PROJECT CEER-TCB18

Dynamic efficiency and productivity changes for gas transmission system operators

MAIN REPORT

2020-04-14 V1.0

Disclaimer

This is the final report on the dynamic efficiency and productivity results 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 gas transmission system operators
Final report. Open. Project no: 370 / CEER-TCB18
Release date: 2020-04-14

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.

The productivity development among the gas transmission system operators in the project was stable at a level corresponding to the general productivity growth in the economy. The non-peer operators on average reduced their total expenditure by 1.7% above inflation, which is a positive result driven in part by good results in the gas transport and planning activities. The best-practice frontier development was negative, especially during the end of the period, amounting to a 1.7% difference with respect to the general inflation. The results with respect to the best-practice frontier should not be overinterpreted given the relatively low number of peers in the dynamic study.

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 gas 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 gas.

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

1.3 Reading guide

1.08 Chapter 2 includes some modelling 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 the 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%.

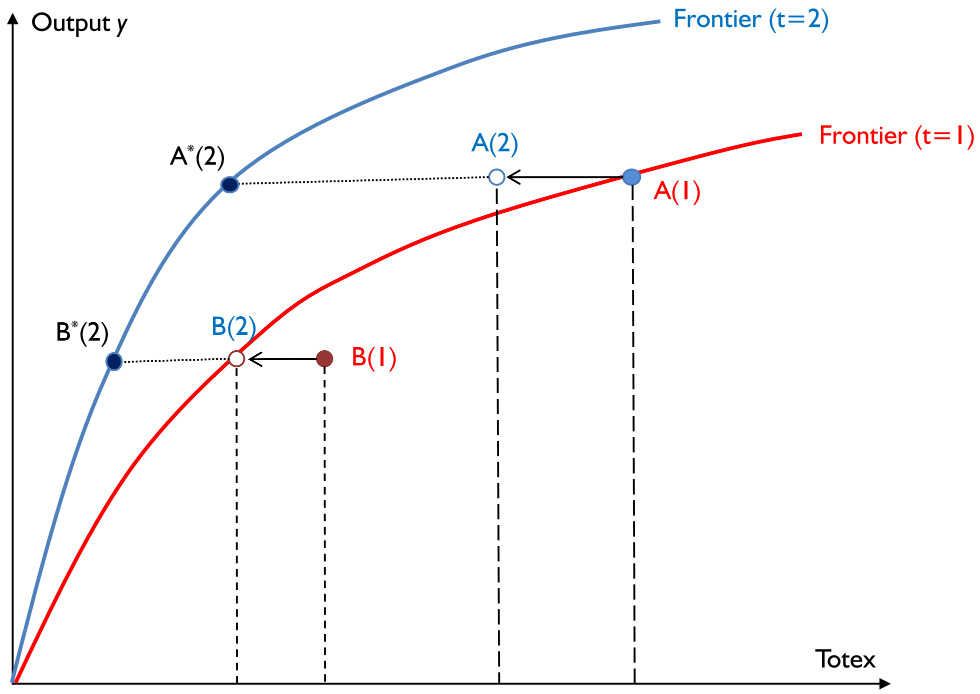

Figure 2-1 Dynamics

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.

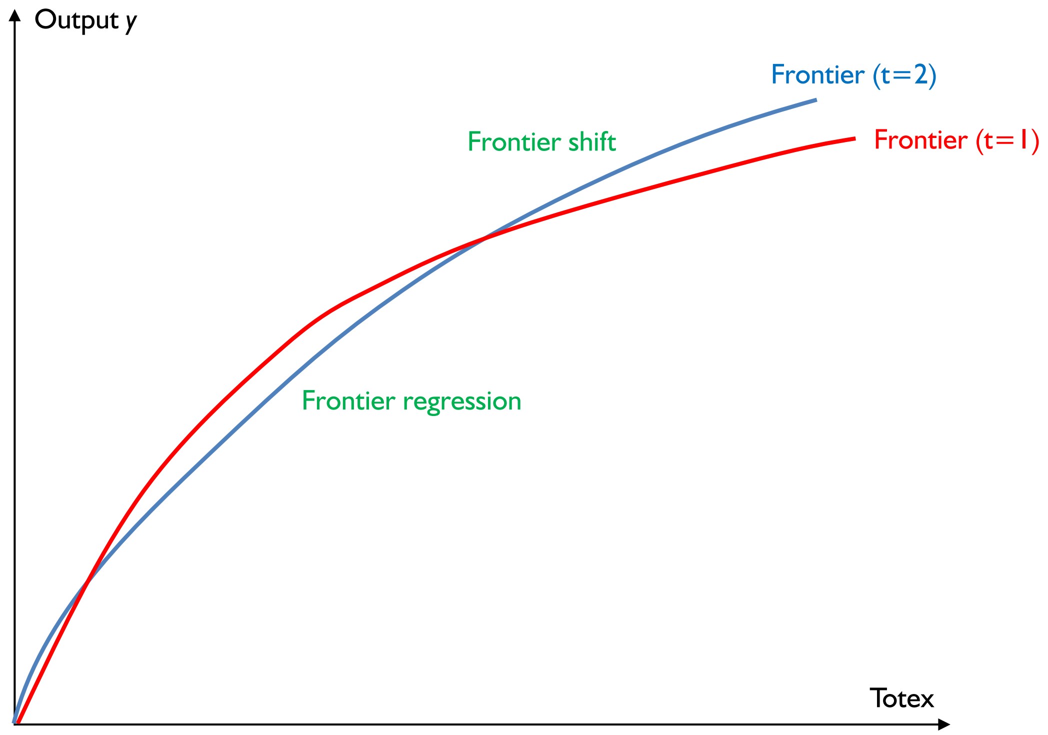

Figure 2-2 Incumbent inefficiency and frontier shifts

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 four cost drivers as shown in below.

