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RIIO-GD2: Step-by-Step Guide to Cost Assessment

Introduction

1.1 This Annex presents a more detailed explanation of our cost assessment methodology in a step-by-step guide format, with a focus on our approach to regional factors and econometric modelling. It provides further clarity on the analysis we have carried out and presented in the RIIO-2 Draft Determintations – Gas Distribution Sector Annex. Our analysis has taken into account stakeholders' responses to the Sector Specific Methodology Consultation (SSMC) and to the RIIO-2 Tools for Cost Assessment Consultation.[1]

1.2 The first section presents an overview of the process we have undertaken to set the baselines. The second section discusses the normalisations and adjustments we have made on the submitted costs. Our econometric modelling and efficiency assessment are discussed in the following sections.

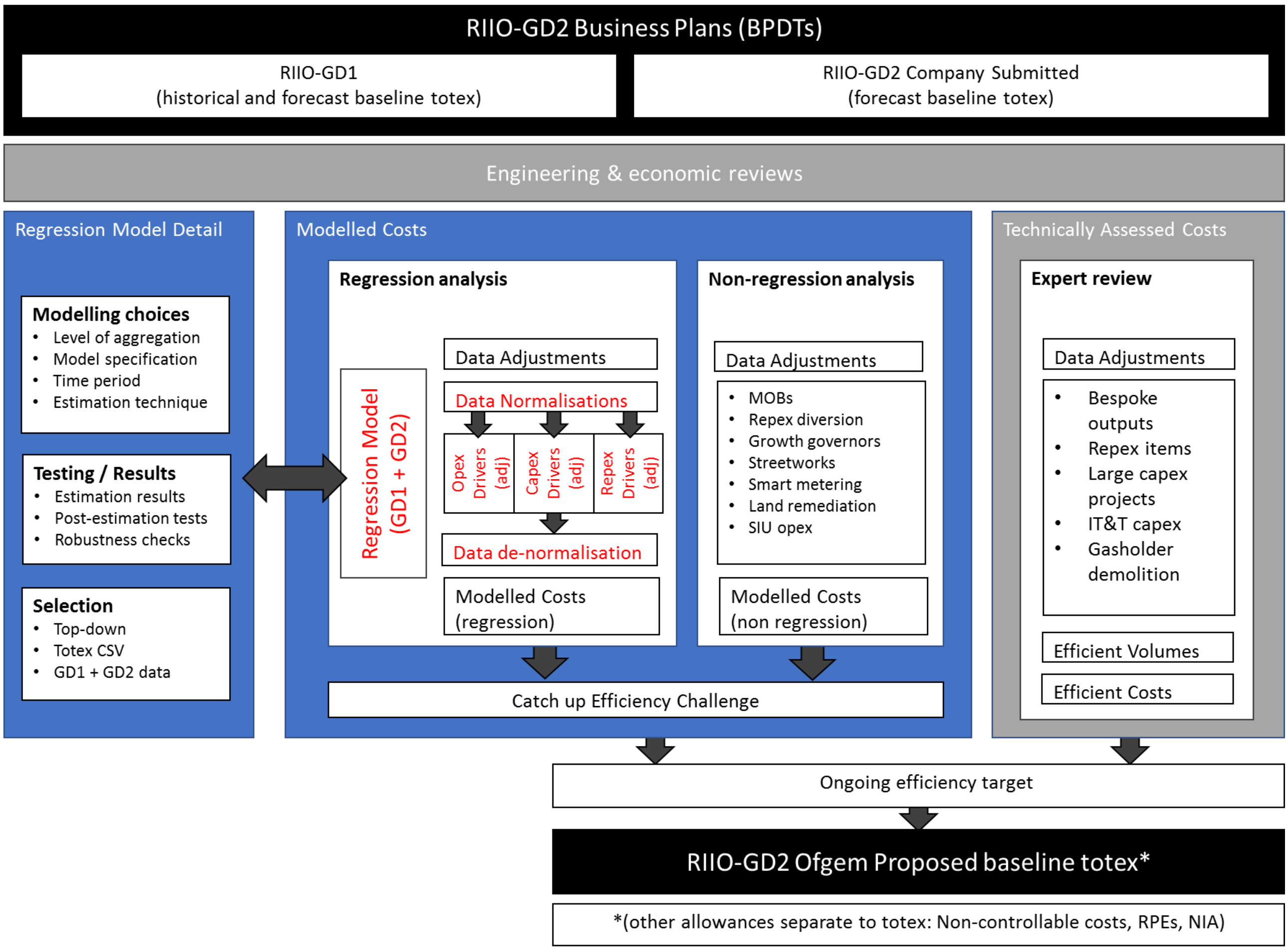
Overview of the totex benchmarking process

1.3 We have used regression, non-regression and technical assessment to determine our proposed totex for RIIO-GD2. The overall process is summarised in the GD Annex.[2]

1.4 Figure 1 below provides a more detailed overview of our econometric modelling approach and of how it fits in the overall process.

Figure 1 Econometric modelling in the overall cost assessment process

[1] The SSMC and related responses can be found here. More details on the RIIO-2 Tools for Cost Assessment Consultation and responses can be found here.
[2] For further information see Chapter 3 of the GD Annex.



Submitted and normalised data

1.5 The data we used for benchmarking was submitted by the GDNs in the RIIO-GD2 Business Plan Data Templates (2013-14 to 2025-26). We adopted total controllable expenditure (totex) as our measure of total costs. This measure closely relates to the current state of technology, government regulation and environmental concerns, and the operators' levels of efficiency.

1.6 We defined controllable totex as:

Controllable Totex = controllable opex + capex + repex.

1.7 As in RIIO-GD1, we used a seven year rolling average to smooth capex because of related sporadic expenditure in some of the GDN cost activities, particularly LTS and other capex. To do this, we used capex data prior to RIIO-GD1 (back to 2007-08).

1.8 Before carrying out our regression analysis, we made data normalisations and adjustments which we have explained in the GD Annex. These adjustments include[3]:

- exclusions
- volume related adjustments
- reclassifications
- non-regression and technical assessment
- regional factors.

A full list of data normalisations and adjustments for each GDN is provided in the company annexes.

1.9 **Exclusions** were made to historical costs which were previously classified as controllable costs but are now classified as non-controllable costs (eg Xoserve, PPF Levy costs). Moreover, we excluded capex relating to historical large projects, in order to align with our approach for forecast large projects, and maintain a consistent dataset over the 13-year period. We also excluded pass-through items and costs we have proposed to be subject to an uncertainty mechanism.

