Annex L – PC21 Efficiency Modelling

Northern Ireland Utility Regulator

6 July 2020

FINAL REPORT

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Contents

1. INTRODUCTION

CEPA has been engaged to support the Northern Ireland Utility Regulator (UR) in assessing the relative efficiency of Northern Ireland Water's (NI Water) operating expenditure (opex) and capital maintenance expenditure for PC21.[2] As we consider relative efficiency, we compare NI Water to water and sewerage companies operating in England and Wales (E&W) using data collected by Ofwat, the economic regulator of the water sector in England and Wales.[3]

The objective of this report is to present the wholesale water and sewerage econometric benchmarking models developed to assess the relative efficiency of NI Water's opex and capital maintenance expenditure and the results of the relative efficiency analysis.

All monetary values presented in this report have been adjusted to a 2017/18 price base using the RPI All Items Index published by the Office for National Statistics (ONS).[4] [5]

The structure for the remainder of this report is as follows:

- Section 2 presents a summary of our approach to modelling, which includes our modelling strategy and model assessment criteria.
- Section 3 presents key data analysis that was conducted ahead of modelling.
- Section 4 presents the selected wholesale water econometric model results.
- Section 5 presents the selected wholesale sewerage econometric model results.
- Section 6 presents relative efficiency analysis based on the selected econometric models before adjustments for Special Cost Factors (SCFs).
- Section 7 presents analysis of SCFs that are quantifiable and their impact on model results.
- Section 8 concludes.

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[2] The price control for NI Water from 2021.

[3] Source: https://www.ofwat.gov.uk/regulated-companies/price-review/2019-price-review/data-tables-models/. Files 'Cost Assessment FM_WW1 with APR 2018-19 data' and 'Cost Assessment FM_WWW1 with APR 2018-19 data'.

[4] Source: Office for National Statistics (16th October 2019). RPI All Items Index.

[5] A multiplier of 1.0306 would need to be applied to convert costs from a 2017/18 price base to a 2018/19 price base.

2. APPROACH TO MODELLING

To ensure the process of model development and selection was objective and transparent, we developed a separate paper describing our a priori assumptions for explanatory variables[6] (based on economic and technical rationale) and provided this to UR before model development commenced. We also produced two short papers setting out in further detail our modelling strategy[7] and model assessment criteria.[8] We summarise these papers in the sections below.

The model development process has also been complemented by Cost Assessment Working Groups (CAWGs) between CEPA, UR and NI Water that took place throughout 2019. The first econometric modelling results were presented in February 2019 at CAWG#5 and the models have since been refined, culminating in the final set of opex and capital maintenance that were presented in December 2019 at CAWG#9.[9]

2.1. Modelling strategy

To develop our modelling strategy, we sought where possible to follow current best practice in the sector, drawing for example on Ofwat's work at PR19. Where necessary or proportionate we have adapted our approach. For example, after evaluating the data collected by UR, we concluded it was only possible to develop models at a high degree of aggregation because it would have been challenging to obtain (robust) more granular data and it was not clear to us that a proportionate approach would warrant such an intensive data collection strategy.

The table below summarises the key points of the strategy used to develop cost assessment models for PC21. Further details are provided in our published opex efficiency modelling strategy paper.

Table 2-1: Summary of model development strategy

Category	Approach
Target modelling suite	We concluded it would be best to focus on developing top-down water and wastewater models. We decided to develop sewerage models that exclude bioresources to control for differences in sludge treatment and disposal between NI Water and England and Wales companies.
Data adjustments	We excluded a number of costs from the models, including business rates, pension deficit repair costs, Traffic Management Act (TMA) costs and atypical costs. No pre-modelling adjustments were made to the data to cover regional price differentials. Instead these are dealt with through a special factor process if the UR deems it appropriate to do so.
Functional form	We aimed to develop simple models. If the data suggested that more complex relationships exist, we considered whether these can be captured by other explanatory variables and whether higher order terms (i.e. quadratic terms) add sufficient explanatory power to the models to justify the additional complexity and reduction in degrees of freedom.
Estimation method and assumptions on efficiency	There are several different estimation methods available, each with different implications for how model residuals and company efficiency are calculated. Transparency is a key UR priority for PC21. Therefore, we focused on pooled ordinary least squares (OLS) as it is easy to replicate and understand compared with other modelling approaches. As part of our

[6] CEPA (March 2018), '*CEPA cost assessment report*', available at https://www.ofwat.gov.uk/wp-content/uploads/2018/03/CEPA-cost-assessment-report.pdf

[7] CEPA (January 2019), '*Opex Efficiency Modelling Strategy*', available at https://www.uregni.gov.uk/sites/uregni/files/media-files/PC21%20CEPA%20Opex%20Efficiency%20Modelling%20Strategy%20Short%20Paper.pdf

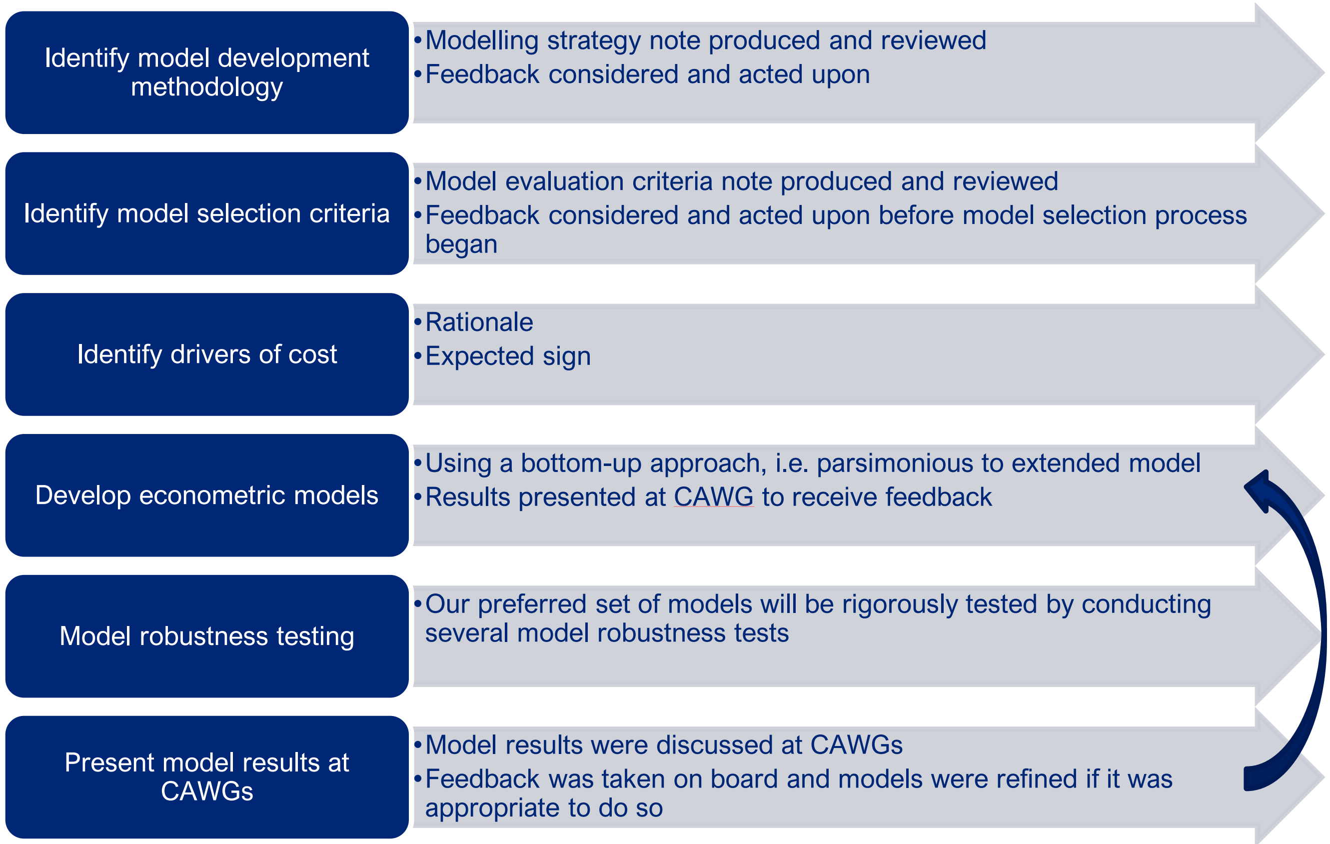
[8] CEPA (January 2019), '*Opex Model Assessment Criteria*', available at https://www.uregni.gov.uk/sites/uregni/files/media-files/PC21%20CEPA%20Opex%20Model%20Assessment%20Criteria%20Short%20Paper.pdf

[9] NI Water made some minor data changes following CAWG#9, which have been reflected in the modelling results presented in this report.

