PROJECT CEER-TCB18

Dynamic efficiency and productivity changes for electricity transmission system operators

MAIN REPORT

2020-08-31 V1.3

Disclaimer

This is the final report on the dynamic efficiency and productivity results for electricity transmission system operators from a CEER project on cost efficiency benchmarking that involves data collection, validation and calculation of various efficiency indicators. Respecting the confidentiality of the submitted data and the prerogatives of each national regulatory authority to use or not the information produced in review of network tariffs or other monitoring, the report does not contain details for individual operators, nor comments or recommendations concerning the application of the results in regulation.

Dynamic efficiency and productivity changes for electricity transmission system operators
Final report. Open. Project no: 370 / CEER-TCB18
Release date: 2020-09-11

Revision 1.3

Version 1.2 of this report contained an error for one of the output parameters (angular towers) for the period 2013-2016, leading to errors in the Malmquist calculations.

The current version is based on the corrected data, implying revisions of articles 3.08-3.10, 3.13, 3.15 and Tables 3.4 and 3.6. The qualitative conclusions stay the same as do all cost analysis results.

Executive Summary

The TSO Cost efficiency Benchmarking 2018 (project TCB18) is an initiative by the Council of European Energy Regulators (CEER) to initiate a stable and regular process for performance assessment of energy transmission system operators. The project covers both electricity and gas transmission and involves in total 46 operators from 16 countries in Europe. The project is the most ambitious regulatory benchmarking project documented so far, mobilizing national regulatory authorities (NRA), transmission system operators (TSO) and consultants in a joint effort to develop robust and comprehensive data and models.

A specific study on the productivity development in the sector 2013-2017 suggests a weak overall development, both in terms of efficiency change among peers and catch-up speed among non-peers. The results are not sensitive to the choice of economic parameters and do not result only from any specific cost type. Instead, the results point at a higher cost intensity increase rate in both operating and capital expenditure than the growth in infrastructure.

Table of Contents

1. Project objectives and organization

In this Chapter we state the project objectives, the organization and the report outline.

1.1 Main objectives

1.01 The main objective with the CEER TSO Cost efficiency Benchmark 2018 (project TCB18) is to produce a robust and methodologically sound platform for deriving cost efficiency estimates for transmission system operators, under process and data quality requirements allowing use of the results to inform regulatory oversight of the operators. In the project, best practice TSOs (forming the so-called frontier) are identified and related to other TSOs in a pan-European and regulatory context. Ultimately this is the purpose of TCB18.

1.02 TCB18 succeeds the E3GRID project in 2012/2013 and the E2GAS study of 2015/2016, combining in a single project a benchmark of gas TSOs and electricity TSOs.

1.2 Project deliverables

1.03 The project produced three deliverables to document the results and the process:

1.04 **Final report**:
This document for electricity constitutes the final report documenting the process, model, methods, data requests, parameters, calculations and average results, including sensitivity analysis and robustness analysis. The report is intended for open publication and does not contain any data or results that could be linked to individual participants.

1.05 **TSO-specific reports:**
Clear and informative report on all used data, parameters and calculations leading to individual results, decomposed as useful for the understanding. The report only contains data, results and analyses pertaining to a single TSO. The confidential report was uploaded in an electronic version to each authorized NRA on the platform.

1.06 **Dynamic report:**
This report constitutes a separate document focused on aggregate, dynamic changes in productivity, efficiency and technological change over the horizon 2013-2017 for electricity.

1.07 The current report constitutes the dynamic report (art 1.06) for electricity.

1.3 Reading guide

1.08 Chapter 2 includes some modeling elements for dynamics, complementing the main report. The dynamic results are presented in Chapter 3. Some final comments are provided in Chapter 4.

2. Methodology

This Chapter provides some elements for the methodology of dynamic productivity analysis.

2.1 Dynamic productivity and efficiency assessment

2.01 In the main report we concentrated on the static performance of the TSOs. We considered different conceptual models of the relationship between costs and services provided by the TSOs, and for each of these models we used several estimation methods to derive calibrated models based on actual data.

2.02 In each situation, we could then estimate the static efficiency of the TSOs, i.e. the extent to which OPEX and CAPEX could have been reduced in a given year.

2.03 Over time, however, both the behaviour of an individual TSO and the nature of the technology are likely to change. These dynamic changes are of considerable interest to regulators and TSOs alike.

2.04 A TSO may reduce its resource usage from one year to another. To understand and decompose this improvement, however, the improvement must be compared to the changes undertaken by other TSOs. If a TSO improves but does so at a slower pace than other TSOs, it effectively is falling behind. Likewise, if a TSO is increasing its cost it may look like increased inefficiency but if other TSOs are increasing costs faster, it may really reflect that the TSO in question is improving but that the technology is regressing.

2.05 In the scientific literature productivity refers to changes over time. If outputs change more than inputs, productivity improves. We shall now discuss how such changes can be measured and decomposed into technological changes and individual changes relative to the technology.

2.2 Fisher indexes

2.06 If prices or priority weights are available for both the resources used and the services produced, one can use classical measures of productivity.

2.07 Productivity is in general defined as the ratio of changes in outputs to changes in inputs. The *Total Factor Productivity* TFP is an extension to the case of multiple inputs and outputs:

$$TFP = \frac{\Delta Y}{\Delta X}$$

where ΔY is the proportional change in output quantity and ΔX is the corresponding change in input quanta. The multiple dimensions are weighted according to some set of weights, the most popular being the Fisher ideal index (Diewert, 2004) that uses (exogenously given) prices. The total factor productivity growth from a base year 0 to a later year *t* is obtained as:

$$TFP^t = \frac{\sqrt{\left(\sum_i p_i^0 y_i^t / \sum_k p_k^0 y_k^0\right)\left(\sum_i p_i^t y_i^t / \sum_k p_k^t y_k^0\right)}}{\sqrt{\left(\sum_i w_i^0 x_i^t / \sum_k w_k^0 x_k^0\right)\left(\sum_i w_i^t x_i^t / \sum_k w_k^t x_k^0\right)}}$$

where p_i^0 is the price for output *i* in the base period 0, p_i^t is the price of output *i* in period *t* = {1,..,*T*}, y_i^0 and y_i^t are the output quantities of item *i* in periods 0 and *t*, respectively, w_i^0 and w_i^t are the input prices for input *i* in periods 0 and *t*, respectively, and x_i^0 and x_i^t are the quantities of input *i* in periods 0 and *t*, respectively. The summation indexes *i* and *k* are covering the same range of all inputs and outputs, respectively. Note that the geometric mean (using the square root) is used in the formula here, as well as in the following, rather than the arithmetic mean. This is linked to the convention to neutralize changes on different scales and ranges that otherwise would have different impacts depending on the scales used.

2.08 An obvious challenge with this TFP method is to obtain an a priori set of valid market prices for all outputs, i.e. prices that should reflect a profit maximizing behaviour. In the case of infrastructure regulation, these prices are normally endogenous from the regulation and the objectives may be mixed or unclear.

2.3 Malmquist methods

2.09 The standard approach to dynamic evaluations when we do not have complete prices or priority weights on both the resource and the service sides is to use so-called *Malmquist index*.