1.10 **Volume related adjustments** were made to specific cost activities that did not satisfy a needs case, such as asset management repex programmes which did not meet our CBA payback criteria. We made upward adjustments to some GDNs' costs where we found the baseline volume assumption to be less than a "P50 forecast", for example for Cadent's connections and mains reinforcement expenditure. We also adjusted historical emergency costs upwards to account for loss of meterwork.

1.11 **Reclassifications** were made where we considered that a GDN reported certain cost activities incorrectly or differently to the majority of GDNs. The main example of this is Cadent's reinforcement for insertion, which we reclassified as repex (from reinforcement) as more in line with the nature of the activity.

[3] Our reference to Business Plans as a source of information includes information from the plans, Business Plan Data Templates (BPDTs) and any corrections/clarifications provided though supplementary questions (SQs).

1.12 We removed certain forecast costs for **separate assessment**. We distinguished between costs separated for a detailed technical assessment and those suitable for a modelled non-regression assessment.[4]

- Technical assessment – around 8% of forecast totex. This includes large Capex projects, IT and Telecoms capex, Gasholder demolitions, Physical security expenditure and the majority of Bespoke outputs (which were considered unsuitable for modelling). Our efficient view of these costs was added to modelled costs, and was not subject to a further efficiency catch up challenge.
- Non-regression assessment – around 8% of forecast totex. This includes MOBs, Streetworks, Repex Diversions, Streetworks, Smart Metering, Land remediation, SIU opex and Growth Governors. We removed these cost activities and modelled the costs, then added these costs to overall modelled costs prior to applying the efficiency benchmark.

1.13 In order to ensure comparability between GDNs, we applied regional labour, urbanity and sparsity adjustments to submitted totex. A detailed explanation of how the related indices were computed can be found in Appendices A and B.

1.14 Finally, we retrieved the capex data we used to calculate the seven-year rolling average from GDPCR Regulatory Reporting Packs (RRPs) over the period 2007-08 to 2012-13. We normalised this data to reflect the adjustments as much as possible (eg regional factors and exclusions) made to the data for the period 2013-14 to 2025-26.

1.15 We used the costs we derived at the end of this process (ie normalised and adjusted costs) for our regression analysis. Modelled costs were assessed on a gross basis (ie including customer contributions) and then adjusted to net costs after regression analysis and non-regression assessment of other costs.

[4] Technical and non-regression assessment are detailed in Chapter 3 of the GD Annex.

Econometric analysis

A single totex model

1.16 For RIIO-GD2, we have proposed a top-down approach for our econometric modelling. In RIIO-GD1, the econometric analysis was performed at two different levels of aggregation, top-down and bottom-up, which were then combined using equal weights.

1.17 Our starting point for the development of the econometric approach for RIIO-GD2 was the models used in RIIO-GD1. In light of the responses to our consultations and the engagement with GDNs within cost assessment working groups (CAWGs), we also tested a variety of models at different levels of aggregation.[5] The detailed list of all the models we considered with a summary of their performance can be found in Appendix C.

1.18 While most top-down models performed relatively well, some of the bottom-up models' fit wasn't satisfactory. The weakness of these models was the prime reason we opted for a top-down view only, without combining it with a bottom-up one as in RIIO-GD1. An option could have been to still use the bottom-up results but assign them a lower weight compared to top-down. However, concerns over the statistical robustness of some of the models (eg work management and mains reinforcement) cast doubts over the appropriateness of this option. Nonetheless, as explained in more detail below, the model we selected still embodies bottom-up considerations.

Selected sample

1.19 The RIIO-GD1 econometric models were estimated on four years of historical data (2008-09 to 2011-12) and on two years of forecast data (2013-14 to 2014-15). This allowed us to take into account both historical and expected relative performance of GDNs.

1.20 When developing the econometric approach for RIIO-GD2, we considered alternative time periods: historical (2013-14 to 2018-19), RIIO-GD1 (2013-14 to 2020-21), RIIO-

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[5] CAWGs minutes and presentations can be found here.

GD2 (2021-22 to 2025-26) and RIIO-GD1+GD2 (2013-14 to 2025-26, including six years of historical data and seven years of forecasts).

1.21 In terms of model fit and estimated coefficient, the performance of the totex model was very similar across the different periods. In order to increase the sample size and thus statistical robustness, we decided to use RIIO-GD1+GD2 data. The inclusion of forecast data also ensures that changes in technology and scope for future efficiency gains are explicitly taken into account.

Model specification and estimation

1.22 As in RIIO-GD1, we employed a Cobb-Douglas functional form. This is a standard approach used in cost assessment literature as it allows for economies of scale to be captured.

1.23 Specifically, our totex model takes the following form:

$$log(totex_{it}) = \beta_0 + \beta_1 \, log(totex \; CSV_{it}) + \beta_2 t1 + \beta_3 t2 + \epsilon_{it},$$

1.24 Where β_0 is a constant term, β_1 is the coefficient associated with the cost driver (totex CSV) and ε_{it} is the error term representing the component of costs not explained by the cost driver (ie noise, measurement errors and inefficiency) for GDN *i* at time *t*.[6]

1.25 To account for time effects, this specification also includes a linear trend for historical data (t1) and another one for forecasts (t2). This allows us to capture changes in real expenditure due to frontier shift and potentially other exogenous factors such as changes in service quality.

1.26 As in RIIO-GD1, the model was estimated via Ordinary Least Squares (OLS), which produced an average relationship between totex and the cost driver, under the assumption that the data points are independent. We estimated the model using clustered robust standard errors to account for the fact that, in reality, data points relating to the same GDN are correlated and thus not fully independent (ie to address

[6] It is worth noting that the logarithmic transformation of the variables results in two advantages. First, the corresponding estimated coefficients can be interpreted as cost elasticities. Second, the transformed variables follow more closely a normal distribution, thus better reflecting the assumptions underlying our estimation approach.

potential heteroskedasticity) and to increase accuracy when assessing statistical significance.

1.27 In principle, we could have exploited the availability of a larger sample size with respect to RIIO-GD1 by employing more sophisticated estimation techniques such as Random Effects (RE) or Stochastic Frontier Analysis (SFA). However, since the number of comparators (eight GDNs) remained unchanged, we decided not to adopt these more data-intensive estimators as our main approach. Nonetheless, as shown later, we checked the robustness of the totex model by estimating it via both RE and SFA.

Totex Composite Scale Driver (CSV)

1.28 In presence of limited sample size, the inclusion of a relatively high number of drivers in the model specification is normally not considered appropriate. However, missing out relevant drivers of costs might limit the explanatory power of the model itself. A way to conveniently address this issue is to use a composite scale variable (CSV).