Table 3-1 Model specification: Final model GAS.

Variable	Definition
INPUT	
dTotex.cb.hicpog_plici	Totex excl energy, Capex break, inflation index HICPOG, labor cost adjusted in OPEX with PLICI
OUTPUT	
yNG_zSlope	NormGrid assets weighted by slope zSlope (% of service area) x complexity factors per class
yConnections_tot	Total number of connection points
yCompressors.power_tot	Total installed compressor capacity (MW)
yPipes_Landhumidity	Total pipeline length, weighted by wetness factor zLandhumidity (% of service area) x complexity factor

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 TCB18 main 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 four outputs: normalized grid (weighted sum of all grid components as explained in section 1.1 of the main report) weighted with the slope class complexity factor, total number of connection points, the total capacity (measured as compressor capacity) and the pipeline length weighted with humidity severity factors. These parameters capture both the investment (capital expenditure) dimension through the normalized grid and the operating cost dimension through the connections and capacity, 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 connections and the weakest candidate statistically is the humidity factor. Together the factors form a very strong explanatory base for the transmission system operators.

3.02 An initial proposal presented at Workshop W5 had a different parameter to capture capacity provision, total injection volume of H and L gas in nm^3. After discussions with project participants and additional analysis, it was decided to replace this parameter with compressor power, which is a parameter independent on exogenous events (temperature and business cycles) and related to actual deployed capacity rather than recent investments (i.e. the normalized grid component).

3.03 The final model has one parameter more than the E2GAS model[2] (three parameters), which reflects both a larger reference set (29 vs 22), but also a more advanced consideration of environmental conditions through GIS-collected data for both slope classes and soil humidity. It is therefore logical that the new model should explain costs to an even higher extent than in the previous study. Nevertheless, it is interesting to note that the same classes and types of parameters are found in the two models, differing primarily on the capacity provision dimension (compressor power vs nominal maximal capacity). The logic of the model specification with respect to the earlier categories is illustrated in below.

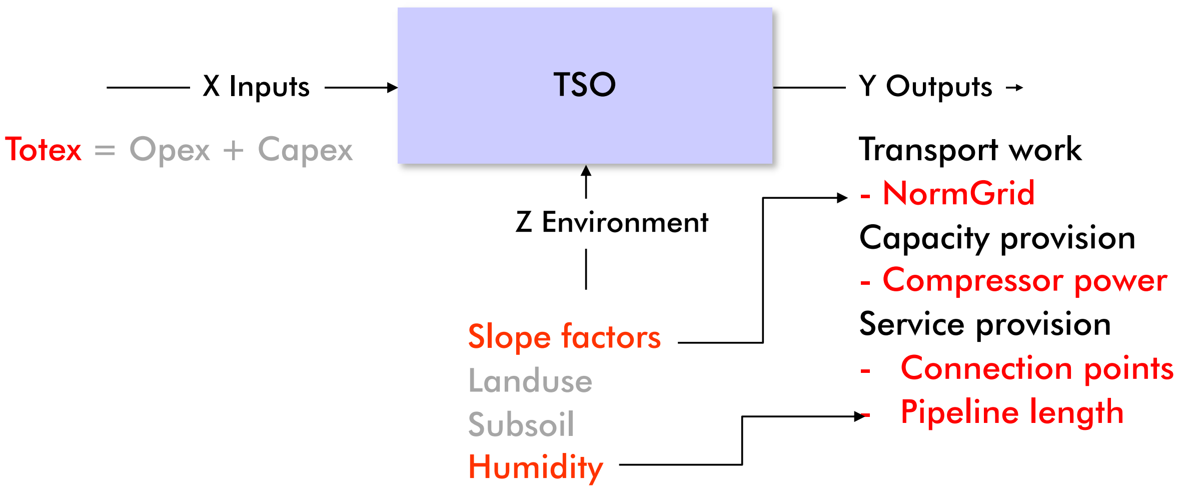

Figure 3-1 Final GAS model with service categories.

3.2 Summary statistics

3.04 Summary statistics of the costs and cost drivers in the base model is 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 for model variables (2013-2017, full sample, *n* = 70)

Variable	Mean	Q1	Q2 (median)	Q3
dTotex.cb.hicpog_plici	151,486,489	31,977,516	55,917,669	261,211,605
yNG_zSlope	125,349,439	29,248,670	42,600,584	139,369,517
yConnections_tot	289	40	190	451
yCompressors.power_tot	242,866	42	22,824	425,697
yPipes_Landhumidity	3,576	1,073	1,385	4,480

3.05 We see that the gas TSOs in the sample vary in terms of size. The 25% largest gas TSOs are approximately 5 times larger than the 25% smallest TSOs. Also, we see that the mean values exceed the median values. This reflects that the size distributions have a relatively long right tail.

[2] yNormGrid, yConnections_tot and yCapacity_max (max of injection and delivery peak flow).

Outliers

3.06 The analyses of the raw data as well as the analysis of a series of model specifications, i.e. models with alternative costs drivers, suggest that one of the 29 TSOs almost always is an extreme outlier. This TSO has therefore been permanently removed from the reference set. In addition, five others have been identified using the model specific outlier detection tests explained in section 1, making in all six TSOs frontier outliers.

