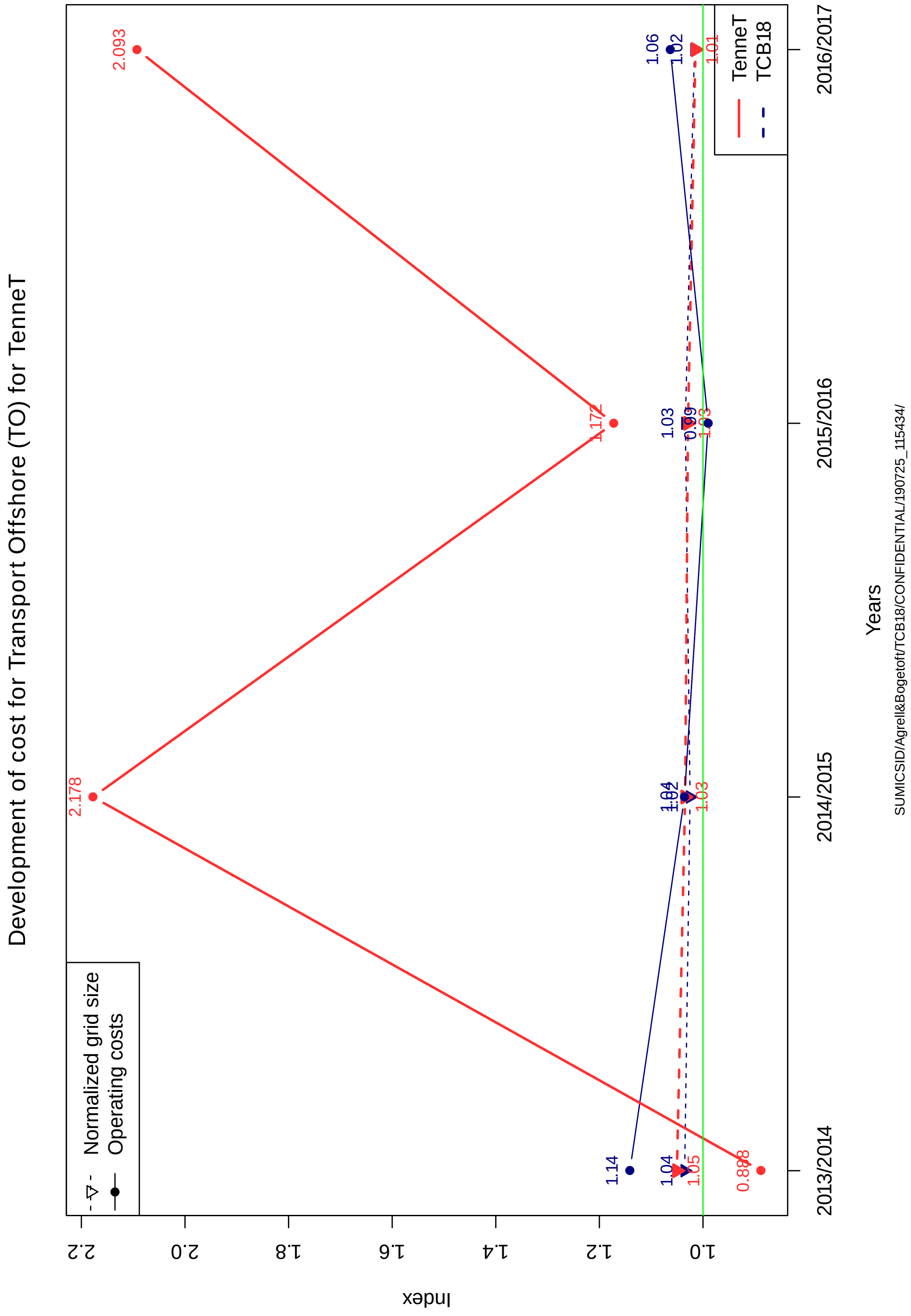


Figure 6.9: Cost development offshore transport (TO) vs grid growth.