1.29 A composite scale variable (CSV) is a weighted average of different drivers. This ensures a parsimonious model (ie a single driver) while incorporating as much information as possible.

1.30 We used a CSV in our totex model. Specifically, we used the same driver as in RIIO-GD1, totex CSV, with the same individual components. These components include a mix of scale and workload drivers, reflecting the disaggregated cost activities included in our definition of totex.

1.31 Specifically, the individual components in the CSV correspond to the drivers used in the bottom-up regression models in RIIO-GD1: emergency CSV, maintenance MEAV, total external condition reports, repex synthetic costs, mains reinforcement synthetic costs, connections synthetic costs and MEAV. By using the drivers from the disaggregated models we have retained the information that we used in the bottom-up analysis, while allowing the model to solve the trade-offs between the expenditure on different activities.

1.32 In terms of weights assigned to the individual components, we followed the RIIO-GD1 approach, where these weights were based on industry spend proportions (ie ratios of controllable, normalised and adjusted costs) for the disaggregated cost activities to which the drivers apply, with the residual weight assigned to the scale driver Modern Equivalent Asset Value (MEAV). This approach was deemed to be intuitive and able to take into account the relative importance of each cost driver based on knowledge of GDNs' costs. The resulting totex CSV is as follows:

$$totex\ CSV = (emer\ CSV)^{\delta_1} * (maint\ MEAV)^{\delta_2} * (tot\ ext\ cond\ rep)^{\delta_3} * (repex\ syn)^{\delta_4} * (reinf\ syn)^{\delta_5} * (conn\ syn)^{\delta_6} * (MEAV)^{\delta_7},$$

where δ_i (*i=1, …, 7*) are the weights corresponding to the individual components (with $\delta_7=1- \delta_1-\ldots- \delta_6$). The values of these weights are showed in Table 1 below.

Table 1 Cost activities, totex CSV components and weights

Cost activities	Totex CSV component	Weight
Emergency	Emergency CSV[1]	0.05
Maintenance	Maintenance MEAV	0.08
Repairs	Total external condition report	0.06
Repex	Repex synthetic cost	0.39
Mains reinforcement	Mains reinforcement synthetic cost	0.02
Connections	Connections synthetic cost	0.06
Work Management, Business Support, Other Direct Activities, Training and Apprentices, Other Capex	MEAV	0.34
[1] Composite scale variable including customer numbers (0.80) and total external condition reports (0.20).		

1.33 In order to account for both fixed and variable elements of emergency costs, the driver for GDNs' emergency activity is a CSV comprising customer numbers (0.80) and total external condition reports (0.20). Customer numbers capture the fixed element of these costs, while total external condition reports are assumed to drive the variable element. The latter are also assumed to be the main driver of repair activities (ie costs for site attendance, excavation, repair of leaking mains and road reinstatement).

1.34 The selected driver for maintenance activities is maintenance MEAV, a subset of MEAV only including above ground assets (ie those primarily requiring both routine and nonroutine maintenance). Finally, the following subsections describe our approach to updating the other components of the totex CSV: MEAV and synthetic cost drivers.

Updating MEAV

1.35 MEAV is the current replacement value of an asset. The sum of MEAVs corresponding to a GDN's assets provides a proxy for the GDN's scale of operation. In RIIO-GD1, the assets included in MEAV calculations were: mains, governors, Local Transmission Systems (LTS), storage, National Transmission System (NTS) offtakes, Pressure Regulating Stations (PRS) and services (proxied by customers number).

1.36 Differently from other scale variables such as network length and customer numbers, MEAV was deemed to better reflect the complexity of the network, and thus was the preferred scale driver in previous price controls. We took the same approach for RIIO-GD2 and employed MEAV as the main scale driver.

1.37 Our update to the MEAV driver relates to the assets' composition and, partially, the replacement values of these assets. In terms of assets' composition, we note that in RIIO-GD1 both Embedded Gas Entry Points (EGEPs) and risers were excluded from MEAV asset base. In order to ensure MEAV better reflects the scale of GDNs' operation and after discussion with stakeholders at CAWGs, we included both asset types in the asset base for RIIO-GD2. While the inclusion of EGEPs did not lead to substantial changes to MEAV values, the inclusion of risers had a relevant impact in MEAV calculations, especially for the London network.

1.38 In terms of replacement values, we used the same values as in RIIO-GD1 (converted into 2018-19 prices) for governors, LTS, storage, NTS offtakes, PRS and services. As for mains, we highlight that RIIO-GD1 Regulatory Reporting Packs (RRPs) and RIIO-GD2 Business Plan Data Templates (BPDTs) record the length of mains on a different diameter banding compared to that used for MEAV calculations when setting RIIO-GD1 allowances. Thus, there was no perfect correspondence between the RIIO-GD1 unit replacement values for mains (based on previous diameter banding) and the current diameter bands. To address this issue, we used linear interpolation as follows:

- we assigned the unit costs used to set RIIO-GD1 allowances to the mid-point of historical bands

- we interpolated the unit costs based on the difference between the midpoint of the old bands and the new bands.

1.39 As for the newly added assets, based on the engineering view, we assumed the replacement value of EGEPs to be 25% of that for a PRS, with no differentiation for pressure level (above or below 7bar). An EGEP is much simpler than a PRS as there isn't any pressure reduction equipment and therefore the pressure level it is connected to has little impact on its configuration. As for risers, we considered historical cost and asset data (below 20m, between 20 and 40m and above 40m), which however we intend to revise due to reporting inconsistencies identified by the GDNs.

Updating synthetic cost drivers

1.40 In RIIO-GD1, synthetic unit costs were used to calculate cost drivers in the repex, connections and reinforcement regressions. For each type of mains replacement activity (defined by material and/or diameter)[7] and related services interventions, as well as for each type of mains reinforcement and connections activity, a fixed synthetic unit cost was calculated for all GDNs.

1.41 These synthetic unit costs consisted of average industry costs determined using historical data. These were then multiplied by the GDN specific workloads for each activity and summed to arrive at a single synthetic cost driver (defined in £m) for each distribution network, which was used in the regression analysis. We consider the RIIO-GD1 approach to still be appropriate.

1.42 For RIIO-GD2, the majority of stakeholders suggested updating the synthetic unit costs. We engaged CEPA to develop an assessment framework and methodology for the update. CEPA proposed a process which considered both quantitative and qualitative criteria for the calculation of appropriate synthetic unit costs covering both RIIO-GD1 and RIIO-GD2 periods. A detailed explanation of the analytical framework and rationale for each of the proposed criteria can be found in the Annex "GD2: Synthetic Unit Costs Update Annex".