3.3 Efficiency scores

3.07 The efficiency scores are obtained using DEA on the final model described. The primary static result concerns the 2017 data for all except German TSOs, for which 2015 was used as benchmark year (costs were indexed to 2017).

Final model efficiencies

3.08 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 average efficiencies of 79%, i.e. the model suggests that the gas TSOs on average can save 21% in benchmarked comparable Totex.

Table 3-3 Efficiency scores in final model GAS, static 2017/2015

	Mean	Q1	Q2 (median)	Q3
Final DEA (2017)	0.793	0.631	0.881	1.000
Peers (non-outliers)	4			
Outliers	6			

3.4 Dynamic results

3.09 Using the base model from the main report, we have calculated the Malmquist index and its components between 2013-2017 for the 11 TSOs for which dynamic data are available (thus excluding among others, all German TSOs). The formulae used are given in art 2.13 above. The results are summarized in Table 3-4 below.

Table 3-4 Malmquist results (2013-2017), gas TSO.

	Malmquist	Efficiency change	Technical change	Number of DMUs
2013 - 2014	0.998	1.010	0.988	9
2014 - 2015	1.028	1.030	0.999	10
2015 - 2016	0.976	0.996	0.981	11
2016 - 2017	0.996	1.033	0.966	11
Mean	1.000	1.017	0.983	

3.10 The results consistently indicate technological regress with technical change TC values between 0.97 and 1.00. 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 gas transmission sector have been lower than for the general economy in the last five years.

3.11 In terms of catch-up or efficiency change EC, the results (mean 1.017) are positive meaning that the average TSO caught up 1.7% compared to the previous year's frontier. This finding is also shown in more detail in the analyses below, e.g. for cost in transport and transit T.

3.12 In total therefore, it seems that the industry is not developing towards more efficient operations. The average Malmquist index is 1.0 suggesting that the overall productivity in gas transmission followed the productivity development in the general economy.

The impact of the indices and allocation rules.

3.13 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	

3.14 The results of studying these variations are summarized in Table 3-6 below. The most striking finding is that the results have little sensitivity to the choice of inflation index, salary correction and allocation key. The standard deviations across the many different runs is low, as is the min-max span. The simulation results confirm (to a precision of two decimals) the stable overall productivity development, the unit-valued Malmquist estimate. However, the sensitivity analysis for the efficiency change (EC) suggest that 1.7% may be an upper bound, with 1% as the mean value across all settings. Likewise, the frontier shift (TC) estimate of a 1.7% regress is here nuanced with a mean regress of 1.3%. We note that the cost development in 2015/2016 affects the productivity of the sector negatively for both frontier and non-frontier operators, excluding this year would report a positive mean productivity growth among the gas transmission operators.

Table 3-6 Index variations in simulations

Malmquist	Period	Average	Min	Max	StDev
	2013 - 2014	0.997	0.987	1.004	0.004
	2014 - 2015	1.019	1.005	1.028	0.005
	2015 - 2016	0.974	0.966	0.985	0.005
	2016 - 2017	0.997	0.983	1.007	0.006
	Mean	0.997			

Efficiency change	Period	Average	Min	Max	StDev
	2013 - 2014	1.002	0.993	1.016	0.005
	2014 - 2015	1.023	1.006	1.039	0.007
	2015 - 2016	0.993	0.977	1.003	0.006
	2016 - 2017	1.024	0.998	1.045	0.011
	Mean	1.010			

Technical change	Period	Average	Min	Max	StDev
	2013 - 2014	0.994	0.981	1.005	0.005
	2014 - 2015	0.996	0.981	1.005	0.005
	2015 - 2016	0.982	0.973	0.994	0.005
	2016 - 2017	0.975	0.962	0.988	0.007
	Mean	0.987			

Opex based Malmquist decompositions

3.15 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.

3.16 The results are shown in Table 3-7 below. We see globally a strong resemblance between the Totex and the conditional Opex results. It suggests that the operators have performed similarly in Opex as for Totex during the period, keeping the level of the general productivity level. (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 = 11 TSOs

	Malmquist	Efficiency change	Technical change	Number of DMUs
2013 - 2014	0.999	1.027	0.974	9
2014 - 2015	0.993	0.977	1.017	10
2015 - 2016	1.004	1.009	0.994	11
2016 - 2017	0.997	1.040	0.962	11
Mean	0.998	1.013	0.987	

3.5 Decomposed dynamic results

3.17 The above results in terms of frontier movements can also be analyzed in more detail by looking at mean changes within the group for operators with data for subsequent years. Single-year observations are not used and no decomposition is made into peers and non-peers. The graphs also exclude 10% extreme values. 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.

3.18 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*:

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

3.19 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

3.20 In Figure 3-2 below we find the mean relative change for each year for grid growth (NG, dashed line) and transport cost (T) solid blue. A ratio lower than one here is a sign of cost contraction, a value above indicates an increase. The red solid line indicates the overall cost development over the period, here 0.98, i.e. a 2% decrease of real cost, beating inflation and grid growth. In more detail, the blue curve shows a stable cost-decreasing tendency with the exception of 2015/2016, where an 8% increase is recorded. The mean annual grid growth (NG) during the period was 1.3%, meaning that the transport activity increases its partial efficiency during the period.