2.10 The Malmquist index uses information about the technology and changes herein as a substitute for fixed prices. Hence, to apply the Malmquist approach, we need to estimate the technology like in the static analysis. We shall rely on the same methods and models here and therefore simply refer to the main report for technical details.

2.11 The Malmquist index measures the change from one period to the next by the geometric mean of the performance change relative to the past and present technology. Specifically, let $E_i(s,t)$ be a measure of the performance of TSO_i in period *s* against the technology in period *t*. Now, the improvement of TSO_i from period *s* to period *t* can be evaluated by the Malmquist index $M_i(s,t)$ given by

$$M_i(s,t) = \sqrt{\frac{E_i(t,s)}{E_i(s,s)}\frac{E_i(t,t)}{E_i(s,t)}}$$

2.12 The intuition of this index runs as follows. We seek to compare the performance in period *s* to period *t*. Hence, we compare the efficiency of each TSO in periods *s* and *t*. If $E_i(t,t)$ is larger than $E_i(s,t)$, it mean that the TSO has moved closer towards the frontier defined by period *t* observations. The ratio $E_i(t,t)$/ $E_i(s,t)$ will then be larger than 1. Now, the base technology could also have been the period *s* technology. Therefore we take the geometric mean (i.e. the square root) of these ratios, the one $E_i(t,s)$/ $E_i(s,s)$ using technology *s* as the base and the one $E_i(t,t)$/ $E_i(s,t)$ using period t as the base. In both cases, improvements make nominator larger than denominator. Hence, *M* > 1 corresponds to progress and for example *M* = 1.2 would suggest a 20% improvement from period *s* to *t*, i.e. a fall in the resource usage of 20%.

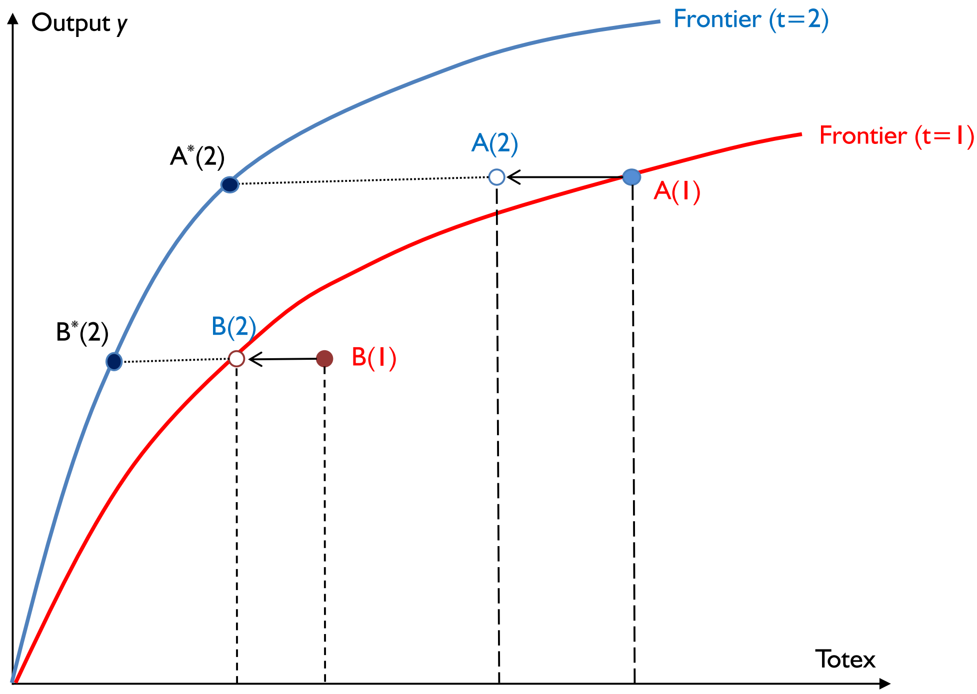

Figure 2-1 Dynamics

2.13 The change in performance captured by the Malmquist index may be due to two, possibly enforcing and possibly counteracting factors. One is the technical change, TC, that measures the shift in the production frontiers corresponding to a technological progress or regress. The other is the efficiency change EC which measures the catch-up relative to a fixed frontier. This decomposition is developed by a simple rewrite of the Malmquist formula above given as multiplication of the two terms:

$$M_i(s,t) = \sqrt{\frac{E_i(t,s)}{E_i(t,t)}\frac{E_i(s,s)}{E_i(s,t)}} \bullet \frac{E_i(t,t)}{E_i(s,s)} = TC_i(s,t)EC_i(s,t)$$

2.14 Again, the interpretation is that values of TC above 1 represent technological progress – more can be produced using less resources – while values of EC above 1 represents catching-up, i.e. less waste compared to the best practice of the year.

2.15 The Malmquist measure and its decompositions are useful to capture the dynamic developments from one period to the next. In the example in Figure 2-1, TSO A improves from time 1 (pos A(1)) to time 2 (A(2)), but it loses in efficiency with respect to the frontier in time 2, since the frontier shift has moved the target A*(2) even further. Likewise, the initially inefficient unit B(1) has caught up with the efficiency target in period 1 at time 2, B(2), but finds itself still inefficient with respect to the new frontier in period 2.

2.16 Malmquist is applicable for general multiple input multiple output production processes.

2.17 Over several periods, one should be careful in the interpretation. One cannot simply accumulate the changes since the index does not satisfy the so-called circular test, i.e.

we may not have M(1,2) x M(2,3) = M(1,3) unless the technical change is so-called Hicks-neutral. This drawback is shared by many other indices.

2.18 Another potential drawback of the Malmquist index is the sensitivity to frontier details and the timing of cost allocations. This is an aspect of the method that does not derive from the theoretical basis but which experience shows us may appear in applications. Small changes and uncertainties in data, e.g. small changes in the timing of cost allocations, may sometimes lead to annual variations that are exaggerated. If for example some costs from period s is registered in period $s+1$, the frontier in period s may be too optimistic and the frontier in period $s+1$ too pessimistic. Thus, it is important to undertake the steps in the analysis below, i.e. investigate whether the variability is linked to technical dynamic assumptions (e.g. changes in price indexes), and to smooth the results over the horizon.

Discussion

2.19 Variations of TFP models are frequently used in incentive regulation in the US and in price-cap regulation in the Anglo-Saxon tradition (e.g. New Zealand in Lawrence and Diewert, 2006). For an excellent introduction to TFP estimations in regulation, see Coelli, Estache, Perelman and Trujillo (2003), further examples of studies are presented in Coelli and Lawrence (2006).

2.20 Frontier shifts in an industry are the result of many factors. It is possible to "push the frontier" by developing new organizational forms, incentive schemes, operational procedures etc. Likewise it is possible to push the frontier by introducing new equipment or by combining known technologies in new ways. This is illustrated in Figure 2-2 below. In this graph, we also illustrate the more unusual case of frontier regression for the lower part of the frontier, meaning that the second period frontier is interior to the previous frontier, meaning that the frontier peers in the second period would have been considered inefficient in the previous period.