[7] Mains replacement activities included capitalised replacement. We did not treat capitalised replacement separately because the nature of the activity is the same as mains replacement, the difference being only in reporting.

1.43 We slightly modified the process proposed by CEPA. Specifically, we applied the following quantitative criteria before computing industry average unit costs:

1. **Minimum number of observations:** data must be provided for a minimum of two historical reporting years and for a minimum of two GDNs

2. **Outlier test:** unit costs must be within 100% of the industry average unit cost over the same period

3. **Maximum unit cost variability between GDNs:** to check whether individual GDN unit costs are within 40% of the industry average over the same period

4. **Maximum unit cost variability over time:** to check whether unit costs calculated in each year are within 40% of the average unit cost over the considered period.

1.44 The first two criteria were assigned a higher level of importance than the last two, implying that failure of criteria three and four didn't necessarily result in discarding a unit cost automatically. In line with CEPA's framework, we also applied five qualitative criteria to complement the quantitative assessment. Specifically, we looked at data quality and comparability, routineness of work and materiality before the quantitative assessment, and considered potential drivers that cause differences in unit costs between GDNs and/or over time after the unit costs were computed.

1.45 In line with RIIO-GD1, we decided to update synthetic unit costs based on historical information. To increase the number of observations, we initially considered data prior to RIIO-GD1 as well. However, given the lack of a sufficient level of disaggregation in the data, we only used RIIO-GD1 historical data (ie 2013-14 to 2018-19).

1.46 As a starting point, for all repex and capex (mains reinforcement and connections) activities, we considered the lowest level of disaggregation to which to apply the proposed criteria. First, we ensured a sufficient number of observations (criterion 1) and removed outlier observations (criterion 2). Then, if the calculated synthetic unit cost strongly failed to meet the other selection criteria, we first re-iterated the procedure at a higher level of aggregation (ie summing up similar cost activities). If the criteria were still not met, we computed the synthetic unit cost for the activity by applying a scaling factor to the closest activity for which it was possible to compute unit costs within this framework. The scaling factor was based on the assumption that the percentage difference between unit costs of different activities was the same as between the synthetic unit costs used in RIIO-GD1. For example, the computed unit cost for the replacement of the smallest diameter band (<75mm) of steel mains <2’’ didn’t pass the proposed criteria, but the next band up (between 75 and 180mm) did pass. We applied a 11% reduction to the latter to get a view of the unit cost for the smaller diameter band, which reflects the difference between the two corresponding synthetic unit costs used in RIIO-GD1.

1.47 It is worth noting that we didn’t account for differences in replacement techniques and innovative processes (eg CISBOT) due to insufficient or inconsistent information available to us. However, we did account for differences in regional wages and productivity by applying the same updated indices used to normalise submitted costs.

1.48 The updated synthetic unit costs were then used to calculate repex and capex synthetic cost drivers for the regression analysis as the sum of the products of synthetic unit costs and workloads of the corresponding activities.

1.49 For repex, the workloads associated with each of the following activities are included within the synthetic cost driver: Tier 1 iron mains, Tier 2A iron mains, Tier 2B iron mains, Tier 3 iron mains, steel mains <=2", steel mains >2", iron mains >30m from a building, other policy & condition mains, services associated with all of the aforementioned mains replacement activities, services not associated with mains replacement.

1.50 Other changes from the RIIO-GD1 calculation of synthetic repex are the exclusion of non-rechargeable diversions (separately assessed) and the inclusion of services not associated with mains replacement (proposed re-opener). We have included services not associated with mains replacement within the totex regression, so as to capture any interplay with GDNs’ opex activities.

1.51 Moving to capex, the synthetic cost driver for mains reinforcement distinguishes between mains below and above 180mm. In terms of synthetic unit costs, no distinction was made between general and specific reinforcement. This is in line with the RIIO-GD1 approach.

1.52 Finally, the synthetic cost driver for connections accounted for mains and services workload, distinguishing between domestic and non-domestic connections. The corresponding synthetic unit costs distinguished between mains below and above 180mm diameter. However, differently from RIIO-GD1, we aggregated new and existing housing, implying that the two types of connections were assumed to exhibit similar unit costs. Moreover, we included connections related to the Fuel Poor Network Extension Scheme (FPNES), which in RIIO-GD1 were assessed separately.

Results and post-estimation tests

1.53 We used OLS with clustered robust standard errors to estimate the coefficients of our totex model on the sample covering the period 2013-14 to 2025-26. Table 2 below shows the regression results. Specifically, column *OLS1* in the table reports the results of the totex model we have proposed, while columns *OLS2* and *OLS3* are alternative specifications that we estimated as a robustness check.

Table 2 Totex regression results

Ln_totex	OLS1	OLS2	OLS3
Ln_totex_csv	0.727*** (0.084)	0.727*** (0.030)	0.740*** (0.031)
Ln_totex_csv_sq			-0.112 (.093)
t1	-0.006** (0.002)		-0.006 (0.006)
t2	-0.018*** (.003)		-0.019*** (0.005)
Year2015		-0.020 (0.047)	
Year2016		-0.032 (0.047)	
Year2017		-0.034 (0.047)	
Year2018		-0.059 (0.047)	
Year2019		-0.043 (0.047)	
Year2020		-0.031 (0.047)	
Year2021		-0.046 (0.047)	
Year2022		-0.093* (0.047)	

Year2023		-0.103** (0.047)	
Year2024		-0.117** (0.047)	
Year2025		-0.123** (0.047)	
Year2026		-.118** (0.047)	
Constant	0.322 (0.606)	0.322 (0.216)	-5.471 (0.022)
Adj R^2	0.865	0.849	0.862
Obs.	104	104	104
Standard errors in parentheses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.			

1.54 Model fit of our proposed model (*OLS1*) is good, as the adjusted R^2 is 0.865. The estimated coefficient of the totex CSV is 0.727, implying that, everything else equal, a 1 percent increase in the totex CSV would result in a 0.727% increase in totex. The two time trends are negative, suggesting a decrease in totex over time (other things being equal), which could be imputable to frontier shift and other unobserved time effects such as changes in service quality. The estimated coefficient is larger in absolute terms for the forecast time trend than the historical time trend, suggesting a stronger negative time effect on forecast data (everything else equal). However, this result is affected by an increase in totex towards the end of RIIO-GD1, followed by a decrease. We obtained similar results when we replaced the two time trends with year dummies (column *OLS2*) and when we estimated the model considering different time periods.[8]

1.55 In line with CEPA and our academic advisor recommendations[9], we also performed the following post-estimation tests:

- **Normality:** to test whether residuals follow a normal distribution as per standard OLS assumptions. It is worth noting that the failure of this test does not affect the properties of the OLS estimator and is only a problem if the sample size is very small.