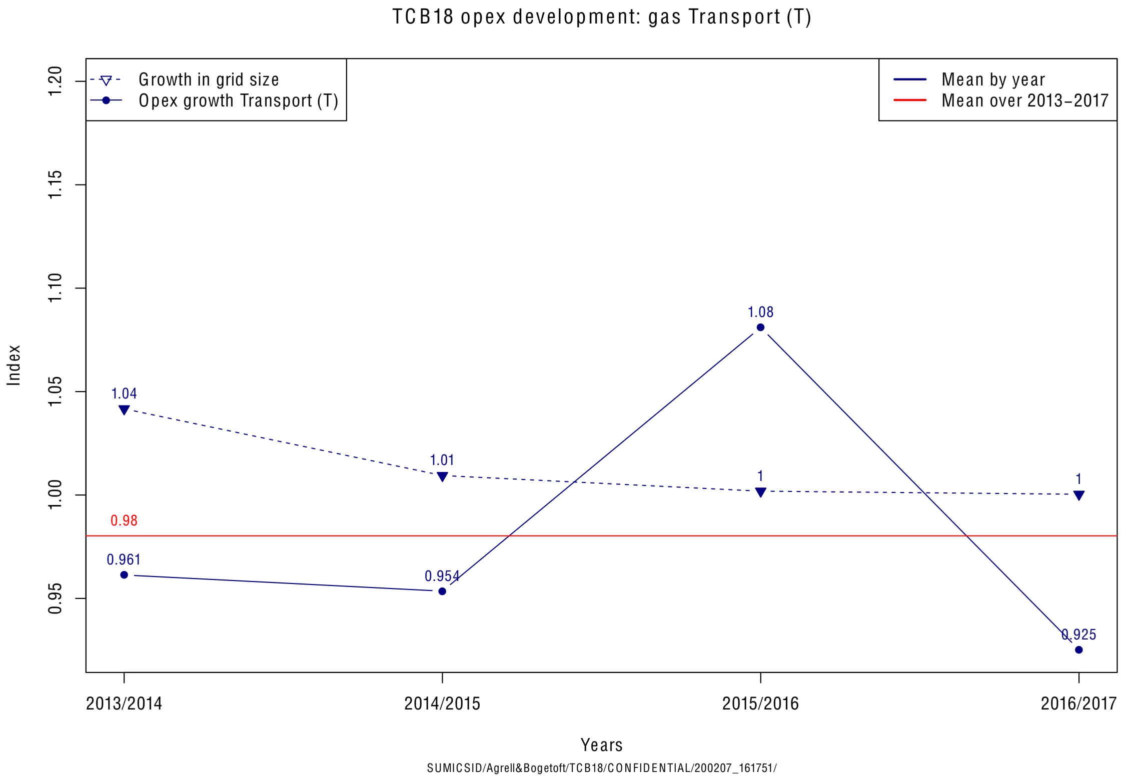

Figure 3-2 Mean cost development T, gas.

Maintenance costs

3.21 The development for M is shown in Figure 3-3 below. The development initially is very positive with reductions in during the period 2013-2015 per normgrid unit, reflecting efficiency efforts combined with good grid growth of 5%. As noticed in the general productivity results, the results for 2015/2016 are negative with an increase of 3% per unit in a setting of almost no grid expansion 2015-2017. However, in total the maintenance activity costs per grid unit decreased by 1.5% per year during the period, a positive results.

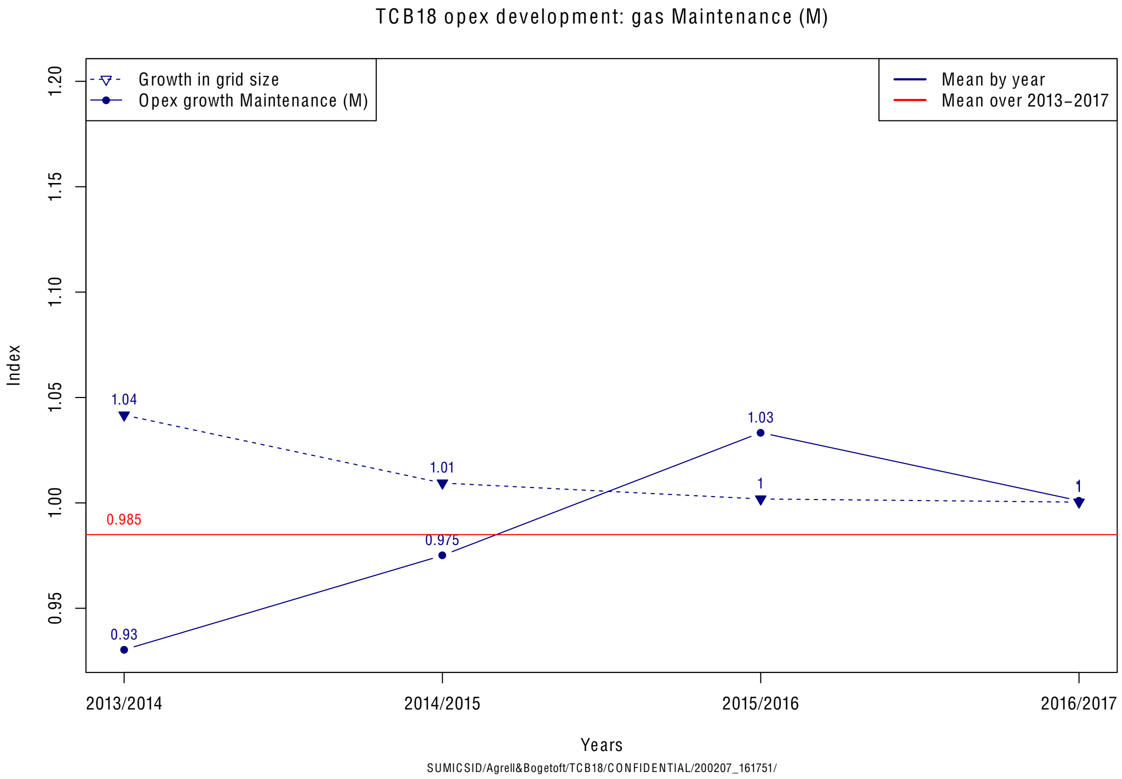

Figure 3-3 Mean cost development M, gas.