Category	Approach
	sensitivity testing, we examined whether other panel data models, such as random effects, provided additional value.
Explanatory variables[10]	Our work for Ofwat for PR19 identified a number of explanatory variables that could be used in the modelling and categorised them into five 'cost driver' groups.[11] The models we developed were based on a subset of these variables, subject to data availability and other factors. We note that some of the variables we use are transformations or combinations of the variables we set out in this report.

CEPA's modelling process is summarised in the figure below highlighting the transparent approach we have followed. Development has been iterative as models have been reassessed and refined to reflect feedback made during the CAWGs.

Figure 2.1: CEPA modelling process



2.2. Model assessment criteria

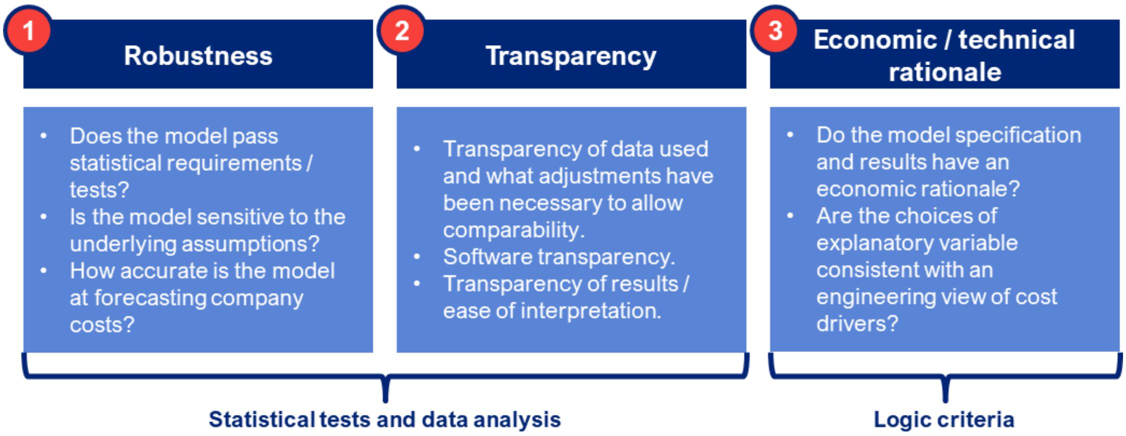
In advance of model development it is important to establish a clear process that allows for proper evaluation of model robustness. Our high-level selection criteria are summarised in the figure below and formed the basis of decisions on whether any given model was sufficiently robust to use in UR's opex and capital maintenance efficiency assessment for PC21.

[10] Throughout this report, we use the term 'driver of cost'. To be clear, the explanatory variables used for modelling purposes are proxies for companies' underlying cost drivers. While we expect some explanatory variables may have a very strong relationship with underlying drivers of cost (for example, length of mains), the use of a given explanatory variable as a proxy does not preclude alternatives.

[11] CEPA (March 2018). '*CEPA cost assessment report*''

The criteria applied are consistent with those used by Ofwat, UR and other regulators in developing cost assessment models. They apply specifically to the econometric models.

Figure 2.2: Model selection criteria



When developing models, we placed most weight on their economic and technical rationale. We considered whether:

1. the selected explanatory variables were line with our a priori expectations of what would be important explanatory variables?
2. the estimated model coefficients were consistent with a priori expectations in terms of magnitude and sign?
3. the selected models were consistent with policy in other areas of the price control?

Ideally, final selected models would pass all model robustness tests they are submitted to. However, setting such a high standard could make it very difficult to develop any models at all. As a result, as part of this work it was important to understand what a model failing a test meant for its potential use in PC21. Trade-offs between test results are an inherent part of model development, meaning that a failure of one test will not necessarily result in the rejection of the model. Nevertheless, where we identified significant concerns which meant a particular model was not robust, we went back through our iterative process and considered model alterations.

The table below provides a summary of the tests conducted within the model selection criteria. Further detail is provided in Appendix A.

Table 2-2: PC21 model selection criteria summary – tests

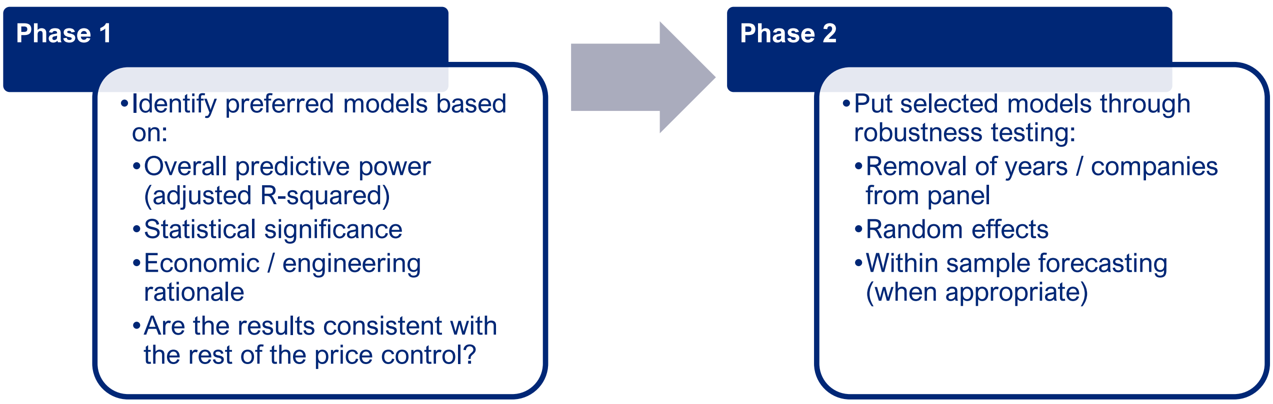
Level of importance	Definition
Very high	• Jointly statistically significant (F-test) • Overall goodness of fit / predictive power (Adjusted R-squared) • Consistency with policy in other parts of the price control
High	• Consistency with a priori expectations of magnitude and signs of estimated coefficients • Stability of efficiency rankings • Stability of inefficiency range • Transparency of results and ease of interpretation

Medium	• Sensitivity to:
	  ○ removal or addition of a year
	  ○ the removal of the most or least efficient company
	  ○ introduction of quadratic terms
	• Statistical significance of individual parameters (t-test)
	• Pooling test
	• Within-sample forecasting power

Low	• Multicollinearity tests • Linearity • Homoscedasticity • Normality • Test of pooled OLS versus random effects (Breusch-Pagan test) • Hausman test for fixed effects

We carried out our analysis in two phases. In a first phase, we identified those models that met the minimum characteristics required for a model to be considered further. In a second phase, those models that were selected in Phase 1 were evaluated further by running the remaining set of robustness tests discussed above. This is summarised in the figure below:

Figure 2.3: Model development stages



Phase 1

Phase 1 of our analysis started by running a simple model including a constant and a scale explanatory variable and then expanding them to add explanatory variables in order of importance (See Section 3.3 below) until all explanatory variables have been tested in the models. This process allowed us to generate a set of preferred models based on the data available that could be stress tested during Phase 2.

The models selected at the end of Phase 1 were those that met the following minimum conditions:

- All coefficients were consistent with our a priori expectations based on economic and engineering rationale.
- The overall predictive power of the model (as indicated by the adjusted R-squared) was 80% or higher.
- The coefficients were consistent with the rest of the price control (e.g. models where leakage would grant higher allowances for companies would be excluded).
- No two variables were correlated by more than 90%. Exceptions are made for variables that are transformations of other explanatory variables included in the model (e.g. quadratic terms).
- All explanatory variables are statistically significant at least at the 20% confidence level. Exceptions are sometimes made for variables that do not make this threshold but reflect relationships that are well set in engineering and/or economic literature and meet all other minimum conditions listed above.

Phase 2

The models selected through Phase 1 analysis were then put through a series of robustness tests to determine whether a model is sufficiently robust to be considered by the UR when setting NI Water's PC21 allowances. Further details on the robustness tests conducted are presented in Appendix A.