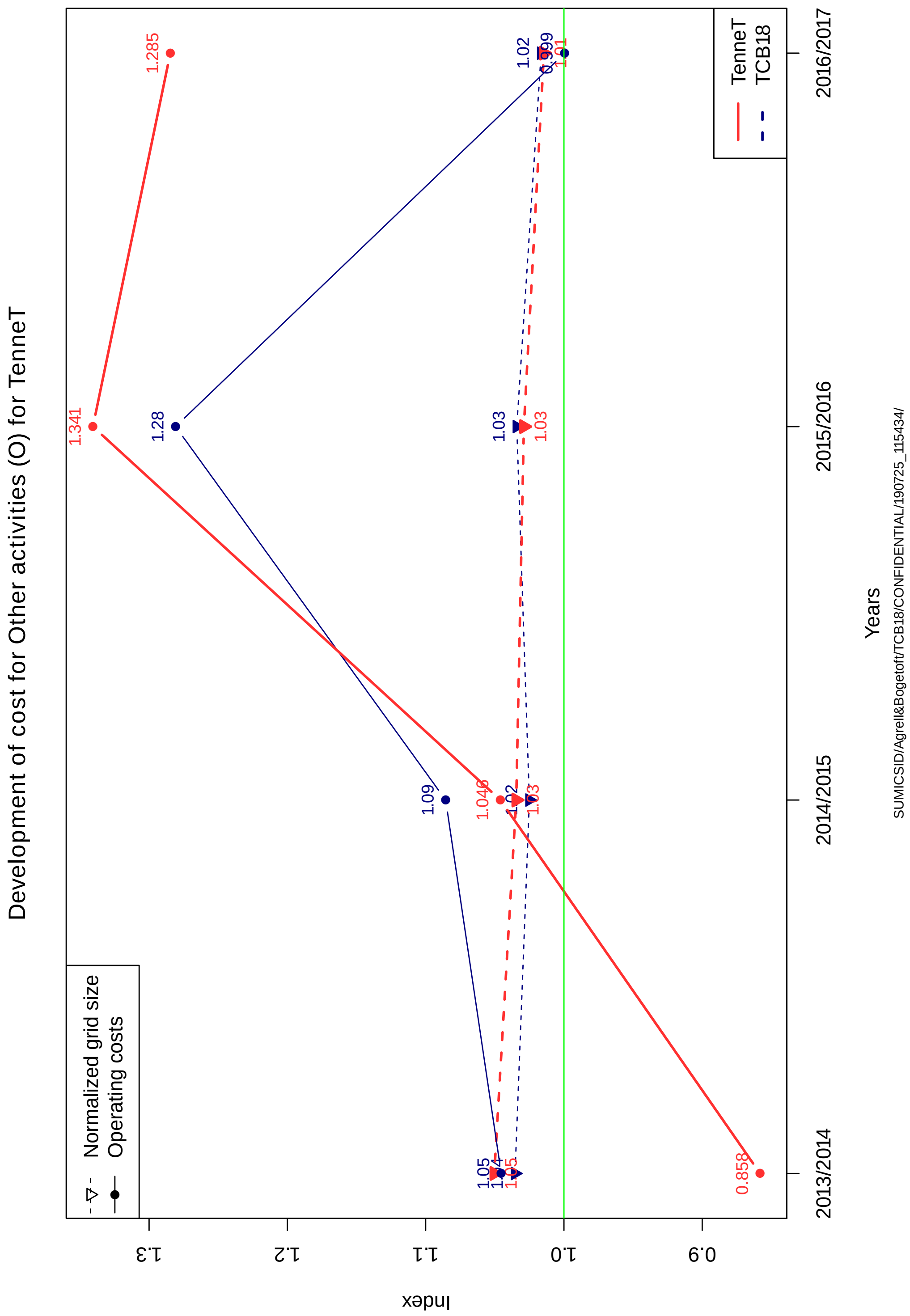


Figure 6.10: Cost development out-of-scope (O) vs grid growth.