Planning costs

3.22 The planning cost data in the sample for gas TSO is rather scarce. Considering the share of planning cost in the total in-scope cost base provides some interesting observations. Initially, this share averaged 13.5%, decreasing the last three years to about 11%. This also coincides with the findings for the cost development in planning in Figure 3-4, an initially higher cost level, transforming into a general reduction at the end of the period. This suggests roughly that the cost development for planning cost is stable, showing a partial reduction as the grid growth is temporarily slowing during the latter part of the period.

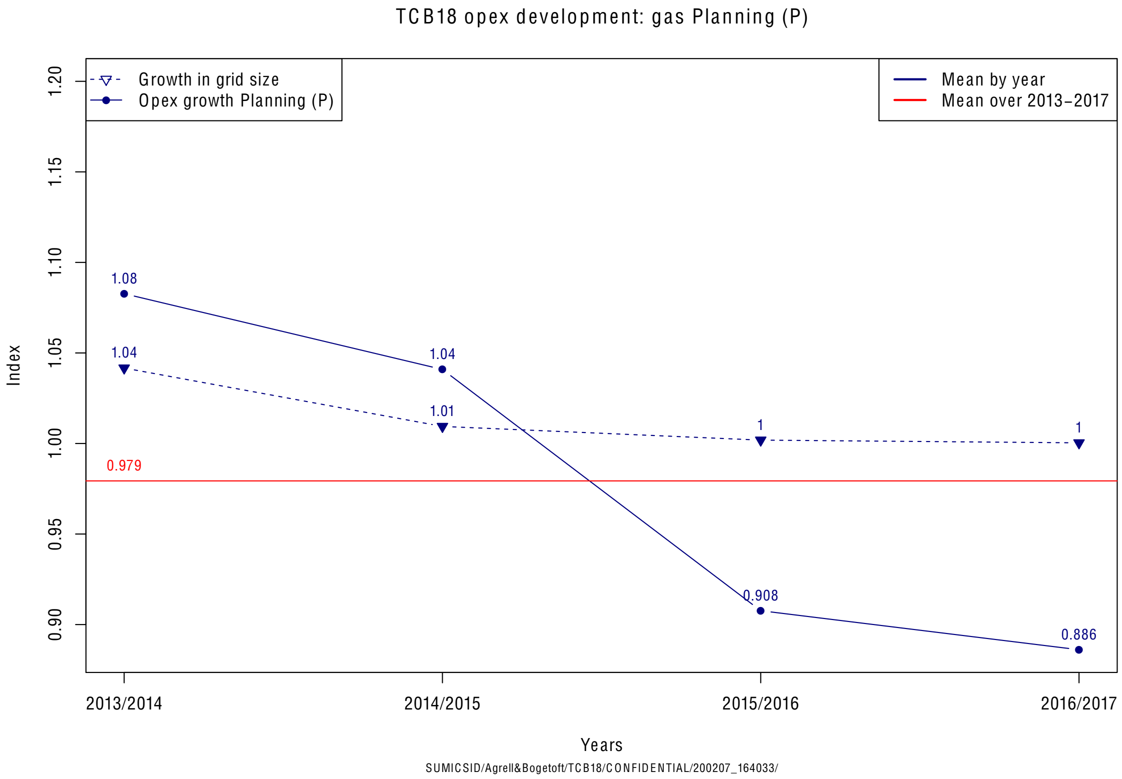

Figure 3-4 Mean cost development planning P, gas.

Indirect expenses

3.23 The total indirect costs I are here analyzed as a separate activity rather than added to the other functions. The graph in Figure 3-5 shows initially the effects from a few units with large allocations in 2014, but the general pattern is very stable around 1, ending with a 6% increase. The average cost development of 13% is not representative as the initial two years' development stands for most of the effect.