3. DATA ANALYSIS

As is the case in any modelling activity, the quality of econometric model outputs depend on the quality of the model inputs. Therefore, before conducting econometric analysis it is important to assure the quality of the data inputs that are being used. In this section, we summarise the actions taken to ensure the data provided was in a form that could be used to develop our econometric models. We clarify the definitions of the variables we have used, including the range of cost drivers considered, and note the change in Ofwat's regulatory accounting guidelines from 2015/16 onwards.

Data for E&W water companies was published by Ofwat, which means the focus of our data analysis and assurance has been on NI Water data as we assumed that the England and Wales data had been assured by Ofwat. That said, we also examined each set for consistency with each other.

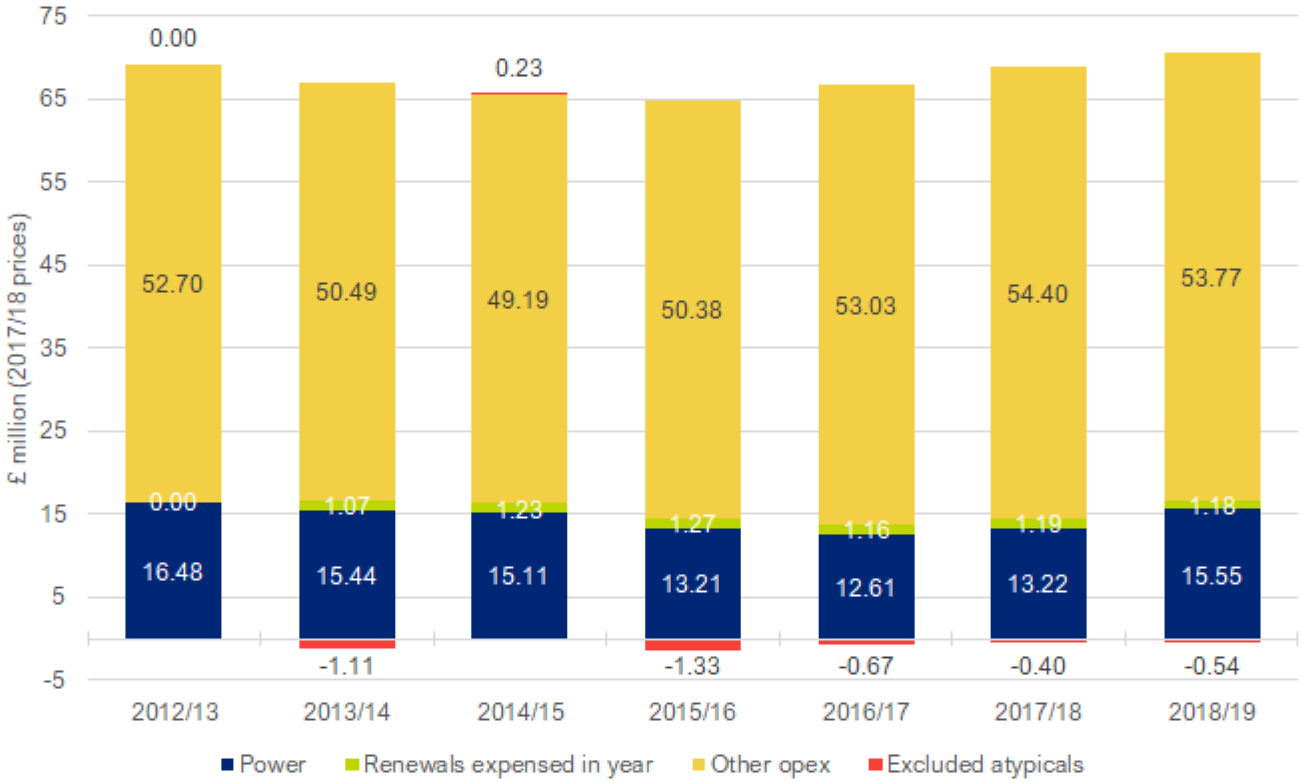
3.1. OPEX ANALYSIS

The value of operating expenditure, used as the dependent variable in our modelling, comprises a number of different components. The box below describes the composition of modelled opex for wholesale water and sewerage:

Modelled wholesale water opex	=	Power + Bulk supply + Renewals expensed in year (infrastructure & non-infrastructure) + Other opex - Atypical expenditure
Modelled wholesale sewerage opex	=	Power + Discharge consents + Bulk Discharge + Renewals expensed in year (infrastructure & non-infrastructure) + Other opex - Atypical expenditure

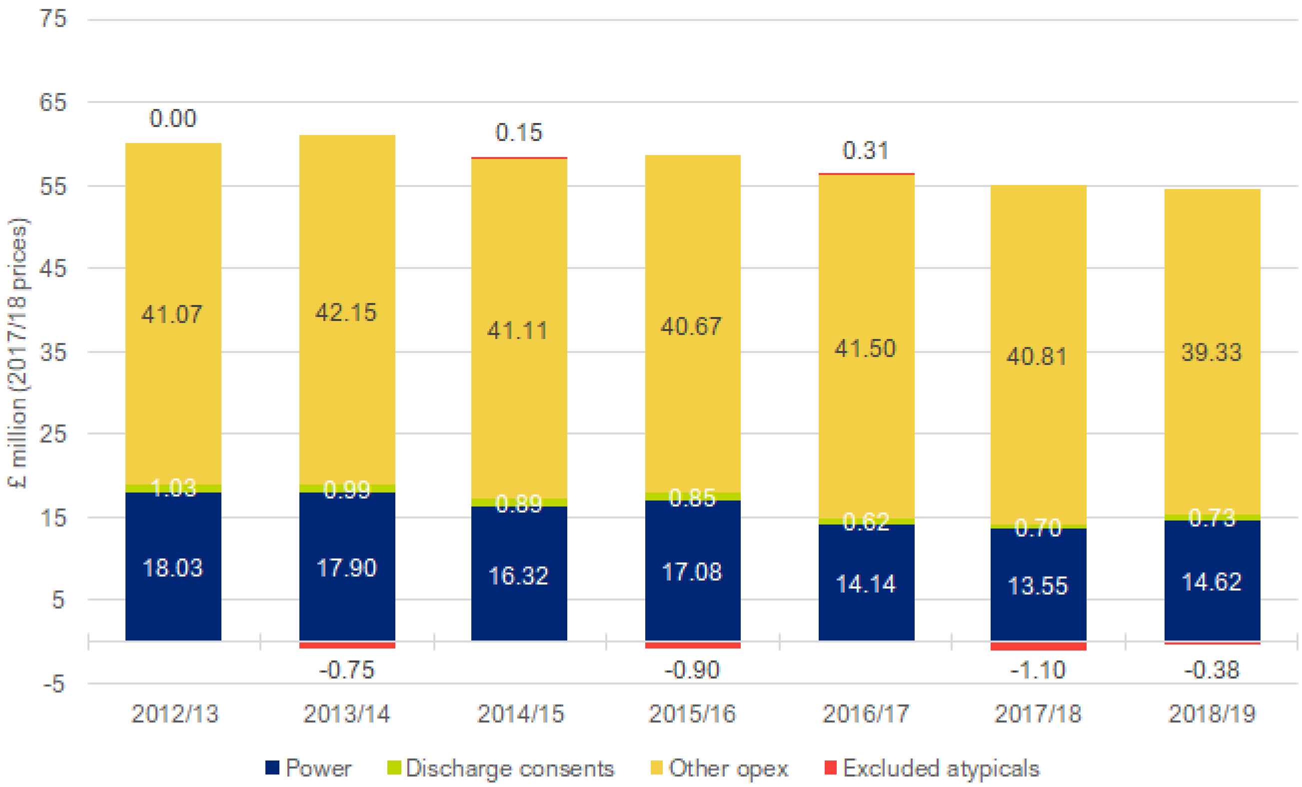
Figure 3.1 and Figure 3.2 summarise these components between 2012/13 to 2018/19. NI Water allocates a relatively large proportion of opex into 'other opex'. We have been assured by NI Water through discussions at CAWGs that data has been reported in line with the definitions followed by E&W companies and additional assurance has been provided by the Reporter. As a result, we are satisfied that the quality of the opex data reported by NI Water is sufficiently good to be used within comparative econometric benchmarking analysis alongside E&W companies' data.

Figure 3.1: NI Water wholesale water modelled opex



Source: CEPA analysis of NI Water data

Figure 3.2: NI Water wholesale sewerage modelled opex



Source: CEPA analysis of NI Water data

Atypical costs can be defined as exogenous costs (i.e. outside the control of the company) that were incurred in PC15 but are not expected to be incurred in PC21 (i.e. one-off costs). In this case, historical information is not a good reflection of future expenditure and it is sensible to exclude these costs from the modelling.