[8] The estimated coefficient of totex CSV was 0.702 on historical data (2013-14 to 2018-19), 0.718 on RIIO-GD1 data (2013-14 to 2020-21) and 0.744 on RIIO-GD2 data (2021-22 to 2025-26). The corresponding R^2 (0.844, 0.851 and 0.872, respectively) were also similar to that of our main model.

[9] See Annexes to RIIO-2 Tools for Cost Assessment Consultation available here.

- **Heteroskedasticity:** to test whether residuals have a constant variance (ie are homoskedastic). However, the presence of heteroscedasticity would only affect standard errors, as the OLS estimates would still be unbiased.

- **Pooling:** to test whether the coefficients of the OLS model are significantly different from the true coefficients of the same model run on each individual cross-section of the data. The failure of this test indicates that panel data analysis might not be appropriate.

- **RESET:** to test whether there are any omitted non-linearities in the model. If this test fails, it might be appropriate to test a different model specification (eg inclusion of a quadratic term in case of univariate regression or a translog specification).

1.56 Table 3 provides a summary of each of the above tests on the selected model (*OLS1*):

Table 3: Model test result summary

Test	Result	Note/Action
Normality	Passed at 1% significance level (p-value 0.0165)	We cannot reject at the 1% level the hypothesis that residuals follow a normal distribution. No action taken.
Heteroskedasticity	Passed (p-value 0.2200)	Residuals are homoscedastic.
Pooling	Passed (p-value 1)	Panel data analysis seems appropriate. See robustness checks below.
RESET	Failed (p-value 0.0000)	Tested alternative model specification (*OLS3*, Table 2)

1.57 As can be seen from Table 3, the selected totex model passed both normality and heteroskedasticity tests. However, the pooling test indicated that panel data analysis might be more appropriate than OLS. It's worth noting that these results should be taken with caution, as the cross-sectional regressions (one for each year) on which the test is based only consider eight data points. Nonetheless, we address this issue in the next subsection, where we show the results of additional robustness checks that explicitly account for the panel nature of the data.

1.58 Moreover, our totex model failed the RESET test, suggesting the presence of omitted non-linearities. To address this issue, we estimated a model that included a quadratic term for the totex CSV. Column *OLS3* in Table 2 shows the results of this alternative model specification.[10] The signs of the coefficients are reasonable from an economic perspective (positive for the logarithm of totex CSV and negative for its square), indicating a U-shaped relationship between totex and totex CSV (ie at first totex increase with the driver, then they decrease). However, coefficients are not all statistically significant and model fit does not improve substantially compared to our main model. Moreover, we obtained similar results to *OLS3* when we estimated a translog functional form to check for additional non-linearities in the model. Thus, we didn’t have strong reasons to discard the selected model *OLS1* based on the RESET test results.

1.59 Finally, in order to explore the stability of the model, we estimated the same model by removing individual years or GDNs. The removal of any year from the sample size resulted in substantially unchanged regression estimates in terms of both magnitude of the estimated coefficients and model fit. However, as expected the estimated coefficient of totex CSV exhibited some variation when individual GDNs were excluded from the sample, although within an acceptable range (between 0.656 when Scotland was excluded and 0.780 when London was excluded).

Additional robustness checks

1.60 We performed additional checks to ensure robustness of the totex model. This was primarily done by comparing the results obtained via OLS estimation with those from different estimation techniques (RE and SFA). Moreover, we investigated how a different approach to the weights assigned to the individual CSV components compared to the one based on industry spend shares that we adopted.

Random Effects (RE) and Stochastic Frontier Analysis (SFA) models

1.61 The selected totex model was estimated via OLS with clustered robust standard errors to account for the fact that the observations in the sample are not fully independent but clustered by GDN. Nonetheless, the pooling test indicated that panel data analysis

[10] We normalised the driver variables with respect to the sample mean to avoid difficulties in coefficients interpretation due to their different magnitude.

might be appropriate, and the Breusch-Pagan test result suggested using a Random Effects (RE) estimator instead of OLS.[11]

1.62 We further investigated the robustness of our totex model by testing alternative Stochastic Frontier Analysis (SFA) models with the support of our academic advisor Prof. Andrew Smith. SFA models explicitly consider the separation between inefficiency and statistical noise. In line with preliminary analysis detailed in the Annex "Note for Ofgem on Alternative Methodologies: Some Preliminary Analysis", the following SFA models were tested:

- Pooled: it doesn't account for the panel nature of the data. The inefficiency term varies over time, but in an unstructured way
- Battese and Coelli (1988): time-invarant inefficiency (*BC88*)
- Battese and Coelli (1992): time-varying inefficiency (*BC92*).

Table 4 Estimation results

Ln_totex	OLS1	RE	SFA Pooled	BC88	BC92
Ln_totex_csv	0.727*** (0.084)	0.632*** (0.071)	0.732*** (0.026)	0.639*** (.051)	0.684*** (0.121)
t1	-0.006** (0.002)	-0.006*** (0.002)	-0.006 (0.005)	-0.006*** (0.002)	-0.006** (0.003)
t2	-.018*** (0.003)	-0.018*** (0.002)	-0.019*** (0.005)	-0.018*** (0.002)	-.015*** (0.004)
Constant	0.322 (0.606)	0.984* (0.507)	0.159 (0.182)	0.802** (0.349)	0.475 (0.881)
Adj R^2	0.865				
Log-likelihood	104.113	177.131	106.375	177.792	178.386
Obs.	104	104	104	104	104
Standard errors in parentheses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.					

1.63 As shown in Table 4, all the estimated models exhibit very similar results, indicating that our totex model is robust to different estimation techniques. Specifically, models

[11] It is worth noting that, when comparing fixed vs. random effects, the Sargan-Hansen test rejected the hypothesis of RE being a consistent estimator. However, results from the standard Hausman test were not conclusive.

OLS1 and pooled SFA produce similar coefficients, while RE results are similar to the SFA models that explicitly account for the panel structure (*BC88* and *BC92*). Interestingly, time variation in *BC92* model is not significant, which might explain the similarity with *BC88* results. It is worth noting that the RE could be used instead of OLS1. However, results are not substantially different, as also confirmed by the low variation in modelled costs (between around one and five per cent depending on the GDN). As expected, efficient costs from SFA models are on average lower than with OLS and RE, which would result in tougher allowances. However, given our data limitations, we prefer not to rely on models that are more data intensive and are based on discretionary distributional assumptions for the error term. Thus, we propose the OLS model as our consultation position, also in light of its higher degree of transparency.