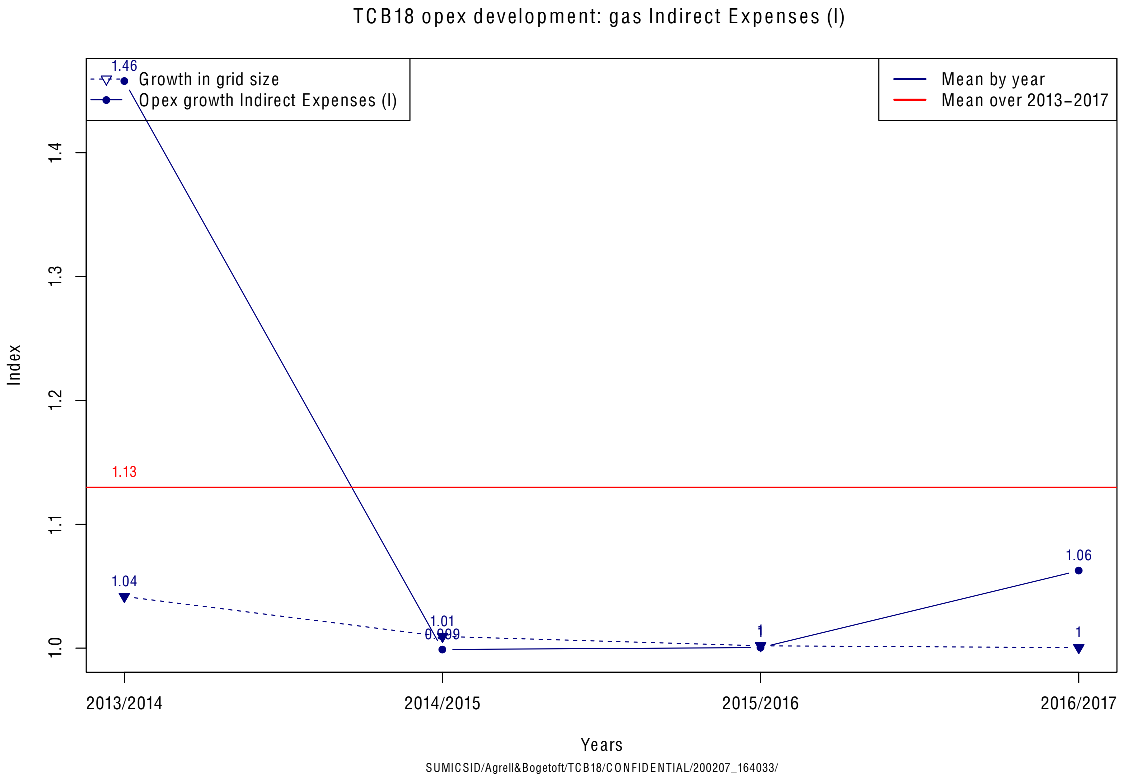

Figure 3-5 Mean cost development total indirect costs I, gas.

3.6 Overall cost development

3.24 We now turn to the overall cost development, as before without overhead and salary cost corrections. Due to a small sample of TSOs (9-11 TSO per biannual period), a decomposition into peer and non-peer units is not reliable.

3.25 The dynamics in the total expenditure is shown in Figure 3-6 below. The overall development is stable, close to the average grid growth, although with a tendency of increase by the end of the period in spite of low grid investments. Altogether, the totex cost increase above inflation amounts to about 0.95% per year compared to an average grid growth of 1.5%.

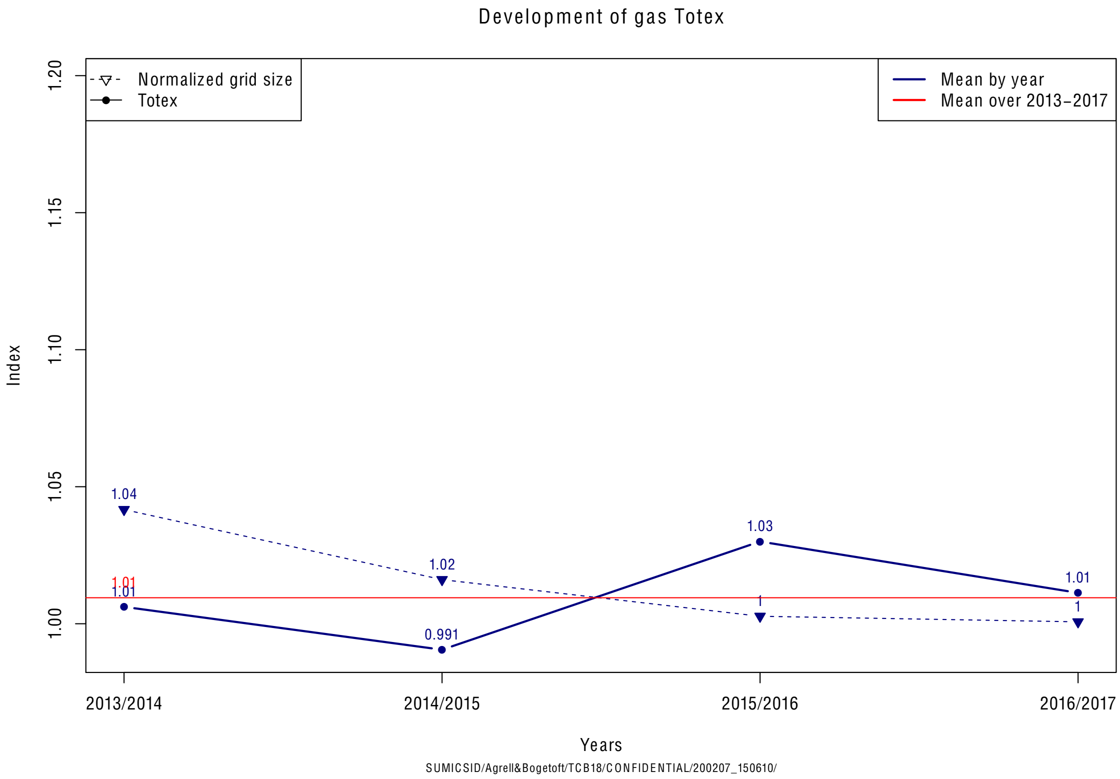

Figure 3-6 Totex development, gas.

Opex development

3.26 The pattern for the operating expenditure in Figure 3-7 provides some explanation for the findings in the Totex graph above, in particular the increase of cost in 2015/16. With the exception of the year 2016, the tendency is on a 2.5% annual reduction in Opex, starting at the beginning of the period. Note that net effect in Opex for the period 2015/2017 is a stable 0% increase, meaning that the operating cost at the end of the period followed inflation under a low grid growth segment in time .