NI Water identified a number of costs items they consider to be atypical. Following discussions at CAWGs, costs related to (i) industrial action, (ii) holiday pay backdate, (iii) extreme weather, and (iv) Project Clear (for wholesale water) were excluded from the modelling. NI Water also proposed excluding costs related to voluntary early retirement (VER), business improvement (BI), consultancy and legal costs for Omega renegotiation. But these were rejected by the UR as they were either not deemed to be atypical in nature (e.g. VER and BI costs are ongoing costs incurred by NI Water) and/or were costs that were incurred as a result of NI Water's own actions (e.g. legal costs for Omega renegotiation).[12]

Details of the atypical expenditure excluded from the modelling are provided in Table 3-1 below.

Table 3-1: Atypical expenditure excluded from modelled opex, £ million (2017/18 prices)

Opex category	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19
Wholesale water							
Industrial action	0.00	1.11	-0.30	0.00	0.00	0.00	0.00
Project Clear	0.00	0.00	0.00	0.00	0.67	0.40	0.00
Extreme weather	0.00	0.00	0.00	0.00	0.00	0.00	0.54
Holiday pay backdate	0.00	0.00	0.00	1.33	0.00	0.00	0.00
Wholesale wastewater							
Industrial action	0.00	0.75	-0.15	0.00	0.00	0.00	0.00
Extreme weather	0.00	0.00	0.00	0.00	0.00	1.10	0.38
Holiday pay backdate	0.00	0.00	0.00	0.90	-0.31	0.00	0.00

Source: CEPA analysis of NI Water data

3.2. Capital maintenance analysis

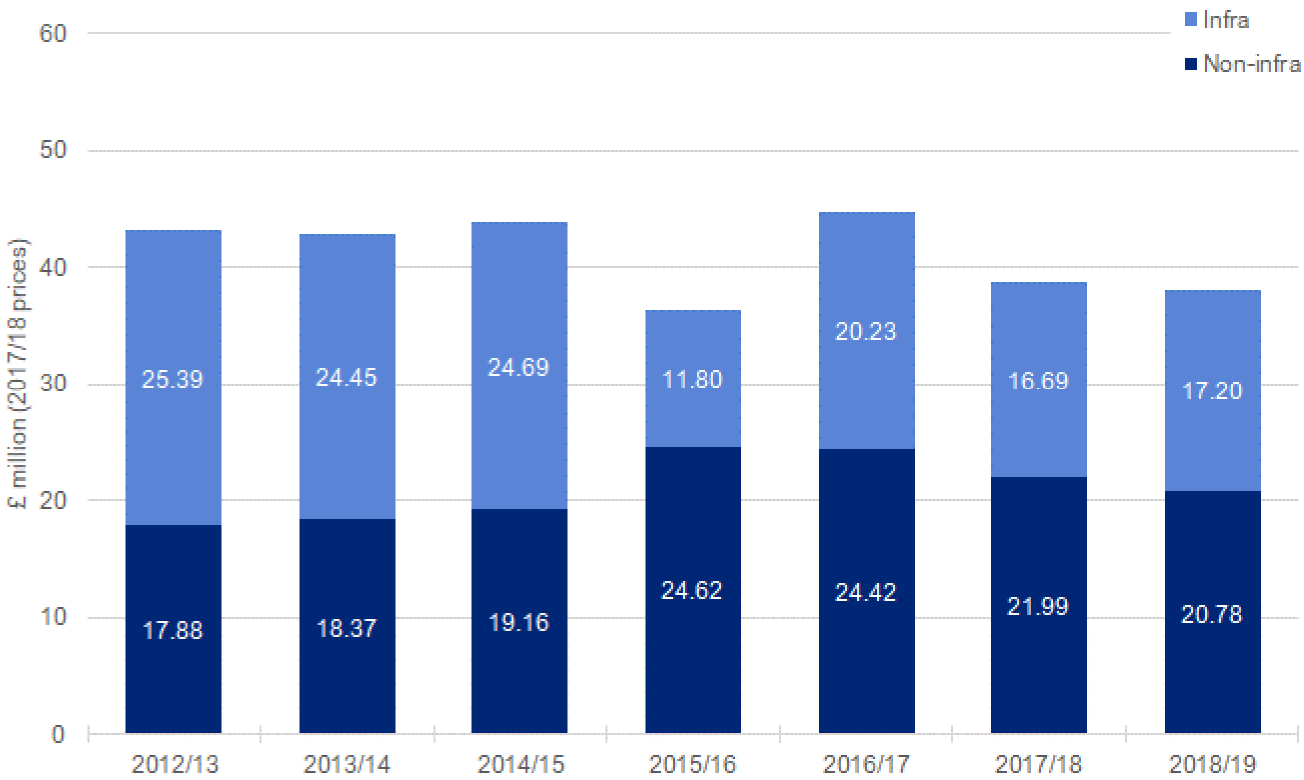
The value of capital maintenance expenditure, used as the dependent variable in our modelling, is comprised of activities that maintain the existing service level. The box below describes the composition of modelled capital maintenance for both wholesale water and sewerage:

Modelled wholesale water maintenance	=	Maintaining the long-term capability of the assets (infrastructure) + Maintaining the long-term capability of the assets (non-infrastructure)
Modelled wholesale sewerage maintenance	=	Maintaining the long-term capability of the assets (infrastructure) + Maintaining the long-term capability of the assets (non-infrastructure) [excluding sludge / bio resources]

Figure 3.3 and Figure 3.4 summarise these components between 2012/13 to 2018/19. Infrastructure capital maintenance costs largely relate to planned maintenance of underground pipes and distribution networks. Non-infrastructure capital maintenance costs largely relate to water and wastewater treatment works and processes.

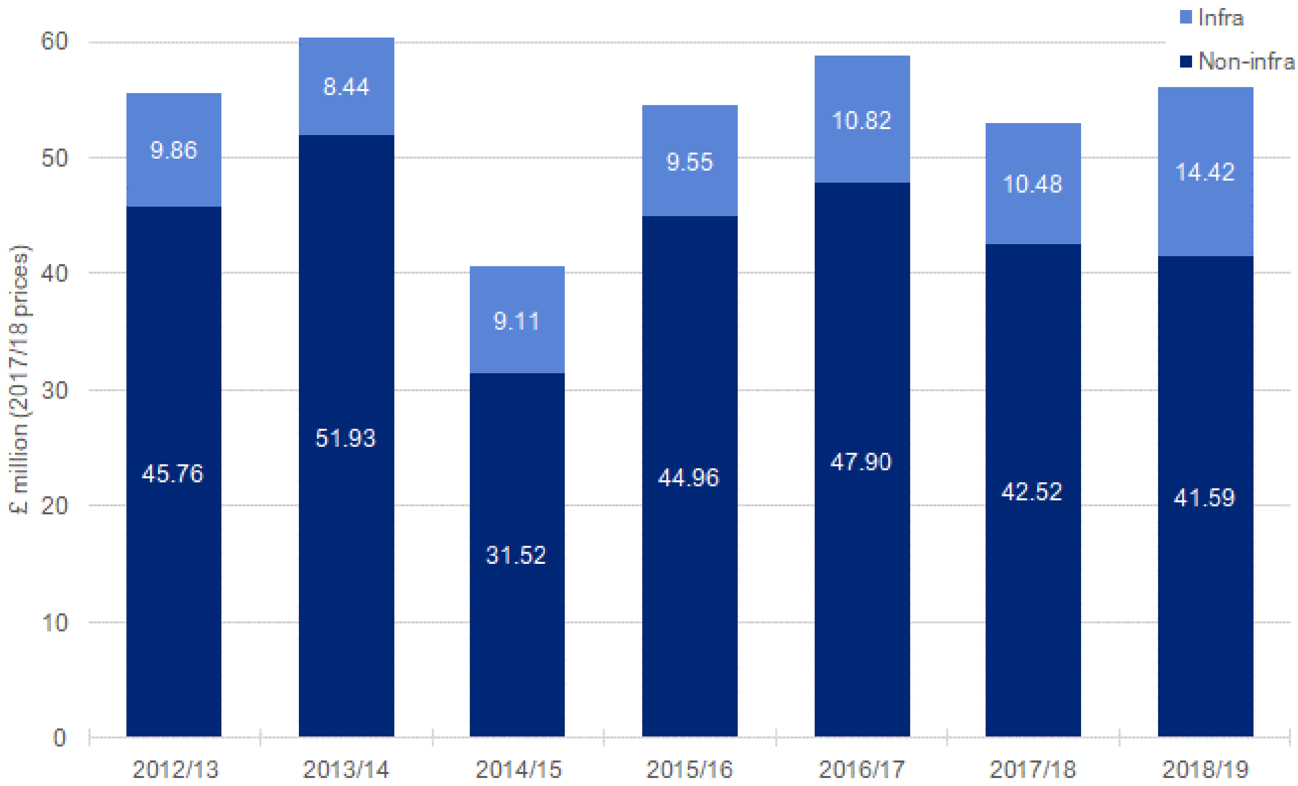
[12] Reconciliation adjustments for industrial action (in 2014/15) and holiday pay backdate (for sewerage in 2016/17) means there is a minor addition to the modelled expenditure in these two years.