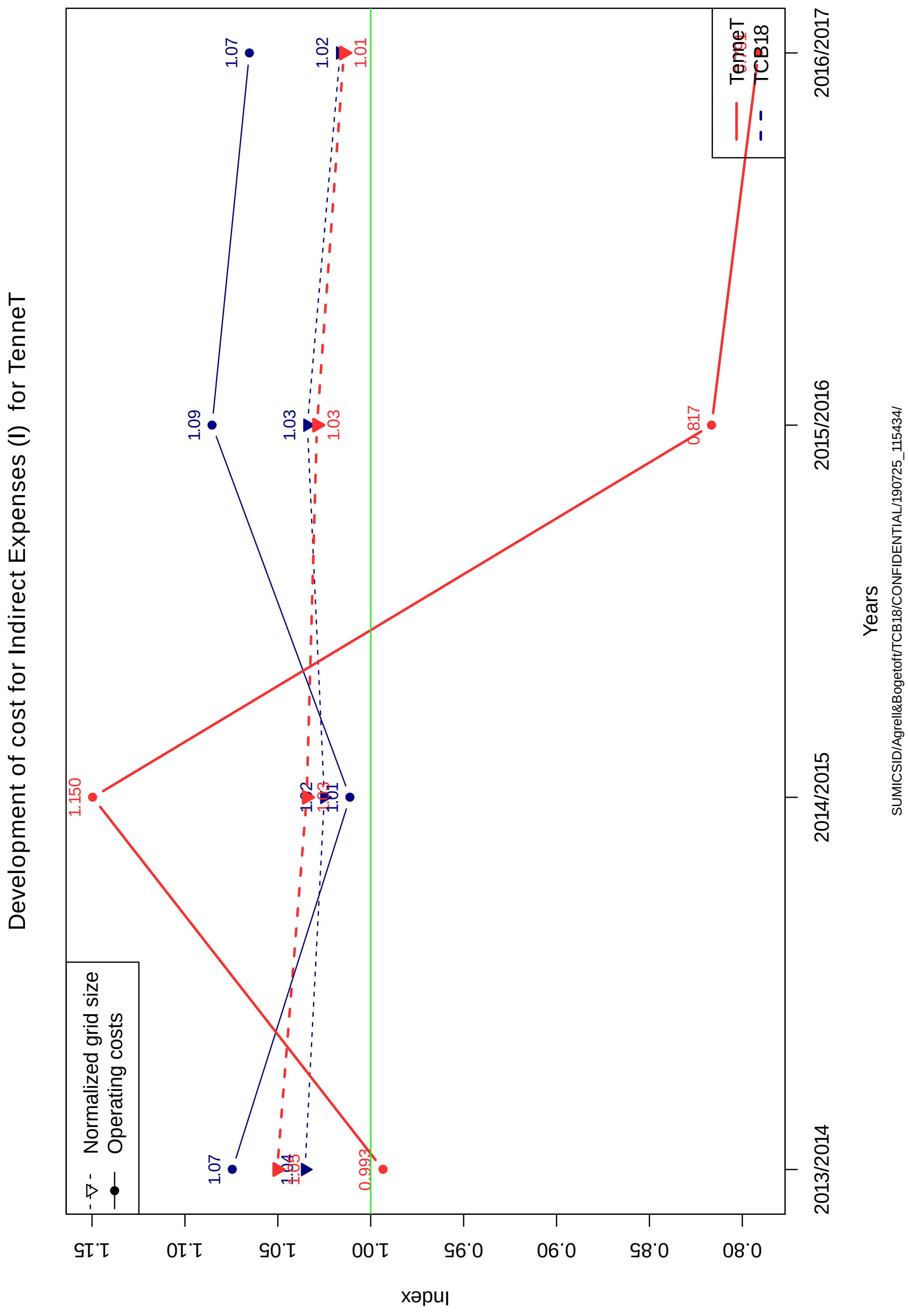


Figure 6.11: Cost development indirect support (I) vs grid growth.