Capex development

3.27 As seen in Figure 3-8, the Capex development in the sector is also very stable, hovering annually around 3%, the average over the period. Although this suggests that the capital expenditure for the investments exceeded both inflation and the grid growth, the magnitude is low and the cost increase is well contained.

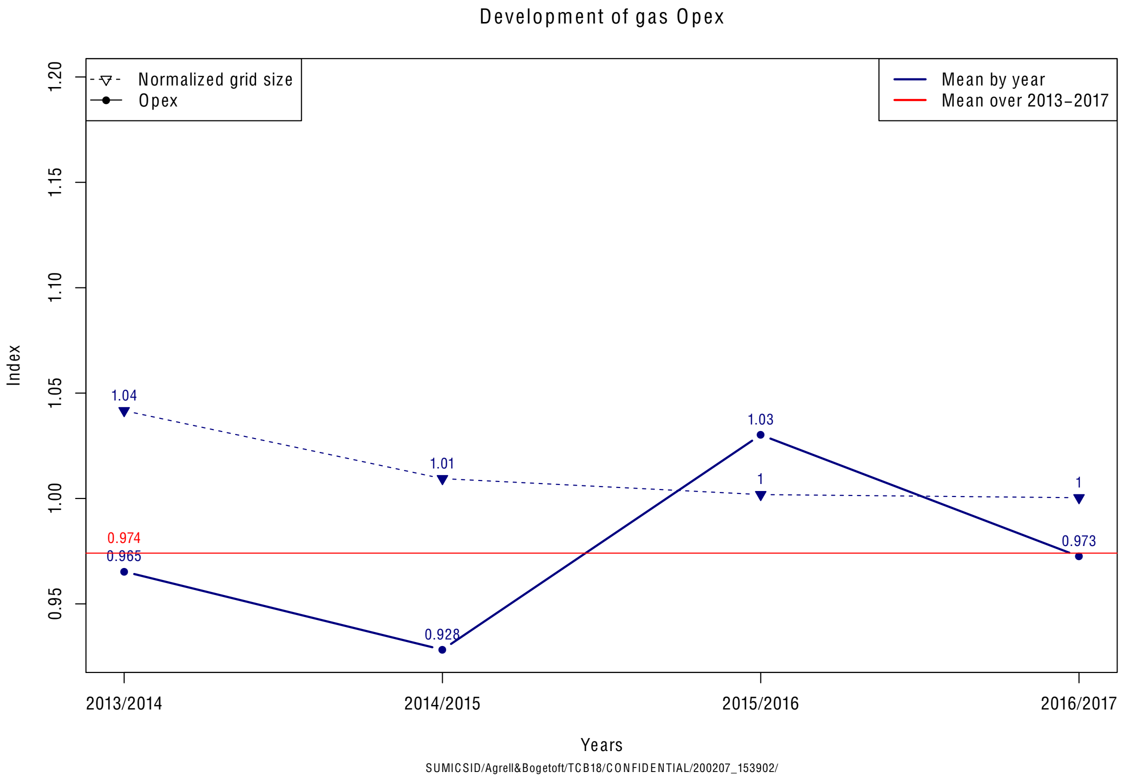

Figure 3-7 Opex development, gas, n = 9 – 11.

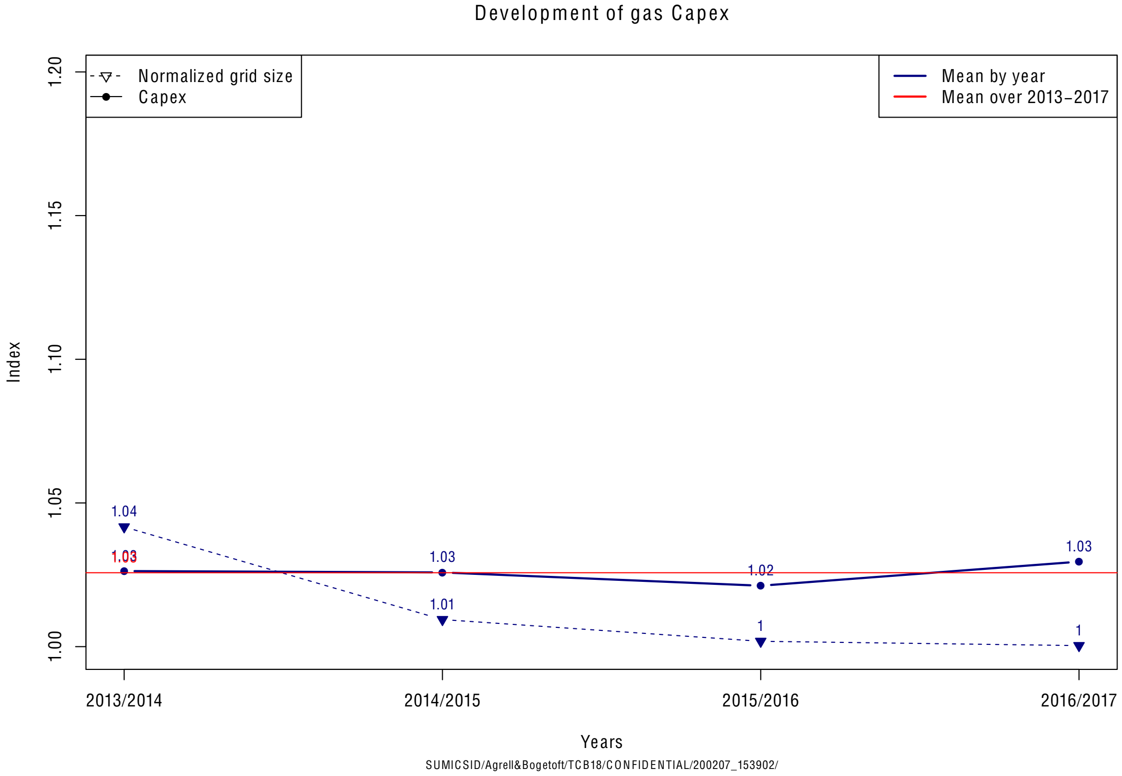

Figure 3-8 Capex development, gas, $n = 9 - 11$.