Figure 3.3: NI Water wholesale water modelled maintenance



Source: CEPA analysis of NI Water data

Figure 3.4: NI Water wholesale sewerage modelled maintenance



Source: CEPA analysis of NI Water data

Capital maintenance expenditure is generally lumpier than opex, which makes it relatively more difficult than opex to model as the costs incurred may not move directly in line with the drivers of cost. This is reflected in the figures above. However, this concern can be mitigated by conducting efficiency analysis over a period of time (e.g. average efficiency gap over the period 2012/13 to 2018/19) rather than selecting any one year. This is reflected in Sections 6 and 7 below.

We note a switch in expenditure from infrastructure capital maintenance solutions (e.g. underground pipes and distribution networks) to non-infrastructure solutions (e.g. water and wastewater treatment works and processes) from 2015/16 onwards when looking at wholesale water. However, we do not consider this to be an issue as they are assessed at an aggregate level.

3.3. Explanatory variables

In advance of model development, we identified five major drivers of cost based on engineering and economic rationale: scale, density, system characteristics, activity level and quality. The rationale behind each cost driver is provided in the table below.

Table 3-2: Major drivers of wholesale water and sewerage costs

Cost driver	Rationale
Scale	The scale of the activities being undertaken by the company is expected to be the most important driver of total costs.
Density	It is often suggested that there is a u-shape relationship between density and costs incurred by a water company. For example, • Companies in sparse areas may have to travel longer distances for maintenance and/or may be forced to treat water using many smaller treatment works meaning they are unable to benefit from economies of scale in water treatment. • Companies in highly dense urban areas may face additional costs related to traffic congestion, traffic management and cooperation with other utilities.
System characteristics	The characteristics of the assets and systems operated by the company could also lead to differences in total costs between companies. Examples include network complexity / topography, economies of scale in water and sewage treatment, water and sewage treatment complexity and the age of the network.
Activity level	Cost differences between companies could reflect that some companies need to deliver a higher but efficient amount of activity to deliver specific outputs. For example, some companies may have a higher number of new connections, increasing the level of maintenance required.
Quality	Increasing the quality of the service delivered by companies can have an ambiguous effect on costs. The company may need to invest to provide the higher level of quality but may also benefit from cost decreases in other areas. For example, investment to reduce the level of leakage may reduce costs associated with fixing leaks on the network as well as reduced costs associated with answering customer calls when reporting supply issues.

Based on data available, we identified explanatory variables that could be used to proxy these cost drivers. For example, the total length of mains is a proxy for the scale of a water company.

Table 3-3 and Table 3-4 set out the set of available explanatory variables that we identified for each cost driver based on the data available and their expected sign. Explanatory variables were added into the models in order of the importance assigned to the underlying cost driver based on economic and engineering rationale. For example, scale explanatory variables were added first and quality explanatory variables were added last.

Table 3-3: Wholesale water explanatory variables

Cost driver		Explanatory variable	Expected sign
Scale		Total connections	Positive
		Total length of mains	
Density		Connections per length of mains	Ambiguous
		Ofwat weighted density measure[13]	
System characteristics	Network complexity / topography	Number of booster pumping stations, service reservoirs and water towers	Positive
		Number of booster pumping stations per length of mains	
	Economies of scale in water abstraction	Number of sources	Positive
		Distribution input per source	Negative
	Water treatment complexity	% of water input from different water sources	Depends
		% of water treated in complexity bands 4 to 6	Positive
		Ofwat weighted complexity variable	
	Economies of scale in water treatment	% of water treated in treatment works sizes 7 to 8	Negative
		% of water treated in treatment works sizes 1 to 2	Positive
		Number of water treatment works	Positive
	Age of network	% of mains installed post-1981	Negative
Activity level		% mains refurbished, relined, or renewed	Positive
		New connections	
Quality		Leakage	Negative

[13] See section3.5.

Table 3-4: Wholesale sewerage explanatory variables

Cost driver		Explanatory variable	Expected sign
Scale		Total connections	Positive
		Total length of sewers	
		Total load	
		Volume of wastewater	
Density		Connections per length of sewers	Ambiguous
		Ofwat density measure	
System characteristics	Economies of scale in sewage treatment	% of load treated in size bands 1 to 3	Positive
		% of load treated in size bands 6	Negative
		Number of sewage treatment works	Positive
		Number of sewage treatment works per length of sewer	
	Network complexity / topography	Number of network pumping stations	Positive
		Number of network pumping stations per length of sewers	
	Sewerage treatment complexity	Volume of trade effluent as a % of volume of wastewater	Positive
		% wastewater subject to tertiary treatment	Positive
		% of load with ammonia consents <=3mg/l	Positive
	Age of network	Total length of sewer laid or structurally refurbished post-2001	Negative
		% sewer laid or structurally refurbished post-2001	
Activity		New connections	Positive
Quality		Number of sewer blockages	Depends
		Number of gravity sewer collapses	
		Number of sewer rising main bursts / collapses	

The selection of explanatory variables is partially driven by data availability. For example, NI Water were unable to provide pumping station capacity, which was used by Ofwat in the wastewater botex models for PR19 as a proxy for network complexity.[14] In addition, data limitations also meant that we were only able to develop wholesale water models using 2013/14 to 2018/19 data, whereas sewerage models were developed using 2012/13 to 2018/19 data. However, we do not consider that these data limitations have affected the quality of the results.

NI Water also assigned confidence grades to the underlying data of each explanatory variable and identified '% of mains installed post-1981' and 'total length of sewer laid or structurally refurbished post-2001' as variables they had the least confidence in. This was because the data had to be manually computed rather than directly extracted from its data systems. We reviewed the data provided and concluded it was sufficiently good to be used within the econometric analysis as both data series followed a trend that looked sensible when compared against E&W company data.

[14] See Ofwat's initial assessment of plans, supplementary technical appendix: econometric approach, available at: https://www.ofwat.gov.uk/publication/supplementary-technical-appendix-econometric-approach/