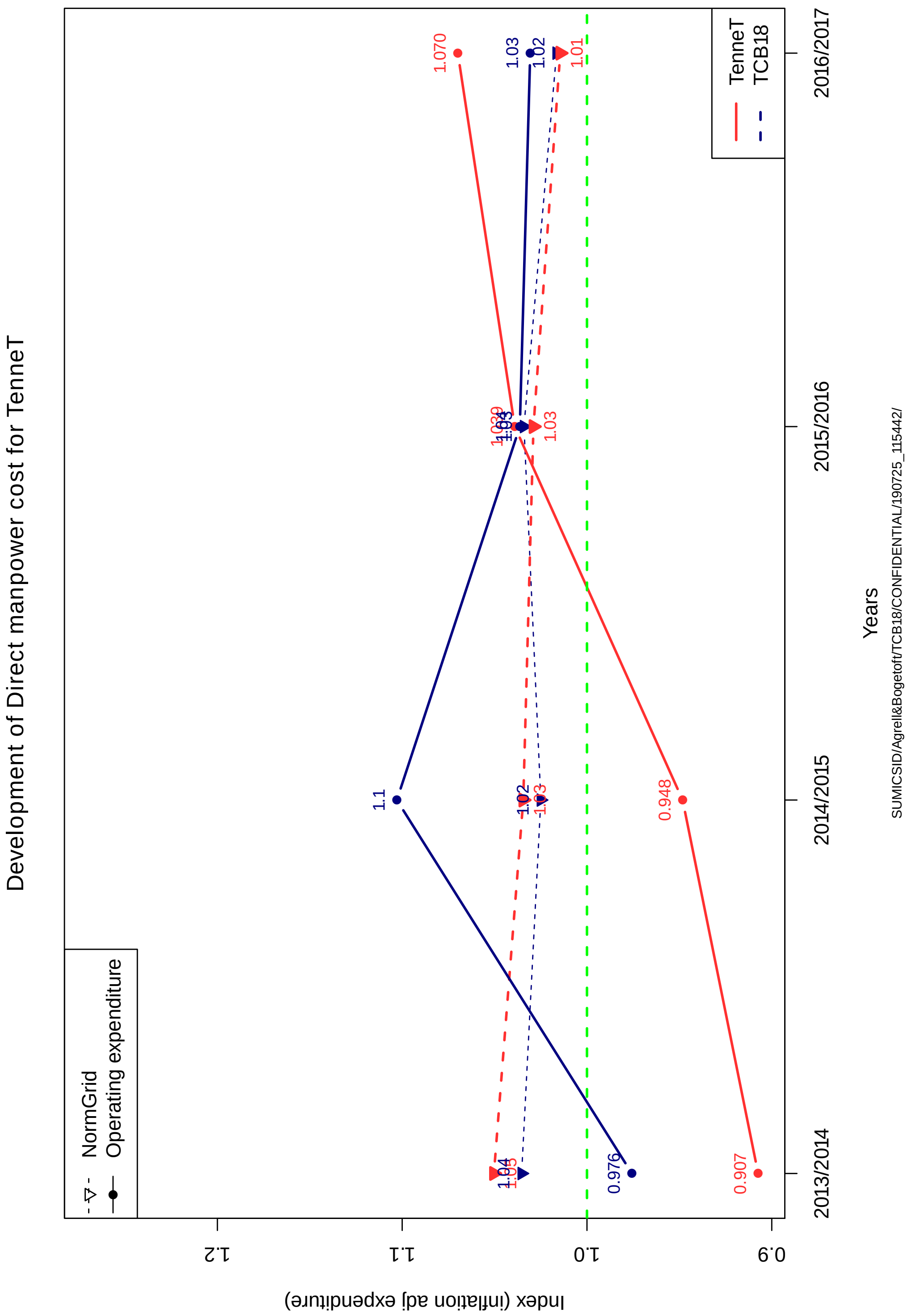


Figure 6.12: Cost development personnel expenditure (TMP)

Chapter 7

Parameters and index

The technical parameters in Table 7.1 and the indexes in Figures 7.1 and 7.2 are used in the calculations for the efficiency. The choice of these parameters is discussed further in the final report.

Table 7.1: Key parameters.

parameter.names	parameter.values
Template version	May 2018
Real interest rate	0.03
Exchange rate EUR 2017	1
Inflation index name:	hicpog_cpiw
Labor cost index name:	plici
Labor cost index 2017	1.07
Labor cost index 2016	1.086
Labor cost index 2015	1.03
Labor cost index 2014	1.057
Labor cost index 2013	0.961
Overhead allocation T	0.197
Overhead allocation M	0.352
Overhead allocation P	0.03
Overhead allocation S	0.171
Overhead allocation X	0.049
Overhead allocation TO	0.079
Overhead allocation SF	0
Overhead allocation O	0.122
Investment life lines	60
Investment life cables	50
Investment life substations	40
Investment life compdev	40
Investment life seriescomp	40
Investment life cc	20
Investment life other	20
Investment life equip	10

Table 7.2: Environmental variables.