Econometric approach to totex CSV weights

1.64 The cost driver in our model, totex CSV, is a weighted average of different drivers, with weights based on industry spend. An alternative approach to setting the weights is the econometric method - running the totex model without restricting the weights and allowing the model to use the data to produce them.

1.65 As noted by our academic advisor in a preliminary analysis (see Annex "Note for Ofgem on the computation of CSV weights"), one issue with the RIIO-GD1 approach is that it places restrictions on the relative elasticities of the individual cost components. It also does not allow the relative unit costs of cost components to be different from the relative marginal costs, as may happen in reality.

1.66 As a further robustness check, we compared our approach to weights calculation to the econometric method. The econometric method produced negative coefficients on some of the CSV components (see Table 5 below). This would imply negative elasticities (ie totex would decrease when these cost components increased), which is clearly counterintuitive. This issue is likely due to multicollinearity – for example, MEAV is highly correlated with Maintenance MEAV and Emergency CSV.[12] Moreover, the econometric method assigned a very low weight (0.09) to the repex driver, which doesn't reflect the fact that repex is a major activity for GDNs. Overall, we have

[12] Correlation with MEAV was higher than 0.90 in both cases. To address this issue, we estimated a model without Maintenance MEAV and Emergency CSV, but this still resulted in negative elasticities for the capex drivers. Moreover, the weight assigned to the repex driver was still very low (around 0.05).

proposed the approach to CSV weights based on industry spend as our consultation position, as it appears to be the most reasonable.

Table 5 Totex CSV components' weights – industry spend vs. econometric method

Totex CSV component	Weights based on industry spend	Weights based on econometric method
Emergency CSV[1]	0.05	0.43
Maintenance MEAV	0.08	0.13
Total external condition report	0.06	-0.19
Repex synthetic cost	0.39	0.09
Mains reinforcement synthetic cost	0.02	0.02
Connections synthetic cost	0.06	-0.04
MEAV	0.34	-0.26
[1] Composite scale variable including customer numbers (0.80) and total external condition reports (0.20).		

Determining modelled costs

Modelled totex

1.67 We used the following formula to compute modelled costs from our regression analysis for each GDN *i* and each year *t*:

$$Modelled\ totex_{it} = \alpha * exponential\ (\hat{\beta}_0 + \hat{\beta}_1\ log(totex\ CSV_{it}) + \hat{\beta}_2 t1 + \hat{\beta}_3 t2),$$

Where α is an alpha correction factor and the coefficients are those estimated from the selected model (*OLS1*).

1.68 Indeed, as we used a logarithmic transformation of the data for our totex regression, the exponential transformation into costs would tend to underestimate modelled costs. To resolve this, we followed the RIIO-GD1 approach and multiplied modelled costs with an estimate of the expected value of residuals (ie the above mentioned alpha correction factor). The alpha correction factor corresponds to the estimated coefficient from a linear regression of normalised adjusted totex on those predicted from the selected model without a constant. The computed alpha factor was 1.002 (equal for all GDNs due to homoscedasticity), implying that the adjustment to totex due to the logarithmic transformation was minimal.

1.69 We also calculated the modelled component of totex using adjusted cost drivers in order to derive the difference between totex based on unadjusted and adjusted cost drivers. As explained in the following section, modelled totex were then used to compute the efficiency score for each GDN.

Efficiency assessment

Calculating efficiency scores and choosing the efficiency benchmark

1.70 For each GDN, we calculated a totex efficiency score for the RIIO-GD2 period as the ratio between submitted normalised adjusted costs and modelled costs:

$$Efficiency\ score = \frac{Submitted\ (normalised\ adjusted)\ costs}{Modelled\ costs}$$

1.71 We selected the 85th percentile efficiency score (0.95) from the GDNs' efficiency scores as our score to benchmark totex over the RIIO-GD2 period (see Table 6). We selected the 85th percentile score rather than the frontier to acknowledge that part of the difference in costs across GDNs related to factors other than GDNs' relative efficiency (ie measurement errors and statistical noise).

Table 6: GDNs' efficiency scores (RIIO-GD2 period)

GDN	Efficiency Score
EoE	1.10
Lon	1.17
NW	1.04
WM	1.04
NGN	0.89
Sc	0.95
So	0.98

WWU	1.00

Applying the benchmark efficiency score

1.72 We took each GDN's modelled costs and added back our modelled view of the separately assessed costs. We also added back the pre-modelling adjustments made for regional factors and workload adjustments. We then converted the modelled gross costs to modelled net costs (ie net of customer contributions), based on the ratio of submitted gross costs to submitted net costs in each year.

1.73 We took the modelled costs for each GDN post reversal of adjustments, and multiplied these by the benchmark efficiency score to determine modelled costs post efficiency challenge ("efficient modelled costs", which exclude ongoing efficiency challenge). This provided efficient modelled costs at the totex level for each GDN in each year of RIIO-GD2.

Disaggregating efficient modelled totex and applying ongoing efficiency assumptions

1.74 We calculated an implied adjustment factor for each GDN by dividing each GDN's efficient modelled costs by the submitted modelled costs (post exclusions and reclassifications).

1.75 We then multiplied the submitted modelled costs (post exclusions, which include volume reductions, and reclassifications) for each disaggregated cost activity by the implied adjustment factor. This approach ensures that the catch up efficiency challenge is applied evenly to totex, and the disaggregated cost activities reflect the exclusions and reclassifications previously made.

1.76 Finally, we applied our ongoing efficiency assumptions to efficient modelled costs and costs assessed via technical assessment to determine overall baseline totex allowances for each GDN. Further details on ongoing efficiency can be found in the GD Annex.

Appendix A - Methodology for calculating regional labour indices

1.77 Following consultations with GDNs and undertaking our own analysis, we consider that the wage differential between London, the South-East and rest of Great Britain still appears to be wide enough to warrant an adjustment in our benchmarking. In line with RIIO-GD1, we have decided to use regional labour indices to make pre-modelling cost adjustments.

1.78 We have estimated labour indices between 2013-14 and 2017-18 using updated BPDT information on the GDNs' FTEs by employment category, ASHE data on regional wages, and ONS population data. We have largely followed the same seven-step process used in RIIO-GD1, but with some changes. Table 7 summarises the changes in our approach between RIIO-GD1 and RIIO-GD2.