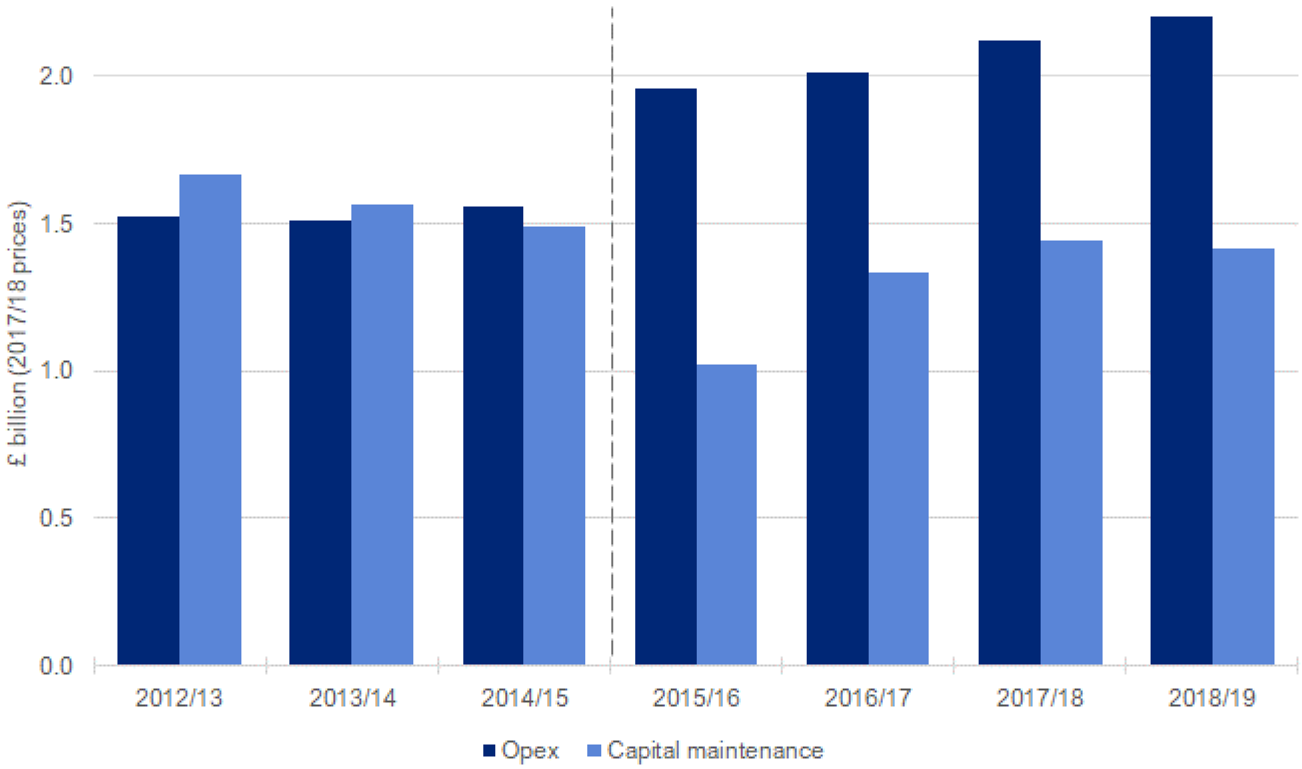
Overall, the data provided by NI Water for modelling purposes has gone through multiple iterations and quality assurance through the CAWGs, and the same data has also been used as part of NI Water's PC21 business plan submission. We are therefore confident that the data provided by NI Water is robust.

3.4. Accounting change

The accounting standards followed by E&W companies changed in 2015/16, which led to the abolition of renewals accounting.[15] The impact of this change is that infrastructure renewals expenditure (IRE) may now be all or partly recorded as opex rather than capital maintenance.

As shown in Figure 3.5 and Figure 3.6, this led to a significant shift in the classification of expenditure. For a number of E&W companies there is a step change in the level of opex and maintenance from 2015/16 onwards.

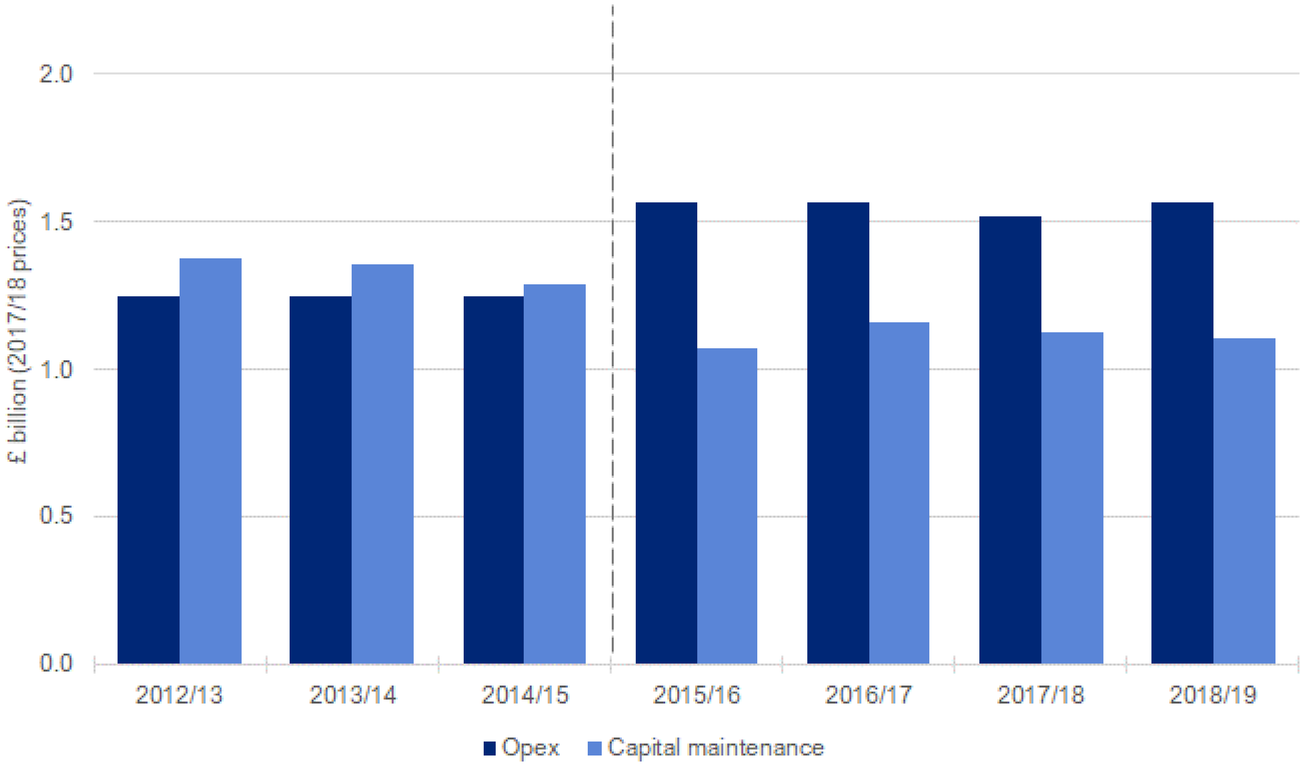
Figure 3.5: England & Wales wholesale water opex and capital maintenance expenditure



Source: CEPA analysis of Ofwat data

[15] Source: https://www.ofwat.gov.uk/wp-content/uploads/2017/04/RAG-1.08-Principles-and-guidelines-for-regulatory-reporting-under-the-new-UK-GAAP-regime.pdf

Figure 3.6: England & Wales wholesale sewerage opex and capital maintenance expenditure



Source: CEPA analysis of Ofwat data

NI Water were not required to implement the change in accounting standards at the same time as E&W companies and as a result did not experience a shift in the classification of expenditure in 2015/16. Accounting procedures at NI Water have now been realigned for the most recent year of data available; 2018/19. However, NI Water's response to the change differs from the majority of E&W companies with only a minor reclassification of expenditure from maintenance to opex reported in 2018/19.

This change in accounting procedures within the modelling period makes it more difficult to compare expenditure between companies in the four most recent years. In order to account for this in our modelling, we include an accounting dummy variable that is zero prior to 2015/16 and one otherwise for England and Wales companies.[16] The effect of this is to isolate the impact of the accounting change on opex and capital maintenance within the model rather than in the model residuals, which reduces the risk that the difference in relative efficiency between companies is caused by the accounting change.

Given that companies have applied the accounting change differently, the dummy variable does not perfectly capture companies' reactions to the accounting change as it only captures an average effect. We tested a range of alternative options but were unable to identify a better solution:

- Models that were estimated excluding the dummy variable performed significantly worse with large unexplained variances in efficiency scores.

[16] The dummy variable is always equal to zero for NI Water as their costs are not affected by the accounting change in England and Wales. This includes 2018/19 given that the reclassification of NI Water costs between opex and maintenance in 2018/19 was very marginal and would be significantly overestimated by the dummy variable.

- Testing alternative specifications for the dummy variable (e.g. grouping companies based on how they responded to the accounting change) had minimal impact on model results and used up degrees of freedom.
- Botex models address the accounting change issue (by definition) but fail to improve the overall robustness and clarity of the results. For example, there were large variances in efficiency scores across botex model specifications and between different years.

Overall, we are satisfied that the accounting dummy variable captures companies' reactions to the accounting change well enough to enable the model results presented in this report to be used by the UR when considering NI Water's PC21 opex and capital maintenance allowances. This judgment was supported by NI Water and their consultants, Economic Insight, who also agreed that the use of a dummy variable was the best option available to address this issue.

To provide an additional level of confidence to our results, we cross-check our opex and capital maintenance model results against botex model results. For example, one may expect that the botex efficiency results fall in between the opex and maintenance efficiency results providing the model specifications being compared are like-for-like. Botex model results are presented in Appendix B.