parameter	datafile
dist_coast	tcb18_env_rugged_10.csv
near_coast	tcb18_env_rugged_10.csv
rugged	tcb18_env_rugged_10.csv
rugged_lsd	tcb18_env_rugged_10.csv
rugged_pc	tcb18_env_rugged_10.csv
rugged_popw	tcb18_env_rugged_10.csv
rugged_slope	tcb18_env_rugged_10.csv
wSubRegion	tcb18_env_area3_10.csv
yArea.arable	tcb18_env_area_10.csv
yArea.artifical	tcb18_env_area2_10.csv
yArea.bareland	tcb18_env_area2_10.csv
yArea.builtup	tcb18_env_area2_10.csv
yArea.coastalwetlands	tcb18_env_area2_10.csv
yArea.cropland	tcb18_env_area2_10.csv
yArea.forest	tcb18_env_area_10.csv
yArea.grassland	tcb18_env_area2_10.csv
yArea.greenhouses	tcb18_env_area2_10.csv
yArea.inlandwetlands	tcb18_env_area2_10.csv
yArea.land.tot	tcb18_env_area_10.csv
yArea.meadows	tcb18_env_area_10.csv
yArea.other	tcb18_env_area_10.csv
yArea.service	tcb18_env_areaservice_10.csv
yArea.shrubland	tcb18_env_area2_10.csv
yArea.tot	tcb18_env_area_10.csv
yArea.water	tcb18_env_area2_10.csv
yArea.wetland	tcb18_env_area2_10.csv
yArea.woodland	tcb18_env_area2_10.csv
yAreaShare.arable	tcb18_env_area_10.csv
yAreaShare.forest	tcb18_env_area_10.csv
yAreaShare.grass	tcb18_env_vegetation_10.csv
yAreaShare.meadows	tcb18_env_area_10.csv
yAreaShare.other	tcb18_env_area_10.csv
yAreaShare.shrubs	tcb18_env_vegetation_10.csv
yAreaShare.woods	tcb18_env_vegetation_10.csv
yClimate.heat	tcb18_env_climate_10.csv
yClimate.icing	tcb18_env_climate_10.csv
yLanduse.agriculture	tcb18_env_landuse_10.csv
yLanduse.industry	tcb18_env_landuse_10.csv
yLanduse.nonproductive	tcb18_env_landuse_10.csv
yLanduse.urban	tcb18_env_landuse_10.csv
yShare.area.agriculture_1	tcb18_env_area3_10.csv
yShare.area.agriculture_2	tcb18_env_area3_10.csv
yShare.area.agriculture_3	tcb18_env_area3_10.csv
yShare.area.agriculture_4	tcb18_env_area3_10.csv
yShare.area.cropland.tot	tcb18_env_area3_10.csv
yShare.area.forest_1	tcb18_env_area3_10.csv
yShare.area.forest_2	tcb18_env_area3_10.csv
yShare.area.forest_3	tcb18_env_area3_10.csv
yShare.area.grassland_1	tcb18_env_area3_10.csv
yShare.area.grassland_2	tcb18_env_area3_10.csv
yShare.area.grassland_3	tcb18_env_area3_10.csv
yShare.area.grassland.tot	tcb18_env_area3_10.csv
yShare.area.infrastructure_airport	tcb18_env_area3_10.csv
yShare.area.infrastructure_port	tcb18_env_area3_10.csv
yShare.area.infrastructure_roadrail	tcb18_env_area3_10.csv