2.21 The frontier shift derived from such changes in the soft- and hardware of an industry can be expected to be less dependent on the specific unit being analyzed. Frontier shift is a matter of change over time, and even if the level of efficiency may depend on many local factors, the change in level is likely to be rather uniform. In turn, this suggests that one can derive interesting frontier shifts from several data sets and that the usual problem of structural comparability (validation of task base, asset base standards etc) are less important.

2.22 On the other hand, the evaluation of changes is complicated by increased variance. The variance of an estimate of a difference or ratio may be significantly larger than the variance of its components (of course depending on the correlation between the two), cf. also the discussion above. This means that more years and more data sets are important in the estimation of frontier shifts.

2.23 The efficiency as discussed in the main report and the productivity measures discussed above allow us to measure both the incumbent inefficiency, i.e. the excess usage of resources in a given period, of a TSO, and the technological progress (or regress) of the industry, i.e. a reasonable dynamic trajectory.

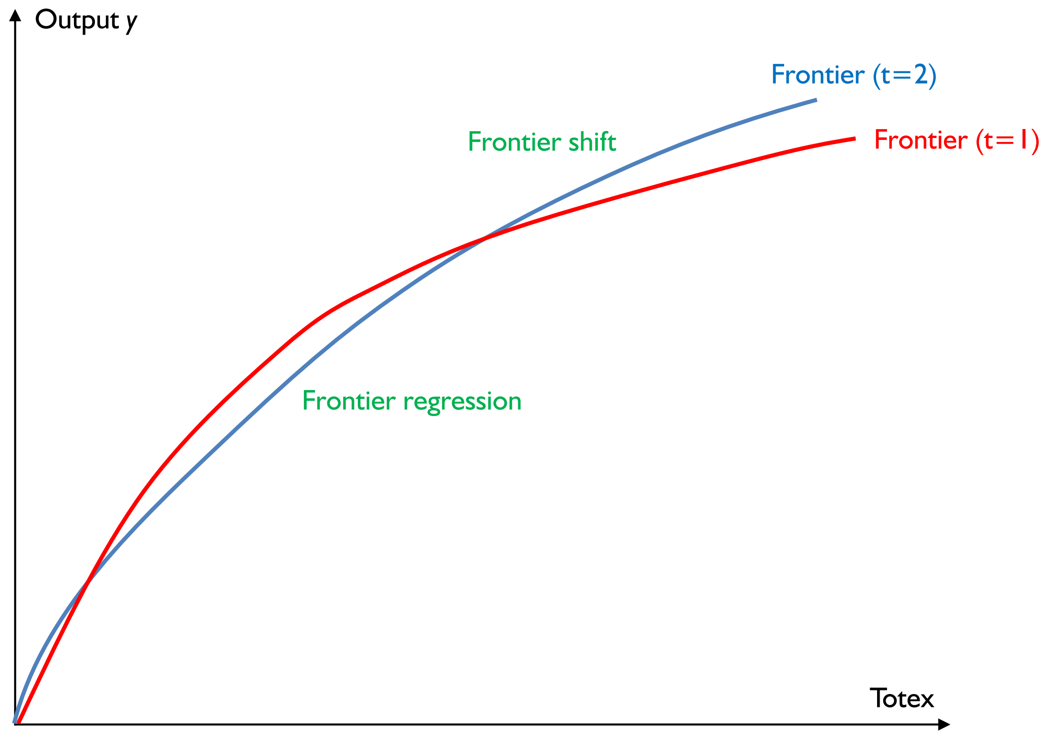

Figure 2-2 Incumbent inefficiency and frontier shifts

3. Benchmarking results

This Chapter provides some general and average results from the benchmarking, without providing any information that may lead to the identification of individual operators and their results.

3.1 Model specification

3.01 Based on conceptual thinking and a statistical analysis reported during Workshops W4 and W5, the final model specification in the TCB18 project includes three cost drivers as shown in Table 3-1 below.

Table 3-1 Model specification: Final model ELEC.

Variable	Definition
INPUT	
dTotex.cb.hicpog_plici	Totex excl energy, inflation index HICPOG, labor cost adjusted in OPEX with PLICI
OUTPUT	
yNG_yArea	NormGrid assets weighted by landuse area yArea (% of service area) x complexity factors per class
yTransformers_power	Total installed transformer power (MW)
yLines.share_steel_angle_mesum	Total line length, weighted by share of angular towers x share of steel towers

Input in the model is total expenditure (Totex). It is calculated as standardized capital costs using real annuities and after correcting for inflation and currency differences plus standardized operating costs excluding cost of energy, out-of-scope activities. See the explicit formula in the main static report: Chapter 4. Labor cost expenditures in Opex are adjusted to average European costs by the PLICI labor cost index. The final model is using three outputs: normalized grid (weighted sum of all grid components as explained the main static report), the landuse area share with complexity factors, the total capacity (measured as transformer power) and the length weighted with angular (routing complexity) and steel share (equipment standards). These parameters capture both the investment (capital expenditure) dimension through the normalized grid and the capacity and the operating cost dimension through the routing complexity parameter, leading to good explanatory results for the average cost in the sample. In general, the strongest candidate in the frontier models is the normalized grid. The next strongest cost driver candidate is the landuse dimension, highly significant with respect to both density, environmental and operational complexities. Thereafter follows the overhead lines, irrespective of age and capacity, representing the routing complexity. Finally, the transformer power completes the model with the capacity provision dimension. Together the factors form a very strong explanatory base for the transmission system operators.

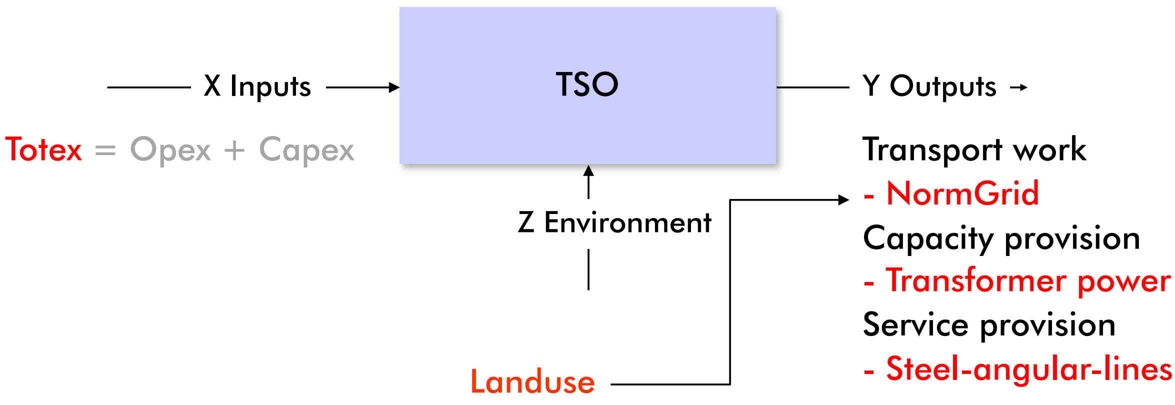

Figure 3-1 Final ELEC model with service categories.

3.2 Summary statistics

3.02 Summary statistics of the costs and cost drivers in the base model are shown in Table 3-2 below. (Note that range values cannot be provided for confidentiality reasons). Q1 denotes first quartile, Q3 third quartile and Q2 the median.