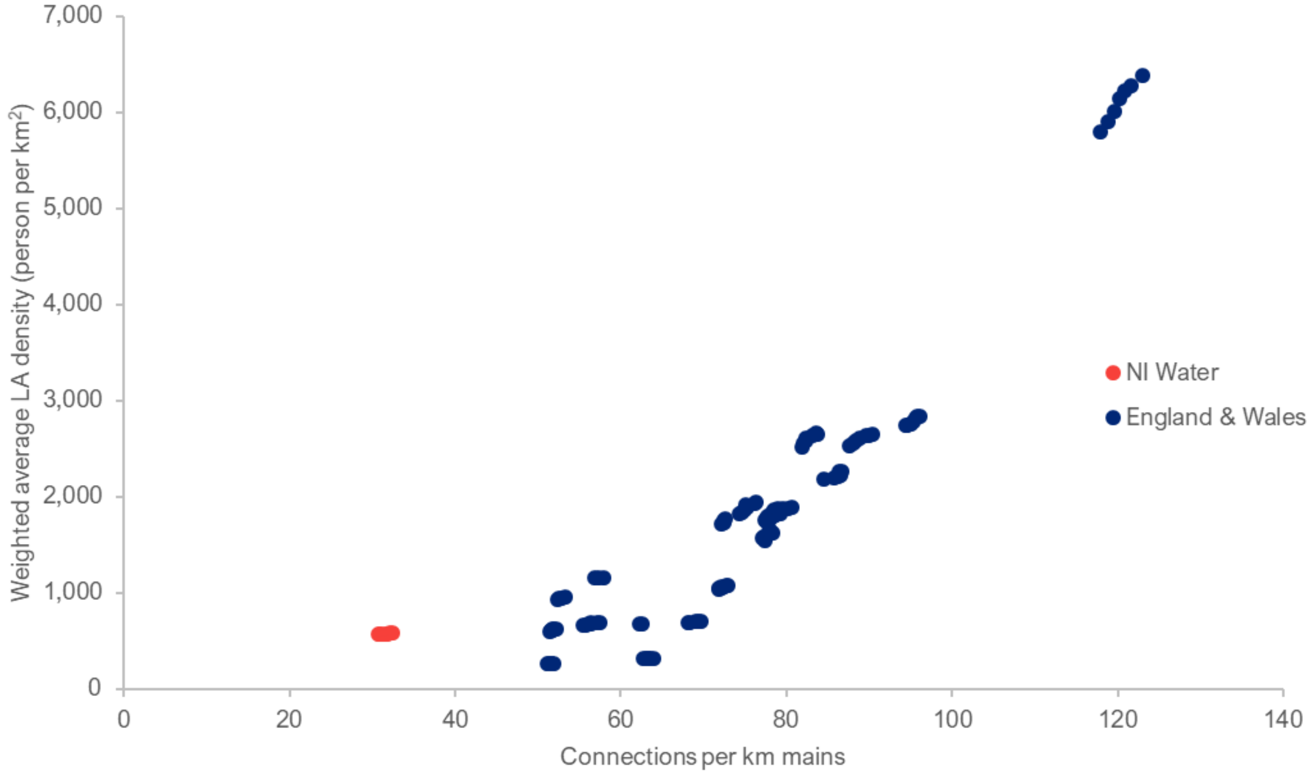
3.5. Density measure

Ofwat employed its own weighted average density measure within their PR19 econometric cost models. This was calculated by taking population density (people per km squared) at a local authority level and weighting by the population in each local authority served by the company in question.

We examined the correlation between Ofwat's weighted average density measure, based on population density at a local authority level, and the conventional connections per length of mains measure. The results indicate that Ofwat's measure may be less suitable in the context of NI Water's network.

Figure 3.7 shows that the broadly linear relationship between the two measures among England and Wales companies begins to break down below roughly 70 connections per km of water mains. As a result, Ofwat's weighted average density measure does not appear to accurately capture the sparsity of NI Water's network given its population density is around 30 connections per km. This was also reflected in our initial model development, which showed that the inclusion of the Ofwat weighted average density measure produced unrealistic efficiency results for NI Water. Therefore, we developed models that used the conventional measure for the effect of density on costs. This approach was agreed with the UR and NI Water within the CAWGs.

Figure 3.7: Comparison of density measures



Source: CEPA analysis

4. WHOLESALE WATER MODELLING RESULTS

This section presents the wholesale water opex and capital maintenance model results. As described previously, we conducted our model development in two phases.

A larger range of models were selected following Phase 1 of the model development process (e.g. models that only include explanatory variables to capture scale and density). But to ensure that this report is digestible for the reader, the tables below focus on the models selected following Phase 2 of the model development process and subsequent further shortlisting following feedback from CAWGs.

A number of considerations and decisions were made in order to reach the final wholesale water model selection:

- **Scale, density, water treatment complexity and network complexity / topography were identified as the most important drivers of wholesale water opex and capital maintenance** based on the data available; a finding supported by engineering rationale. This is reflected in the models selected, which include explanatory variables to capture each of these cost drivers.
- **Age of the network is also an important driver of wholesale water capital maintenance.** As expected, older networks incur additional maintenance costs which are reflected in the model results. However, the UR may want to consider whether there are any perverse incentives associated with age explanatory variables, when deciding how to use the model results. For example, all else being equal, having an older network leads to higher predicted costs from the models, which may not provide an incentive to NI Water to maintain / replace its network. The UR may also want to note that NI Water has **less confidence in the data underlying the age explanatory variable** (% of mains after 1981) as it is not captured within their data reporting systems and has been manually constructed to inform CAWG.
- Our analysis indicates that there is a **u-shape relationship between density and wholesale water opex**. This finding is in line with Ofwat's PR19 econometric cost models and supports the hypothesis that operating costs are higher both for companies operating in very sparse areas and companies operating in highly dense urban areas. The evidence is not as clear for wholesale water capital maintenance as the explanatory variable used to capture the u-shape relationship (connections per length of mains squared) is not individually statistically significant. However, 'connections per length of mains' and 'connections per length of mains squared' are jointly statistically significant (see Appendix B).
- **We identified three different explanatory variables which capture the effect of water treatment complexity on costs**: (i) % of water treated in complexity bands 4 (single stage complex treatment) to 6 (works with one or more very high cost processes); (ii) Ofwat's weighted average treatment complexity; and (iii) % water from pumped reservoirs. All three variables performed well in the opex models, which is reflected in the models selected. However, concerns have been raised by NI Water and their contractor, Economic Insight, during CAWG meetings on the weights applied to the different complexity bands by Ofwat when calculating the weighted average treatment complexity variable. The UR may want to take this into account when deciding how to use the model results to assess the relative efficiency of NI Water's wholesale water opex (e.g. by placing relatively less weight on opex model 2). The capital maintenance models only include '% water treated in complexity bands 4 to 6' to capture water treatment complexity, because this variable performed better during the model development process.
- **Total number of connected properties was also tested as a scale explanatory variable** within the model development process, but the models selected all include length of mains in preference to connected properties. This decision reflects the fact that all three model specifications include 'connections per length of mains' to capture the effect of density on costs. Use of 'connections per length of mains' captures both the total number of connected properties and length of mains. This means that using the total number of connected properties instead of length of mains as the scale cost driver would lead to the same efficiency results.

The following tables present wholesale water model results and include the full names of the variables to facilitate presentation. However, it should be noted that the models are developed in logs (except for percentage variables that have been modelled using levels). The full results of our model robustness assessment, including additional models excluded from the final selection, are available in full in Appendix B.