4. Summary and discussion

4.1 Main findings

4.01 For gas transmission, the static TCB18 findings for 2017 suggest that there is an average 21% efficiency margin to reach best international practice. The dynamic results in this report show a relatively positive result concerning the development in the sector. In global terms, the sector has kept the productivity improvement pace of the general economy, especially driven by a good catch-up (1.7%) by non-peers in terms of technological efficiency change. However, the best practice frontier has not advanced substantially during the period, the regress can be estimated to 1.7%. 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. In the particular case for gas transmission, the frontier shift results are moreover affected by the low number of peers in each year (3-4), making the frontier generalizations less robust than the efficiency change estimates.

4.02 In more detailed decompositions of the cost development, the positive impression is shared when noticing average functional cost reductions that go below the average grid growth rate, indicating partial productivity gains in transport and transit, maintenance and planning activities. These results lead to an average improvement in the operating expenditure for the TCB18 operators, detected in the model primarily as the efficiency change factor.

4.2 Discussion

4.03 The earlier E2GAS study for gas transmission (Agrell, Bogetoft, Trinkner, 2016) was limited to a static assessment, to our knowledge no structured dynamic productivity study has been made for European gas transmission operations. The results herein are therefore the first authoritative that provide a coherent view of the cost development using a recent time series of validated data.

4.04 However, the TCB18 results in gas could be compared with those obtained for electricity transmission in the same project. A similarity is found in a weak frontier shift component, but contrary to electricity, the gas operators show ongoing continuous partial productivity gains in operating expenditure, based on the three in-scope activities. This difference may be partly due to a higher efficiency differential in the sample with higher margins for catch-up among the gas operators. Given the precursory nature of the study, subsequent studies may contribute shedding light on this issue, also providing more data material for determining the magnitude of the overall technology development for the best practice frontier.

5. References

Aivazian V. A., J. L. Callen, M. W. L. Chan and D. C. Mountain (1987), Economies of Scale Versus Technological Change in the Natural Gas Transmission Industry, The *Review of Economics and Statistics*, 69(3), pp. 556-561.

Agrell, P. J. and P. Bogetoft (2009b) International Benchmarking of Electricity Transmission System Operators. Project e3GRID. SUMICSID http://e3grid.sumicsid.com/pub/2009-03-09_e3grid_final_report_open_main.pdf

Agrell, P. J., P. Bogetoft, H. Beaussant, J. Talarmin (2014) *Benchmarking European Gas Transmission System Operators: A Feasibility Study*. Project PE2GAS. SUMICSID. Report for CEER. https://www.researchgate.net/publication/272094391_Benchmarking_European_Gas_Transmission_System_Operators_A_Feasibility_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., P. Bogetoft, U. Trinker (2016) *Benchmarking European Gas Transmission System Operators.* Project E2GAS. SUMICSID and Swiss Economics. Report for CEER. https://www.ceer.eu/documents/104400/-/-/f919650e-0f9b-fb96-ebf8-47cac308667e

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

Coelli, T., Estache, A., Perelman, S., & Trujillo, L. (2003). *A primer on efficiency measurement for utilities and transport regulators*. The World Bank.

Coelli, T. and Lawrence, D. Eds. (2006) *Performance measurement and regulation of network utilities*, Edward Elgar.

Granderson G. and C. Linvill (1996) The Impact of Regulation on Productivity Growth: An Application to the Transmission Sector of the Interstate Natural Gas Industry, *Journal of Regulation Economics*, 10, pp. 291-306.

Jamasb, T., Newbery, D., Pollitt, M., and Triebs, T. (2007) International benchmarking and regulation of European gas transmission utilities. Report prepared for the Council of European Energy Regulators (CEER). http://portal.e-control.at/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_PAPERS/Gas/2006/ERGEG_Cost_benchmark_final_tcm7-107140.pdf

Jamasb, T., Pollitt, M., and Triebs, T. (2008) Productivity and efficiency of US gas transmission companies: A European regulatory perspective. *Energy Policy*, 36(9), 3398-3412.

Kim, T.-Y., J.-D. Lee, Y. H. Park and B. Kim (1999) Industrial comparisons of productivity and its determinants in the natural gas industry. *Energy Economics*, 21, pp. 273-293.

Lawrence, D., and Diewert, W. E. (2006). Regulating electricity networks: The ABC of setting X in New Zealand. In Coelli, T. and D. Lawrence (Eds.) *Performance measurement and regulation of network utilities*, Chapter 8, 207-241, Edward Elgar.

Sickles R. C. and M. L. Streitwieser (1998) An Analysis of Technology, Productivity, and Regulatory Distortion in the Interstate Natural Gas Transmission Industry: 1977-1985, *Journal of Applied Econometrics*, 13, pp. 377-395.

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