Table 3-2 Summary statistics of model variables (2013-2017, full sample, n = 81)

Variable	Unit	Mean	Q1	Q2 (median)	Q3
dTotex.cb.hicpog_plici	M€	272.3	63.1	153.8	303.9
yNG_yArea	10^6	293.2	86.9	244.9	339.0
yTransformers_power	MVA	43,102	12,343	25,754	39,990
yLines.share_steel_angle_mesum	#	1,772	678	1,286	1,752

3.03 We see that the electricity TSOs in the sample vary in terms of size. The two largest electricity TSOs are approximately twice as large as the third biggest TSO. Also, we see that the mean values exceed the median values. This reflects that the size distributions have a relatively long right tail.

Outliers

3.04 The outlier analysis follows identically that implemented in the static analysis. Thus, one of the 17 TSOs was classified as an extreme outlier and was permanently removed from the reference set as in the static analysis. In addition, three others have been identified using the model specific outlier detection tests explained in the main static report, making in all four TSOs frontier outliers, also as in the static analysis.

3.3 Efficiency scores

3.05 The efficiency scores are obtained using DEA on the final model described. The primary static result concerns the 2017 data. Data are standardized to EUR in 2017 as reference year with inflation and salary cost corrections as in the main static report.

Final model efficiencies

3.06 Summary statistics for the efficiency scores in the final TCB18 model are shown in Table 3-3 below. We see that the DEA model leads to mean efficiencies of 89.8%, i.e. the model suggests that the electricity TSOs on average can save 10.2% in benchmarked comparable Totex.

Table 3-3 Efficiency scores in final model ELEC, static 2017

	Mean	Q1	Q2 (median)	Q3
Final DEA (2017)	0.898	0.795	0.991	1.000
Peers (non-outliers)	4			
Outliers	4			

3.4 Dynamic results

3.07 Using the base model from the main report, we have calculated the Malmquist index and its components between 2013-2017 for the 16 TSOs for which full data is available. The formulae used are given in art 2.13 above. The results are summarized in Table 3-4 below.

Table 3-4 Malmquist results based on 16 TSOs

Years	Malmquist	Efficiency change	Technical change	Number of DMUs
2013 - 2014	0.984	0.975	1.010	16
2014 - 2015	0.964	1.012	0.954	16
2015 - 2016	0.952	0.984	0.969	16
2016 - 2017	0.976	0.978	0.997	16
Mean	0.969	0.987	0.983	

3.08 The results consistently indicate technological regress with technical change TC values between 0.95 and 1.01. On average, it looks as if the cost frontier has moved up with 1.7 % (=1-0.983) on average per year. However, note that the analysis is made on data adjusted for inflation using the harmonized index of consumer prices for overall goods, which is essentially the difference between the exogenous price increases (scarcity, market imperfection) and the general productivity increases (technology, process). Thus, the dynamic analysis here gives a measure for the differential for the transmission sector compared to the productivity gains in the general economy. The regress here indicates that the productivity gains in the electricity transmission sector have been lower than for the general economy in the last five years.

3.09 In terms of catch-up or efficiency change EC, the results are analogous to the technical change: a single year of net improvements and elsewhere a slight regress (-1.3% per year on average). This means that the average inefficient operator did not improve their relative standing towards the frontier.

3.10 In total therefore, it seems that the industry is not developing towards more efficient operations, primarily linked to a weak best-practice development. The average Malmquist index is 0.969 suggesting yearly decline in efficiency of about 3.1%.

The impact of the indices and allocation rules.

3.11 One might suspect that dynamic results are the consequence of a particularly unfavorable choice of economic parameters, such as inflation and salary adjustment indexes. To explore the impact of the choice of the inflation and the salary applied, we have done extensive simulations. In addition, we have also varied the allocation rule for overhead costs, between the default cost-based allocation (key), to a TSO-common average cost-based allocation (ave) and to an exclusion of overhead costs. Altogether, we have redone all the dynamic calculations using 107 different combinations. We have varied according to the options below.

Table 3-5 Indexes used in dynamic simulations.

Inflation index	Salary index	Allocation
cpio	lcis	key (default, st.ind.)
cpiw	lcic2	no alloc
hicpg_cpiw	plits	ave (average alloc)
hicpog_cpiw	plitg	
hicpig_cpiw (default)	plici (default)	
	plico	
	nocorr	

3.12 The results of studying these variations are summarized in Table 3-6 below

3.13 The most striking finding is that the overall results have very little sensitivity to the choice of inflation index, salary correction and allocation key. The standard deviations across the many different runs is very low, as is the min-max span for the overall Malmquist effect. Naturally, some simulations show lower and higher values for individual firms or periods, but the averages across all simulations are within 1% of the base run results. The only year with higher variability is 2015-2016 where the variance and the range of result are higher than in any period for the two decompositions (efficiency and technical change).

Table 3-6 Index variations in simulations

Malmquist	Period	Mean	min	max	StDev
	2013 - 2014	0.978	0.962	0.988	0.006
	2014 - 2015	0.962	0.951	0.972	0.006
	2015 - 2016	0.949	0.936	0.960	0.007
	2016 - 2017	0.971	0.957	0.980	0.006
	Average	0.965			
Efficiency change	CRS	Mean	min	max	StDev
	2013 - 2014	0.970	0.941	0.995	0.013
	2014 - 2015	1.026	1.011	1.049	0.008
	2015 - 2016	0.995	0.943	1.070	0.030
	2016 - 2017	0.984	0.974	1.005	0.008
	Average	0.994			
Technical change	CRS	Mean	min	max	StDev
	2013 - 2014	1.009	0.983	1.040	0.012
	2014 - 2015	0.939	0.914	0.958	0.010
	2015 - 2016	0.958	0.892	1.010	0.029
	2016 - 2017	0.987	0.953	1.001	0.011
	Average	0.973			

Opex based Malmquist decompositions

3.14 We have also evaluated the dynamic development taking a purely Opex perspective. The dynamic approach is analogous to the one described above except that we only look for changes in the Opex. To make sure that lower (higher) Opex is not explained (coursed) by higher (lower) Capex, the Opex efficiencies are calculated as directional distances, i.e. we condition on the amount of Capex used when the reduction in Opex is measured as explained also in individual report, section 3.2.

3.15 The results are shown in Table 3-7 below. We see that the Malmquist index on average is very close to the value in the Totex model, but the catching up effect is positive on average (+3.4%), whereas the technical change is lower (-3.8% compared to -1.7%) also higher than in the Totex case. Hence, it seems that the inefficient TSOs dynamically have done better when we focus on Opex as compared to Totex. (Since we now work with a two-dimensional input and the number of observations is limited, it is not always possible to project observations to a frontier. In such cases, we have assigned a TSO a partial efficiency of 1. This also means that the Malmquist will not always be the product of the two factors, Efficiency and Technical change.)