Table 7 Calculating regional labour indices, RIIO-GD1 and RIIO-GD2

Step	RIIO-GD1	RIIO-GD2
1. Calculate occupational weights	GDNs split their direct and contract labour across 3-digit Standard Occupational Classification (SOC) codes. For each SOC code, we averaged the GDNs' spend relative to total labour spend to obtain an industry average.	Occupation weights now based on FTEs rather than labour spend. Occupational weights calculated at the 2-digit SOC code level.
2. Calculate regional wage indices	For each administrative region of the UK and occupational category, we calculated the region's mean annual wages relative to the UK mean wage and averaged these across occupational categories, using	Regional mean wages and indices calculated at the 2-digit SOC code level to reduce uncertainty and missing data in the ASHE wage estimates.

	the weights calculated in Step 1, to obtain regional wage indices. This was based on 3-digit SOC wage data from the Annual Survey of Hourly Earnings (ASHE) published by ONS.	Gross hourly mean wages (including overtime) are used rather than annual wages, as these are more robust to regional differences in the number of hours worked.
3. Calculate the wage index for 'Elsewhere'	The average of the regional wage indices calculated at Step 2 (excluding the London and South-East regions), weighted according to the regions' population.	Same approach as RIIO-GD1, except Northern Ireland is excluded from the Elsewhere index as it isn't served by any GDN. Wage indices rescaled so that the Elsewhere index equals 1, meaning that only GDNs operating in London and the South-East will have an adjustment applied, making it easier to detect adjustments.
4. Estimate GDNs' work across the London, South-East and Elsewhere regions	We assumed that GDNs' work was distributed across these three areas in the same proportion as the area's share of the GDN's total population. Two GDNs, London and Southern, have the majority of their operations in London and the South-East, and East of England has a small share of its population in London. All other GDNs operate exclusively in the Elsewhere region.	Same approach as RIIO-GD1.

5. Estimate work that should be done locally in the London and South-East regions	The amount of work done by the GDNs in the London and South-East regions calculated in Step 4 was adjusted to reflect the fact that some work does not need to be carried out locally and can be done in lower cost regions. We assumed that only 40% of Work Management needed to be done locally, whereas the remaining activities were 100% local.	Rather than applying an average local work percentage across all activities, we apply a specific percentage to each cost activity. This makes it unnecessary to separate direct and contract labour. We assume that 44% of Work Management occurs locally.
6. Calculate the GDNs' labour indices	For each GDN, the labour index was the average of the regional wage indices for London (Step 2), South-East (Step 2), and Elsewhere (Step 3), weighted by the amount of work that the GDN needs to carry out in each region (Step 5).	The calculation is the same, however the local work proportion is activity-specific.
7. Standardise the labour indices	Lastly, we divided each GDN's labour index by the indices' average and used these standardised indices to make labour cost adjustments for each cost activity.	Labour indices are not standardised to avoid losing the benefit of scaling in Step 3.

1.79 In addition, our RIIO-GD2 approach differs in the way that the indices are rolled forward to cover years in which historical data is not available. In RIIO-GD1, we calculated the labour indices for 2008-09, 2009-10 and 2010-11, then applied the 2010-11 indices to later years. For RIIO-GD2, we have calculated the indices between 2013-14 and 2017-18 and set the indices for later years equal to the average of this period. We consider that this approach makes use of the available historical data and is more robust to year-to-year variations in the historical indices.

1.80 Calculating the proportion of expenditure that is related to labour and therefore subject to labour adjustments is not necessary to calculating the labour indices, but is required to determine the size of each GDN's labour adjustments. In RIIO-GD1 we calculated the labour ratios based on GDNs' actual expenditure, then adjusted them based on the labour indices and a historical industry average ratio for direct and contract labour. For RIIO-GD2 we have adopted the approach used in RIIO-ED1, and applied industry average labour ratios to all GDNs for each cost activity. Using these notional weights will ensure that we do not reward a potentially inefficient company.

Calculating occupational weights and regional wage indices

1.81 The SOC is a common classification of occupational information for the UK. It is a hierarchical structure that categorises jobs in four increasing levels of detail: 1-digit SOC codes indicate nine broad occupational categories which are further broken down into 25 2-digit groups, 90 3-digit groups, and 369 4-digit units.[13]

1.82 As lower-digit (shorter) groups are aggregates of higher-digit (longer) groups, the decision of which level to adopt presents a trade-off between robustness and granularity. Lower-digit wage estimates refer to more broadly defined occupational categories which may encompass more jobs than those strictly relevant to the GDNs but are based on larger samples and are more reliable than higher-digit estimates.

1.83 GDNs reported FTEs by SOC code at a 3-digit level in their Business Plans, however there were some inconsistencies in reporting across GDNs. For example, some GDNs did not report historical data, and some GDNs classified a large number of FTEs under different SOC codes with similar names. We therefore asked the GDNs to resubmit this data on a consistent basis, and clarify any differences in reporting.

1.84 We have used 2-digit SOC codes in our calculation of regional labour indices. This is in line with our approach in RIIO-ED1 and appears to have a stronger statistical basis than using 3-digit SOC codes. Using 2-digit codes also reduces the occurrence of missing data from the ASHE wage estimates.

[13] Data from the Annual Survey of Hours and Earnings (ASHE) 2014-2019, Table 15.5a. Available here.

1.85 Cadent noted in its Business Plan that hourly wages better represent the price of labour compared to annual wages because they are not affected by people in some regions working more hours than in other regions. We agree and have used mean hourly wages to calculate the regional wage indices. This approach is in line with our RIIO-ED1 decision.

Regions requiring a labour adjustment

1.86 In RIIO-GD1 we made a labour adjustment for three regions: London, South East, and Elsewhere (ie the rest of Great Britain). We have retained the three-region adjustment in RIIO-GD2. Although not as high as London, the South East wages are still systematically higher than the other regions (excluding London) and the national mean.

1.87 We have rescaled the wage indices so that the Elsewhere index equals 1. This means that only Cadent's London and East of England networks and the SGN Southern network will have an adjustment applied.

Estimating work that should be done locally in the London and South-East regions

1.88 In RIIO-GD1 we assumed that, for most cost activities, all work needed to be done locally. For Work Management (opex), we assumed that 40% of work was done locally. The overall proportion of work needing to be done locally was calculated as the average percentage across the various cost areas.

1.89 We note that using an average percentage is reasonable when assessing totex, as all the costs are summed together. But when assessing a specific cost activity, eg repex, which work is estimated as being 100% done locally, it is not appropriate to use a labour index that has been calculated to reflect the fact that another activity, ie work management, is only partly done locally.