yShare.area.infrastructure.tot	tcb18_env_area3_10.csv
yShare.area.noaccess_1	tcb18_env_area3_10.csv
yShare.area.noaccess_2	tcb18_env_area3_10.csv
yShare.area.otherw.tot	tcb18_env_area3_10.csv
yShare.area.shrubland.tot	tcb18_env_area3_10.csv
yShare.area.urban_1	tcb18_env_area3_10.csv
yShare.area.urban_2	tcb18_env_area3_10.csv
yShare.area.urban_ind	tcb18_env_area3_10.csv
yShare.area.urban.tot	tcb18_env_area3_10.csv
yShare.area.wasteland_1	tcb18_env_area3_10.csv
yShare.area.wasteland_2	tcb18_env_area3_10.csv
yShare.area.wasteland_3	tcb18_env_area3_10.csv
yShare.area.wasteland.tot	tcb18_env_area3_10.csv
yShare.area.water_1	tcb18_env_area3_10.csv
yShare.area.water_2	tcb18_env_area3_10.csv
yShare.area.water_3	tcb18_env_area3_10.csv
yShare.area.water_4	tcb18_env_area3_10.csv
yShare.area.water_5	tcb18_env_area3_10.csv
yShare.area.wetland_1	tcb18_env_area3_10.csv
yShare.area.wetland_2	tcb18_env_area3_10.csv
yShare.area.wetland_3	tcb18_env_area3_10.csv
yShare.area.wetland_4	tcb18_env_area3_10.csv
yShare.area.wetland_5	tcb18_env_area3_10.csv
yShare.area.wetland.tot	tcb18_env_area3_10.csv
yShare.area.woodland.tot	tcb18_env_area3_10.csv
yShare.motorways	tcb18_env_roads_10.csv
yShare.other	tcb18_env_area3_10.csv
yShare.urbanroads	tcb18_env_roads_10.csv
zDensity.railways	tcb18_env_roads_10.csv
zDensity.roads	tcb18_env_roads_10.csv
zGravel_S_mean	tcb18_env_subsoil_10.csv
zGravel_S00	tcb18_env_subsoil_10.csv
zGravel_S05	tcb18_env_subsoil_10.csv
zGravel_S15	tcb18_env_subsoil_10.csv
zGravel_S40	tcb18_env_subsoil_10.csv
zGravel_S41	tcb18_env_subsoil_10.csv
zGravel_T_mean	tcb18_env_subsoil_10.csv
zGravel_T00	tcb18_env_subsoil_10.csv
zGravel_T05	tcb18_env_subsoil_10.csv
zGravel_T15	tcb18_env_subsoil_10.csv
zGravel_T40	tcb18_env_subsoil_10.csv
zGravel_T41	tcb18_env_subsoil_10.csv
zHumidity.wwpi	tcb18_env_wetness_10.csv
zLandhumidity.dry	tcb18_env_wetness_10.csv
zLandhumidity.water.perm	tcb18_env_wetness_10.csv
zLandhumidity.water.temp	tcb18_env_wetness_10.csv
zLandhumidity.wet.perm	tcb18_env_wetness_10.csv
zLandhumidity.wet.temp	tcb18_env_wetness_10.csv
zSlope.flat	tcb18_env_slope_10.csv
zSlope.hilly	tcb18_env_slope_10.csv
zSlope.mountain	tcb18_env_slope_10.csv
zSlope.undulating	tcb18_env_slope_10.csv
zSoil.dr_D	tcb18_env_subsoil_10.csv
zSoil.dr_M	tcb18_env_subsoil_10.csv
zSoil.dr_S	tcb18_env_subsoil_10.csv
zSoil.dr_V	tcb18_env_subsoil_10.csv