Table 3-7 Malmquist in the conditional Opex model, *n* = 16 TSOs

	Malmquist	Efficiency change	Technical change	n
2013 - 2014	0.977	0.954	1.049	16
2014 - 2015	0.939	1.061	0.907	16
2015 - 2016	0.960	1.127	0.896	16
2016 - 2017	0.987	0.992	0.996	16
Mean	0.966	1.034	0.962	

3.5 Decomposed dynamic results

3.16 The above results in terms of frontier movements can also be analyzed in more detail by looking at mean changes within the group, among (DEA) peer firms and non-peer firms. Below we provide insights into this analysis for which the simplest possible scenario is used, i.e. no salary cost corrections (since only ratios within countries are considered) and no overhead allocations. To render the comparisons useful, inflation is corrected with the default index as in the general study.

3.17 The figures show the mean relative change by year. As an example, consider the cost of planning in 2013 for a TSO *k* (CPk_2013) and in 2014 (CPk_2014). In this case, the relative change between 2013 and 2014 is the average of the ratios of all operators *k*:

$$\text{Change\_P\_2013-14} = \text{mean}_k \{\text{CPk\_2014/CPk\_2013}\}$$

3.18 The natural measure of growth in this case is the increase in NormGrid Totex, including both Capex and Opex effects. In our example, the relative grid growth between 2013 and 2014 is the average of the ratios of all operators *k*:

$$\text{NG\_change\_2013-14} = \text{mean}_k \{\text{NGTotex\_k\_2014/NGTotex\_k\_2013}\}$$

Transport cost development

3.19 In Figure 3-2 below we find the mean relative change for each year for grid growth (NG, dashed line), transport cost (T) solid blue, mean cost change for peers in green and for non-peers in red, respectively. A ratio lower than one here is a sign of cost contraction, a value above indicates an increase. The results in this graph indicate a better cost control among the peer firms. Although the entire sector shows an overall increase in cost level for transport, the last year 2016/17 shows good results for both peer and non-peers firms (catch-up).

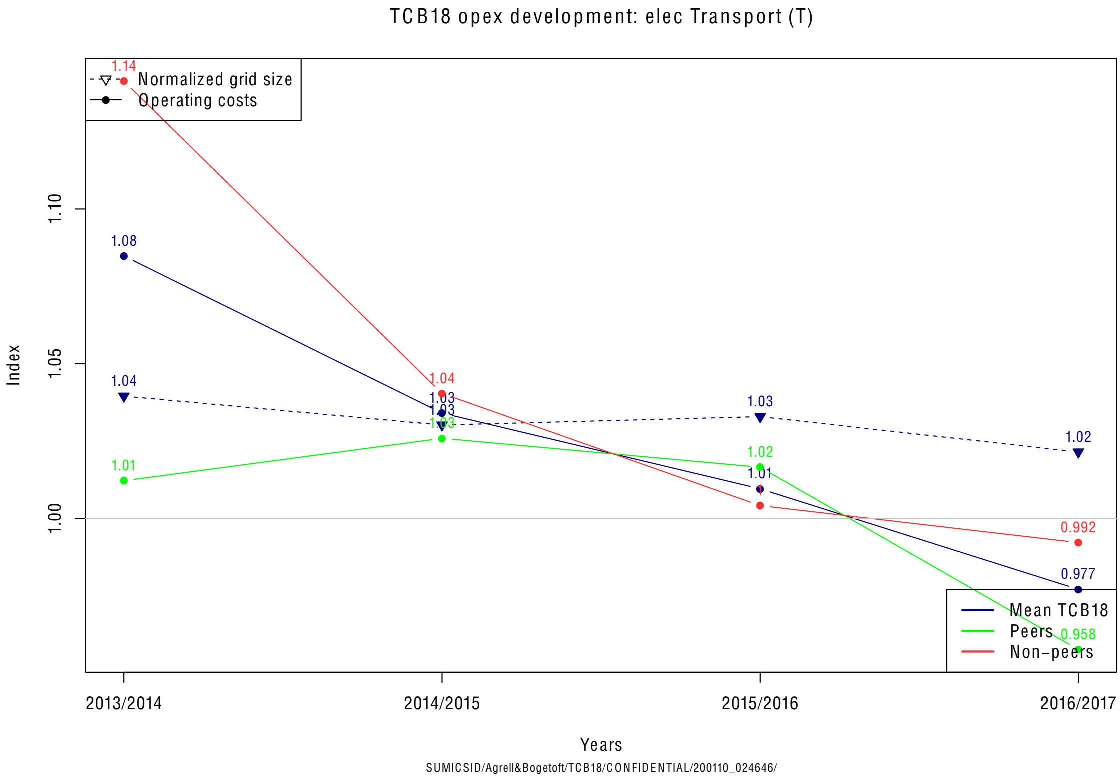

Figure 3-2 Mean cost development T, electricity.

Maintenance costs

3.20 The development for M is shown in Figure 3-3 below. As for T, the overall development is mixed with both peers and non-peers increasing their costs more rapidly than grid growth (and of course inflation). However, once again the peer operators show a better cost containment whereas the non-peers increase their maintenance cost with about 10% for two consecutive years, followed by a slowdown in the last year.

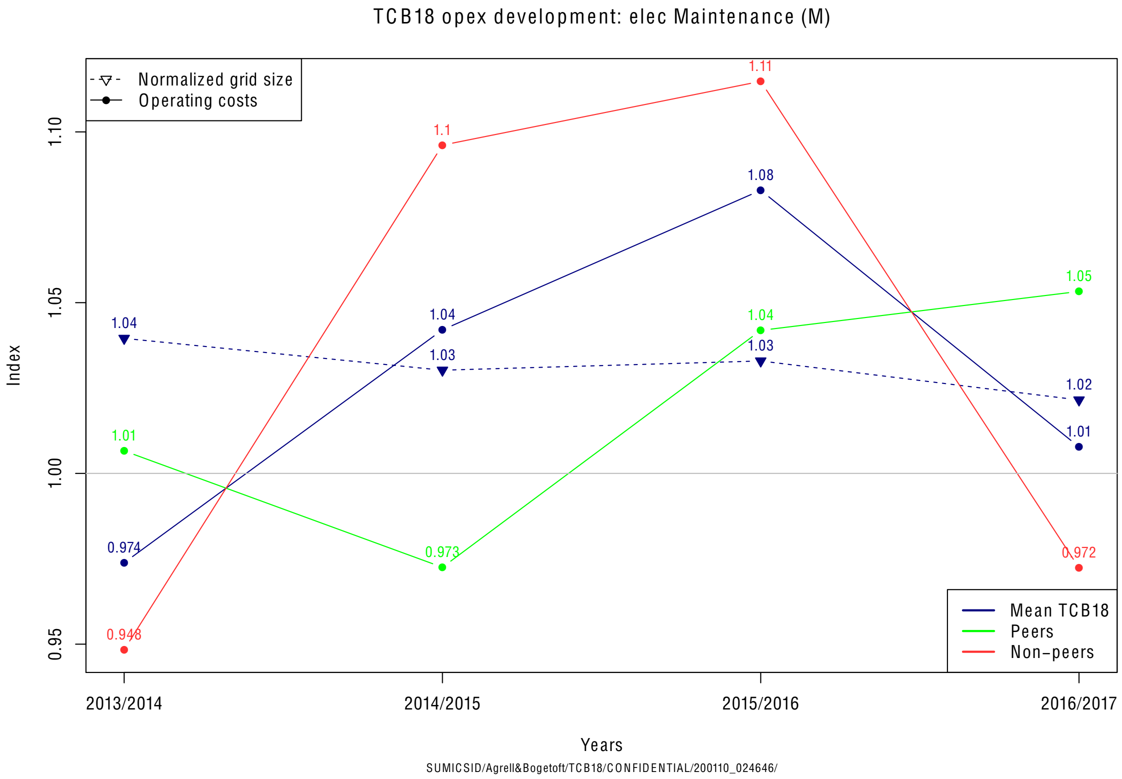

Figure 3-3 Mean cost development M, electricity.