1.90 To address this inconsistency, we calculate a single labour index for each GDN and apply this to each activity's labour proportion. In the calculation of the labour adjustment to work management, we apply a correction to the labour index to reflect the fact that work management is only partly done locally.

1.91 In RIIO-GD2 we have updated the local work proportion of Work Management to 44%, based on Cadent's submission. Cadent noted that this was calculated as approximately 66% for all GDNs over the period from 2013-14 to 2018-19, reduced by one third to reflect Operations Management costs that are centrally incurred (with the proportion based on actual data for 2018-19).[14] We did not receive any other information to suggest a different local work proportion for Work Management.

Table 8: RIIO-GD2 regional labour indices

GDN	Indices
EoE	1.01
Lon	1.16
NW	1.00
WM	1.00
NGN	1.00
Sc	1.00
So	1.09
WWU	1.00

[14] Cadent Business Plan, Appendix 9.21.

Appendix B - Methodology for calculating sparsity indices

1.92 We have maintained the sparsity adjustment that we made in RIIO-GD1. This adjustment is to compensate for the productive time lost during the additional time spent on travelling in a sparse area when attending Emergency and Repairs.

1.93 We estimated district-specific population density using ONS Open Geography Portal data on the districts' land area and ONS population estimates. We eliminated from the analysis the districts that were identified in RIIO-GD1 as having no gas network coverage. We also calculated industry-level density by dividing total population by total area in districts with gas network coverage.

1.94 We calculated the population served by each GDN in each district using the same assumed split of districts between GDNs as in RIIO-GD1. This is the same split that was used to allocate GDNs' work to regions in the calculation of labour indices. Most districts are included entirely in one GDN's service area, but there are a number of cases where we split a district's population between two GDNs.

1.95 We classified districts with a population density lower than the industry density as sparse and calculated their sparsity indices as the ratio between the district's density and the industry density. We normalised these indices by converting them into deviations from 1.

1.96 We calculated GDNs' unstandardised sparsity indices as the average of district sparsity indices, weighted by the district's proportion of the GDN's total population. Our approach to the indices differs from RIIO-GD1 in the way the indices are rolled forward to cover years in which historical data is not available. In RIIO-GD1, we calculated the sparsity indices for one year only, based on 2010 population data, then applied the same indices to later years. For RIIO-GD2, we have calculated the un-standardised indices using historical data until 2017-18 and set the indices for later years equal to the 2013-14 – 2017-18 average.

1.97 We calculated the ratio between the GDNs' un-standardised indices and the un-standardised index for the sparsest GDN (WWU). We then multiplied these ratios by the percentage sparsity adjustment applied to WWU's Emergency and Repair labour costs (-

13%). This means that each GDN receives a sparsity adjustment that reflects its sparsity relative to WWU's. All the sparsity adjustments will be negative (ie a reduction to modelled costs) aside from the Cadent London network, which does not receive an adjustment as it is considered to have no sparse areas in its network. For consistency with the other regional factors, we converted the percentage adjustments into standardised sparsity indices, which are presented in Table 9 below.

Table 9: RIIO-GD2 sparsity indices

GDN	Indices
EoE	1.09
Lon	1.00
NW	1.02
WM	1.06
NGN	1.10
Sc	1.12
So	1.05
WWU	1.15

Table 10: RIIO-GD2 regional factors, by cost activity

Cost activity	Regional labour	Sparsity	Urbanity reinstatement	Urbanity productivity
Work Management	Yes	No	No	No
Emergency	Yes	Yes	Yes	No
Repairs	Yes	Yes	Yes	No
Maintenance	Yes	No	Yes	No
Other Direct Activities	Yes	No	Yes	No
Business Support	No	No	No	No
LTS Pipelines, Storage & Entry	Yes	No	No	No
Connections	Yes	No	No	Yes
Reinforcement	Yes	No	No	Yes
Governors	Yes	No	No	No
Transport & Plant	No	No	No	No
Other Capex	Yes	No	No	No
Repex	Yes	No	No	Yes

Appendix C – List of econometric models considered

1.98 Table 11 and 12 list the econometric models we considered and discussed with stakeholders at CAWGs. For each model, we note specification (cost and corresponding driver) and estimated coefficient and R^2.

Table 11 Bottom-up and middle-up models

Model #	Cost	Driver	Coeff.	R^2
1	Work Management	Opex CSV	0.943	0.543
2	Work Management	MEAV	0.745	0.405
3, 3a	Emergency	Emergency CSV (model 3a uses max PREs over 5 years)	0.967 1.047	0.750 0.731
4	Maintenance	Maintenance MEAV	0.950	0.675
5	Repairs	Tot. Ext. Cond. Reports	0.734	0.769
6	Connections	Connections synthetic costs	0.619	0.895
7	Reinforcement	Mains synthetic costs	0.357	0.679
10	Repex	Repex synthetic costs	0.671	0.899
11	Capex	Capex CSV	0.575	0.410
12	Opex	Opex CSV	0.835	0.715

Making a positive difference for energy consumers

Table 12 Top-down models and alternative cost pools

Model #	Cost	Driver	Coeff.	R^2
13	Totex	Totex CSV	0.727	0.865
14	Totex	Maintenance MEAV	0.701	0.756
15	Totex	MEAV	0.809	0.787
16	Totex	Network length	0.626	0.650
17	Totex	Throughput	0.783	0.783
18	Totex	CSV1 Customers (0.25), Network Length (0.50), Throughput (0.25)	0.734	0.769
19	Pool1 (Asset mgt, Operations mgt, Business support, ODAs)	MEAV	0.668	0.459
20	Pool2 (Emergency, Repairs, Repex Other Services)	MEAV	0.731	0.422
21	Pool2A (Emergency, Repairs, Repex Other Services, Operations mgt)	CSV3 Customers (0.22), PREs (0.34), Tot. Ext. Cond. Reports (0.44)	1.008	0.919
22	Pool3 (Emergency, Repairs, Customers mgt, Operations mgt, Repex Other Services)	Maintenance MEAV	0.763	0.552
23	Pool4 (OpexPlus)	MEAV	0.706	0.669
24	Pool4 (OpexPlus)	Totex CSV	0.608	0.682
25	Pool4 (OpexPlus)	CSV1 Customers (0.25), Network Length (0.50), Throughput (0.25)	0.650	0.673
26	Pool4 (OpexPlus)	CVS2 Emergency CSV (0.08), Tot. Ext. Cond. Reports (0.10), Maintenance MEAV (0.14), Connections synthetic costs (0.07), MEAV (0.61)	0.714	0.676