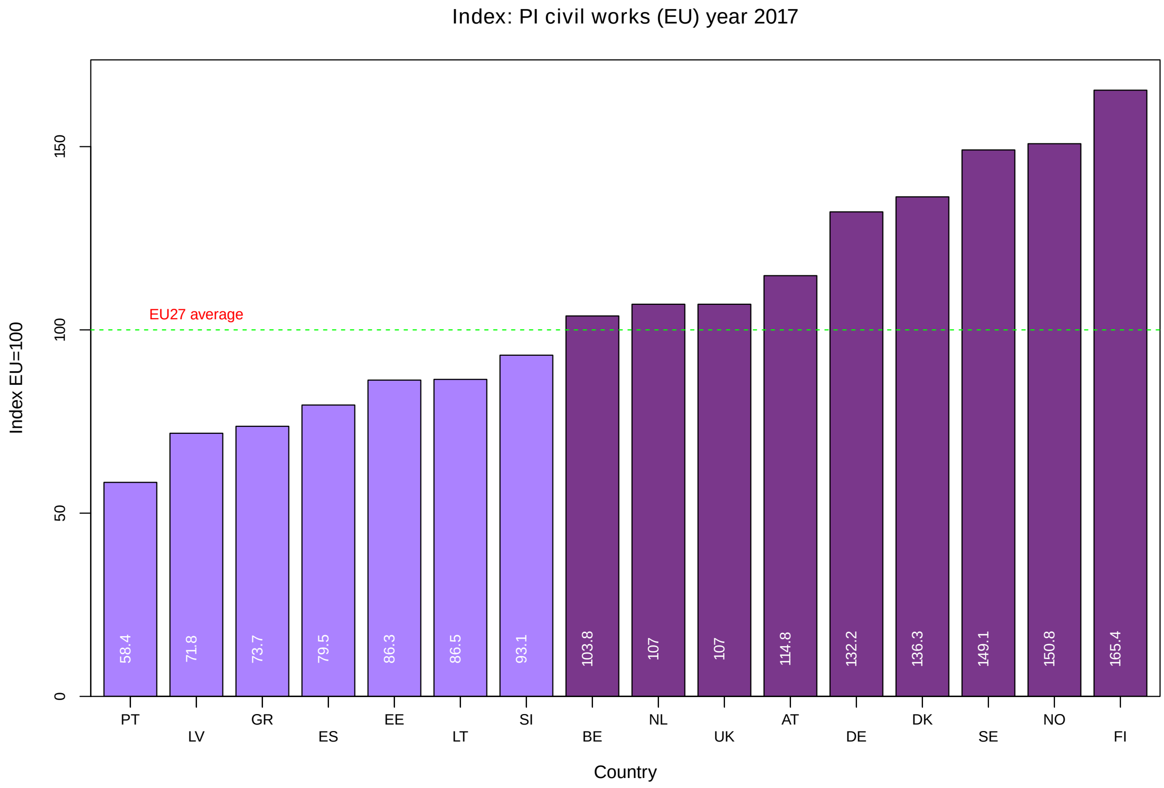


Figure 7.1: Labour cost index PLICI (EU civil engineering) by country 2017.

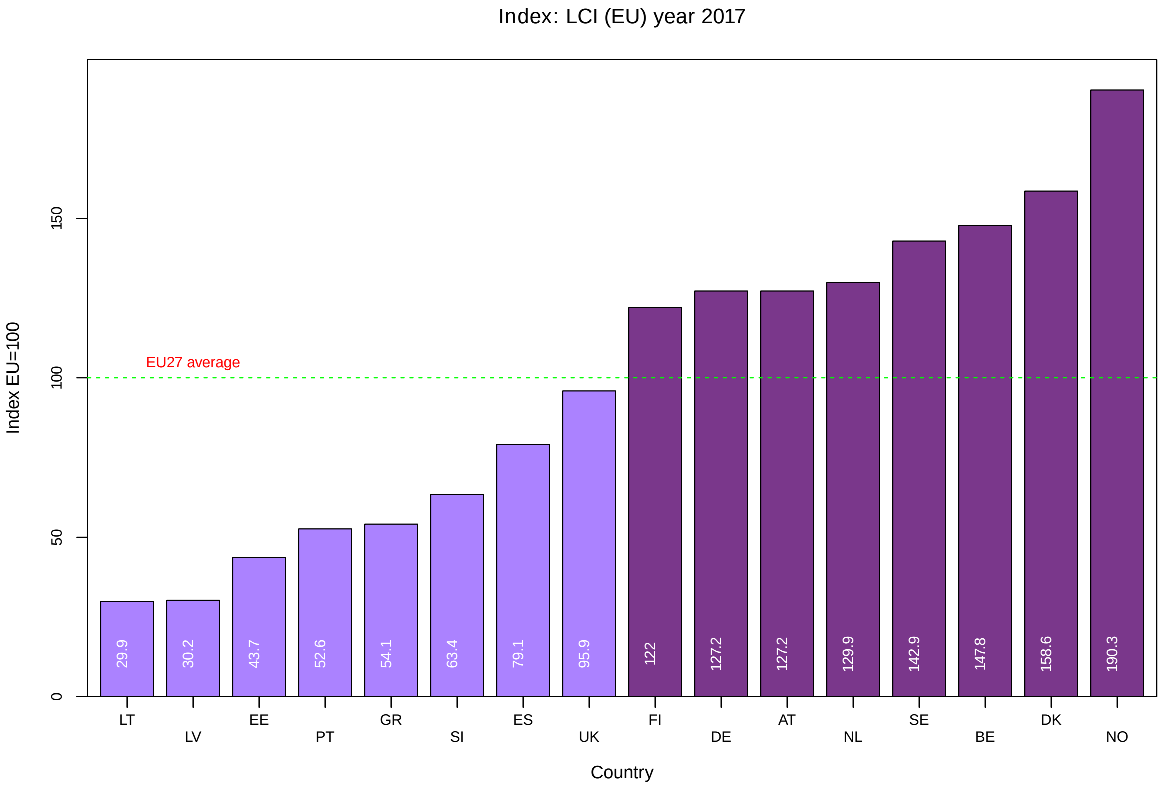


Figure 7.2: Labour cost index LCIS (EU general) by country 2017.