Planning costs

3.21 The cost development for planning costs P is analyzed in Figure 3-4 below. The non-peer operators have a strong increase in 2013/14 followed with continuous increases at a lower rate throughout the period. The peer operators, on the other hand, follow relatively closely the average grid growth, until the last year 2016/17 when their cost increase surpasses that of the non-peers. Note however that the changes are by year, meaning that the overall change is lower for the peer firms than the non-peer firms, both in rate with respect to the base year 2013.

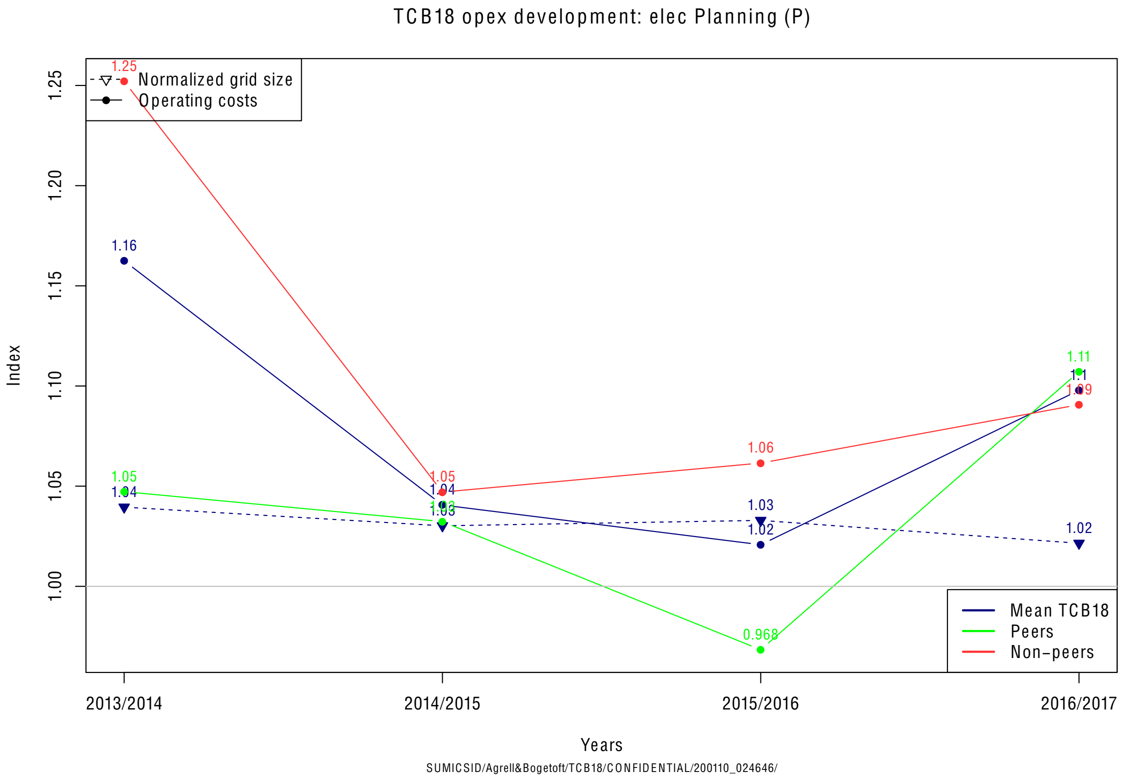

Figure 3-4 Mean cost development P, electricity.

Indirect expenses

3.22 The total indirect costs I are here analyzed as a separate activity rather than added to the other functions. This allows a specific highlight in Figure 3-5 below showing a pattern almost the inverse from the situation in P. The peer operators have stronger increases in indirect costs throughout the period, well beyond grid growth and that of non-peer operators. As before, the development converges at about 5% for all operators in the final year. This may give some suggestion about the organization of the operators and that lower levels of direct cost in the functions may result in higher indirect costs with some lagged effects.

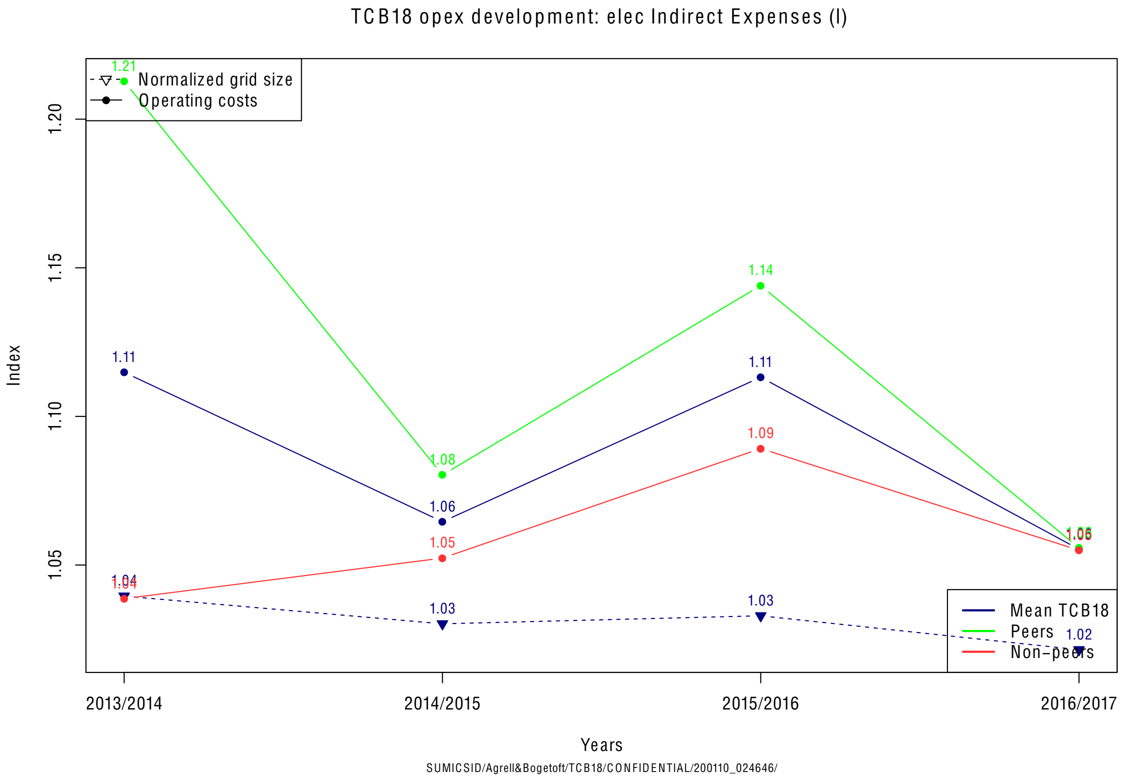

Figure 3-5 Mean cost development total indirect costs I, electricity.

3.6 Overall cost development

3.23 We now turn to the overall cost development, as before without overhead and salary cost corrections, dividing the sample into (DEA) peers and non-peers.

3.24 The dynamics in the total expenditure is shown in Figure 3-6 below. Clearly, all operators increase total expenditure above the infrastructure growth rate, as suggested by the negative productivity growth. The pattern is particularly interesting in 2015/16, where the non-peer operators increase the totex by 14% whereas the peer operators contain the cost increase to 4%, reversing the tendency the year after.

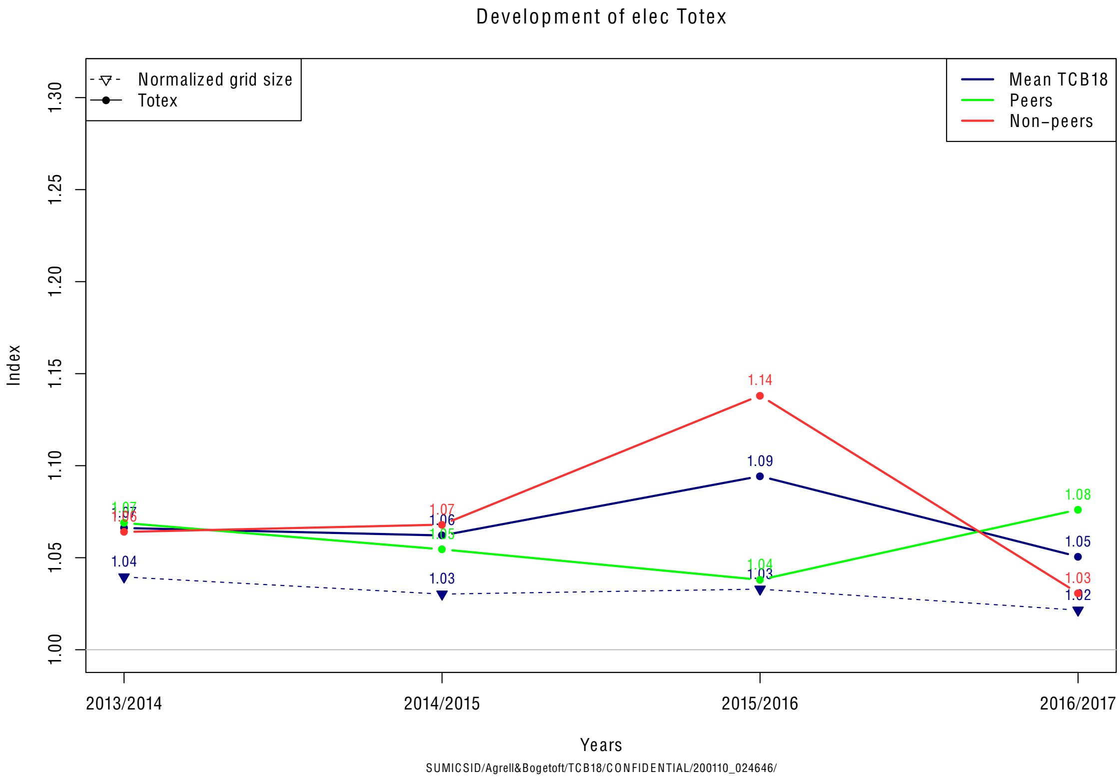

Figure 3-6 Totex development, electricity.

Opex development

3.25 The pattern for the total operating expenditure in Figure 3-7 follows the findings for the components above, meaning cost increases for the first four years for non-peers followed by a last year of contractions. For peers, the picture in Opex is more positive, as also suggested by the component analysis.

Capex development

3.26 As seen in Figure 3-8, the development in Capex hints at a substitution effect between Opex and Capex for the peers: the strong containment in Opex initially is indeed accompanied by a higher than average growth in Capex, lowered during the period only to come back strongly in the last year. For non-peers, the pattern is more correlated to general Opex, contributing to the large Totex peak in the middle of the period. It is notable that the Capex increases exceed the grid growth for all years in the period.

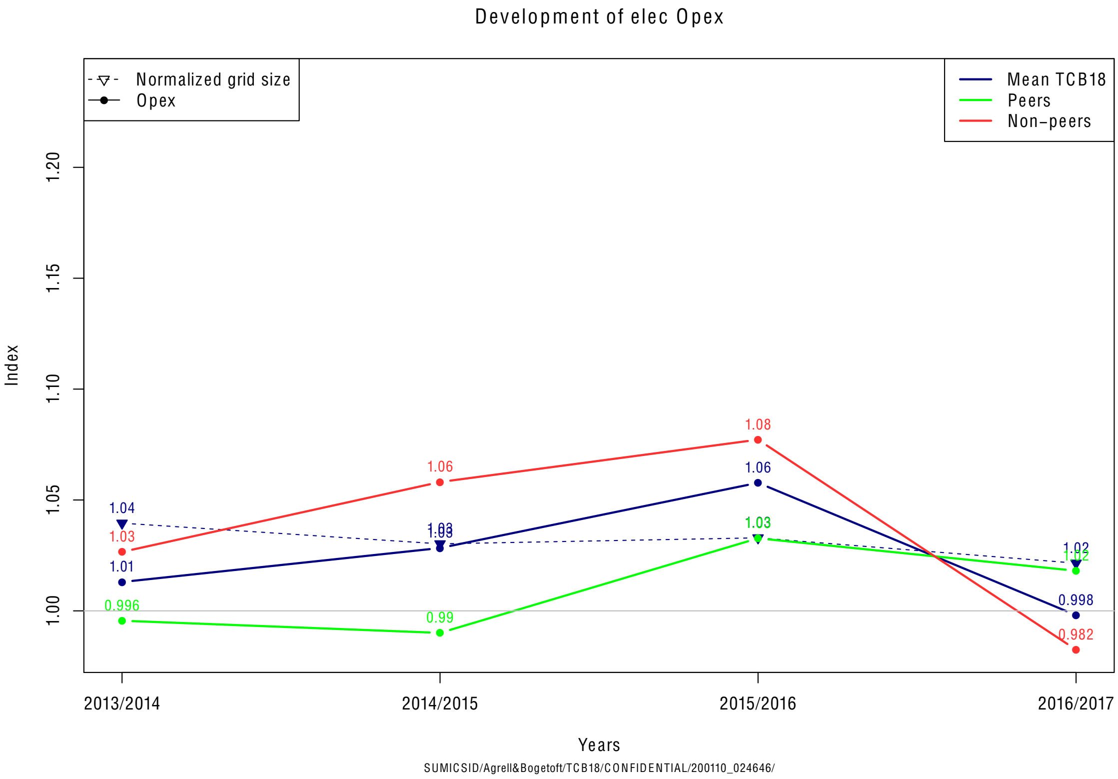

Figure 3-7 Opex development, electricity.

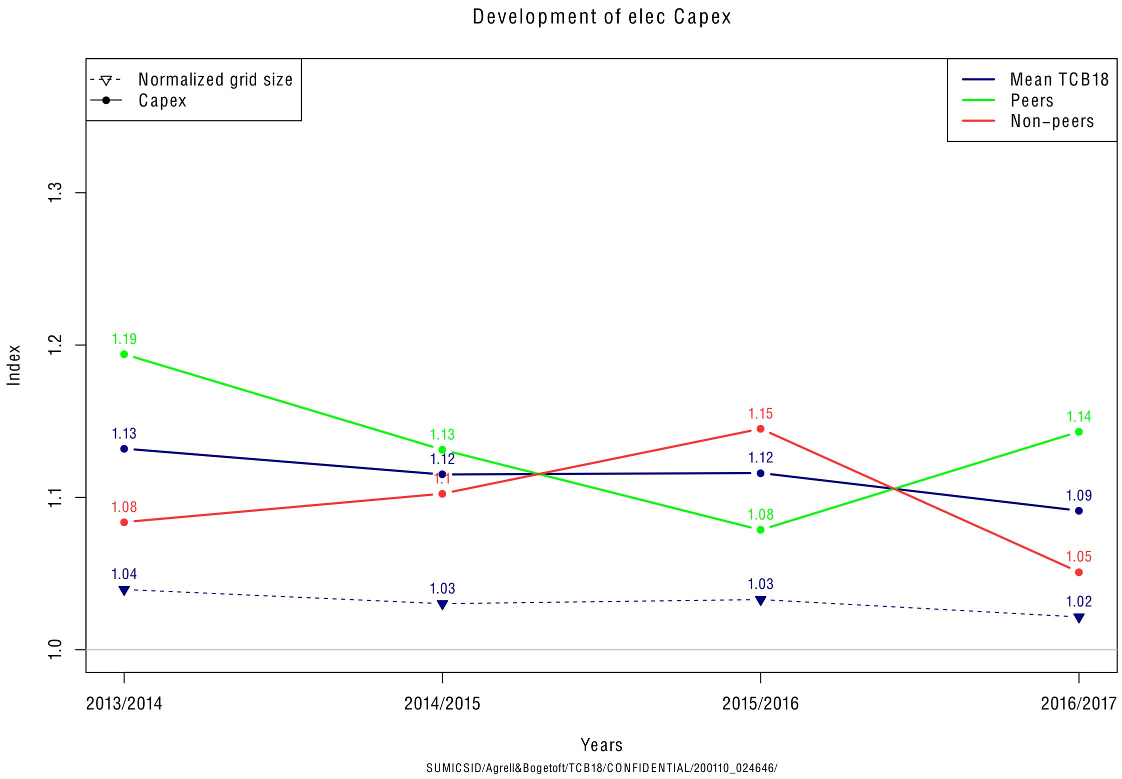

Figure 3-8 Capex development, electricity.

4. Summary and discussion

4.1 Main findings

4.01 The main TCB18 findings suggest that the static efficiency level in 2017 leaves room for efficiency improvements in terms of total expenditure compared to best international practice. The dynamic results in this report show a general productivity regress in the sector, both for non-peer firms in terms of efficiency catch-up and for peers in terms of technological efficiency change. As the data is adjusted for both inflation and price changes in civil engineering work (salary), the regress here should be interpreted relative to the market efficiency and productivity gains in the general economy. Entering in a period of increased competition, low capital costs facilitating market entry and increasing gains from IT-investments in particular in services, the net inflation has been low and the general productivity gains likely more important than before. The finding that the regulated, capital-intensive and less service-innovative transmission industry has experienced a 3% lower productivity growth than the general economy is not contradicting economic intuition. Often, infrastructure sectors produce productivity growth in discrete jumps, corresponding to a particular shift in technology or process, then the relatively lower share of non-asset driven costs limit the gains from general productivity increases in staff and services.

4.02 A more detailed analysis shows some clear differences between the peer and non-peers in terms of cost containment for benchmarked functions (T, M, P), but less so in indirect costs. Whereas the peers seem to contain Opex increases better than non-peer operators, keeping productivity higher, it comes at a higher investment rate in terms of Capex. Taken together, the Totex development compared to grid growth indicates that the sector could not keep up with the general economy's productivity growth in the period 2013-2017. As regards the frontier shift (peer) results, the limited number of operators included in the assessment raises a caveat into overinterpreting the decomposed dynamic results for regulatory usage. An alternative policy would be to use a longer horizon for the analysis or to use a TFP (total factor productivity) approach to control the impact of the few peer operators.

4.2 Comparison with E3GRID

4.03 The earlier E3GRID model (Agrell and Bogetoft, 2009, 2014) has a similar base structure using a grid asset proxy (NormGrid) and a routing complexity output linked to the line length and the angular towers (cf. main report). However, the TCB18 approach is more advanced than E3GRID in three aspects as discussed in the main TCB18 report. Nevertheless, the similarity of the model structure makes the comparison of the dynamic results particularly interesting.

4.04 In E3GRID 2012 (Agrell et al., 2013), the productivity development during 2007-2011 was shown to be nil for continental Europe and negative for Scandinavia and the UK. Interestingly, the rise of the cost was here noticed at the end of the period, especially in maintenance cost. Our results here suggest that this tendency was strong in 2011-2014 and that the negative tendency also for peers have lowered their absolute advantage in the sector. However, a finding in this study is that the catch-up speed for non-peers is lower than in the previous period, suggesting stationarity in the productivity improvement rate or lack of adoption of best-practice technology.

References

Agrell, P. J. and P. Bogetoft (2009) *International Benchmarking of Electricity Transmission System Operators*. Project e[3]GRID. SUMICSID. http://e3grid.sumicsid.com/pub/2009-03-09_e3grid_final_report_open_main.pdf

Agrell, P. J. and P. Bogetoft (2014), International Benchmarking of Electricity Transmission System Operators *Proceedings of European Energy Market Conference EEM14, IEEE Proceedings*, pp. 1-5 doi: 10.1109/EEM.2014.6861311

Agrell, P. J., P. Bogetoft, C. Riechmann, A. Rodgarkia-Dara, C. Zimmer (2013) *e3GRID 2012 – European TSO Benchmarking Study*. Project e3GRID 2012. SUMICSID, Consentec and Frontier Economics. Report for CEER. https://www.researchgate.net/publication/265592571_E3GRID2012_European_TSO_Benchmarking_Study

Agrell, P.J., P. Bogetoft, and J. Tind (2005), DEA and Dynamic Yardstick Competition in Scandinavian Electricity Distribution, *Journal of Productivity Analysis*, 23, 173–201.

Agrell, P. J., and Niknazar, P. (2014). Structural and behavioral robustness in applied best-practice regulation. *Socio-Economic Planning Sciences*, 48(1), 89-103.

SUMICSID

SUMICSID SPRL (GROUP)
Rue Maurice Lietart 56
B-1150 Brussels, BELGIUM
belgium @ sumicsid.com

Tel: +32 (0)2 675 15 23
Fax: +32 (0)2 706 53 58

www.sumicsid.com

CEER
Council of European Energy Regulators

Cours Saint-Michel 30a, box F (5th floor)
1040 Brussels, BELGIUM

Tel: +32 (0)2 788 73 30
Fax: +32 (0)2 788 73 50

www.ceer.eu