4.1. Opex models

Table 4-1: Main model results, wholesale water opex

Variables	Model 1	Model 2	Model 3
Length of mains	1.006***	0.970***	1.000***
Number of booster pumping stations per length of mains	0.306**	0.290*	0.216
% of water treated in complexity bands 4 to 6	0.004***		
Weighted average treatment complexity		0.396**	
% of water input from pumped reservoirs			0.004***
Connections per length of mains	-3.238*	-4.000**	-2.742**
Connections per length of mains squared	0.490**	0.586***	0.425**
Post-2014/15 UK GAAP accounting treatment	0.187***	0.193***	0.196***
Constant	0.402	1.843	-0.647
Overall predictive power	97.0%	96.8%	97.1%
Number of observations	111	111	109

*Source: CEPA analysis. Note: Significant at the * 10% level, ** 5% level, *** 1% level.*

4.2. Capital maintenance models

Table 4-2: Main model results, wholesale water capital maintenance

Variables	Model 1	Model 2	Model 3	Model 4
Length of mains	1.190***	1.244***	1.191***	1.249***
Number of booster pumping stations per length of mains	0.528*	0.339	0.525*	0.305
% of water treated in complexity bands 4 to 6	0.011**	0.011**	0.011**	0.011***
% of mains after 1981		-0.019***		-0.019***
Connections per length of mains	0.943***	0.637**	1.076	1.992
Connections per length of mains squared			-0.016	-0.166
Post-2014/15 UK GAAP accounting treatment	-0.209**	-0.173*	-0.210*	-0.179*
Constant	-9.962***	-9.302***	-10.248	-12.244
Overall predictive power	88.6%	90.0%	88.5%	89.9%
Number of observations	111	109	111	109

*Source: CEPA analysis. Note: Significant at the * 10% level, ** 5% level, *** 1% level.*

4.3. DISCUSSION

Overall, the selected wholesale water opex and capital maintenance models presented above perform well against our assessment criteria. A summary of the findings is as follows:

- The estimated coefficients on the explanatory variables all have a plausible sign and magnitude. In addition, most explanatory variables are individually statistically significant at a 10 percent significance level. The exceptions being:
  - The number of booster pumping stations per length of mains in opex model 3 and capital maintenance models 2 and 4. However, these models are included in our final model selection because network complexity / topography is an important driver of wholesale water opex and capital maintenance from an engineering perspective, and the estimated coefficients are sensible in terms of sign and magnitude.
  - 'Connections per length of mains' and 'connections per length of mains squared' are not individually significant in capital maintenance models 3 and 4. However, we include these models in our final selection as these variables capture the u-shape relationship between density and costs, which NI Water has stressed is important given the sparsity of its network. These variables are also jointly statistically significant (see Appendix B).
- All the models perform well in terms of goodness of fit, with an adjusted R-squared of at least 88.5%. The opex models also satisfy the within sample forecasting test, which indicates that these models could be used to predict wholesale water opex allowances. However, capital maintenance Model 1 fails this test, which means that caution should be applied if capital maintenance Model 1 is used to predict allowances.
- Efficiency results are stable across the different model specifications. All models for both opex and capital maintenance satisfy the ranking and score stability tests.
- The opex models fail the linearity test (RESET), which may indicate that a different functional form could perform better. However, more complex functional forms increase complexity whilst not always producing better results. In the case of the models tested here, we are not convinced that the added complexity of alternative functional forms is warranted given relatively good performance on other tests and lack of clarity regarding which alternative functional forms would be objectively justifiable.
- Where a quadratic variable has not been included, the models have a max and mean variance inflation factor (VIF) of less than 10, indicating a low risk of multicollinearity. Where the test is failed, it is driven by the inclusion of a quadratic variable, which is necessarily closely related to the linear density variable. As mentioned, the quadratic density variable is included to capture the u-shape relationship between opex and density.
- The models perform well in other tests. All models pass the Chow / Pooling test, which suggests that the inclusion of the accounting dummy variable sufficiently captures the accounting change that was faced by E&W companies in 2015/16 (see Section 3.4). The models are also consistent with a priori expectations and price control incentives. Two opex models fail the normality test but we place a low level of importance on this test result as it does not distort the estimated coefficients.

5. WHOLESALE SEWERAGE MODELLING RESULTS

As with the previous section, this section presents the wholesale sewerage opex and capital maintenance models selected following Phase 2 of the model development process and subsequent further shortlisting following feedback from CAWGs.

A number of considerations and decisions were made to reach the final wholesale sewerage model selection:

- **Scale, density, economies of scale in sewage treatment, and age of the network were identified as the most important drivers of wholesale sewerage opex and capital maintenance** based on the data available. This finding is supported by engineering rationale and is reflected in the models selected, which include explanatory variables to capture each of these cost drivers.
- The UR may want to consider whether there are any **perverse incentives associated with age explanatory variables** when deciding how to use the model results. For example, all else being equal, having an older network leads to higher predicted costs from the models, which may not provide an incentive to NI Water to maintain / replace its network. The UR may also want to note that NI Water has **less confidence in the data underlying the age explanatory variable** (% sewer laid or structurally refurbished post 2001) as it is not captured within its data reporting systems and has been developed based on assumptions.
- Our analysis indicates that there is a **u-shape relationship between density and wholesale sewerage opex and capital maintenance**. Identification of this relationship supports the hypothesis that operating costs are higher for companies operating in very sparse areas but are also higher for companies operating in highly dense urban areas. This is reflected in the final selection of sewerage opex and capital maintenance models, which all contain 'connections per length of mains' and 'connections per length of mains squared' explanatory variables to capture this relationship.
- **All selected wholesale sewerage models contain length of sewer as the scale cost driver.** Total number of connected properties was also tested as a scale explanatory variable but is not included in the final model selection due to the same reasons given in Section 4. We also tested models with load as the scale cost driver, but significant concerns were raised during CAWG meetings with this variable, which led to models including load being excluded from the final model selection. The concerns related to significantly higher load per connected property in Northern Ireland compared to E&W companies, which may be driven by a combination of: the use of an incinerator by NI Water; a relatively high occupation rate in Northern Ireland; and/or differing underlying assumptions being used by companies to calculate load.

The following tables present wholesale sewerage model results and include the full names of the variables to facilitate presentation. However, it should be noted that the models are developed in logs (except for percentage variables that have been modelled using levels). The full results of our model robustness assessment, including additional models excluded from the final selection, are available in full in Appendix B.

5.1. OPEX MODELS

Table 5-1: Main model results, wholesale sewerage opex

Variables	Model 1	Model 2
Total length of sewers	1.017***	0.978***
% of load treated in size bands 1 to 3	0.072***	0.063***
% sewer laid or structurally refurbished post-2001		-0.009***
Connections per length of mains	-11.858*	-10.687**
Connections per length of mains squared	1.550*	1.393**
Post-2014/15 UK GAAP accounting treatment	0.167***	0.180***
Constant	16.351	14.726
Overall predictive power	94.8%	96.4%
Number of observations	77	76

*Source: CEPA analysis. Note: Significant at the * 10% level, ** 5% level, *** 1% level.*

5.2. CAPITAL MAINTENANCE MODELS

Table 5-2: Main model results, wholesale sewerage capital maintenance

Variables	Model 1	Model 2
Total length of sewers	0.695***	0.693***
% sewer laid or structurally refurbished post-2001		-0.008
Connections per length of sewers	-21.988***	-21.776***
Connections per length of mains squared	2.796***	2.763***
Post-2014/15 UK GAAP accounting treatment	-0.196**	-0.178**
Constant	40.455***	40.248***
Overall predictive power	82.4%	84.2%
Number of observations	77	76

*Source: CEPA analysis. Note: Significant at the * 10% level, ** 5% level, *** 1% level.*

5.3. Discussion

The selected wholesale sewerage opex models perform well against our assessment criteria, with a high overall goodness of fit, and satisfy most sensitivity tests:

- The estimated coefficients on the explanatory variables all have a plausible sign and magnitude and are all statistically significant at the 10 percent significance level.
- The models perform well in terms of goodness of fit, with an adjusted R-squared well over 90%. They all also satisfy the various robustness tests, with results broadly remaining stable after including or excluding different data points.
- Efficiency results are stable across the different model specifications. However, Model 2 does not satisfy the within sample forecasting test, which means that caution should be applied if Model 2 is used to predict allowances.
- The models perform well in all other tests, which all pass with the exception of the test for normality for Model 2. But we place a low level of importance on this test result as it does not distort the estimated coefficients.

The selected capital maintenance models have a lower overall goodness of fit and do not perform as well as the opex models. This is expected given that maintenance expenditure is more variable than opex. The models, however, still satisfy the majority of our assessment criteria, with model 1 performing slightly better than model 2:

- The estimated coefficients on the explanatory variables are all consistent with a priori expectations. All coefficients, except for the network age variable, are consistently significant at a 10% level. While the network age variable is not significant at the 10% level in the capital maintenance model it is statistically significant at the 20% level and does increase the overall goodness of fit as measured by the adjusted R-squared.
- Overall goodness of fit is above 80% when measured by adjusted R-squared. While these models are the most robust achievable with the data available, they achieve only our minimum threshold in terms of predictive power.
- Both models satisfy tests assessing the stability of results to the removal of different data points. Model 1 satisfies both the within-sample forecasting test and the stability of efficiency scores, while model 2 does not. The models broadly perform well in the other tests, such as normality and homoscedasticity.

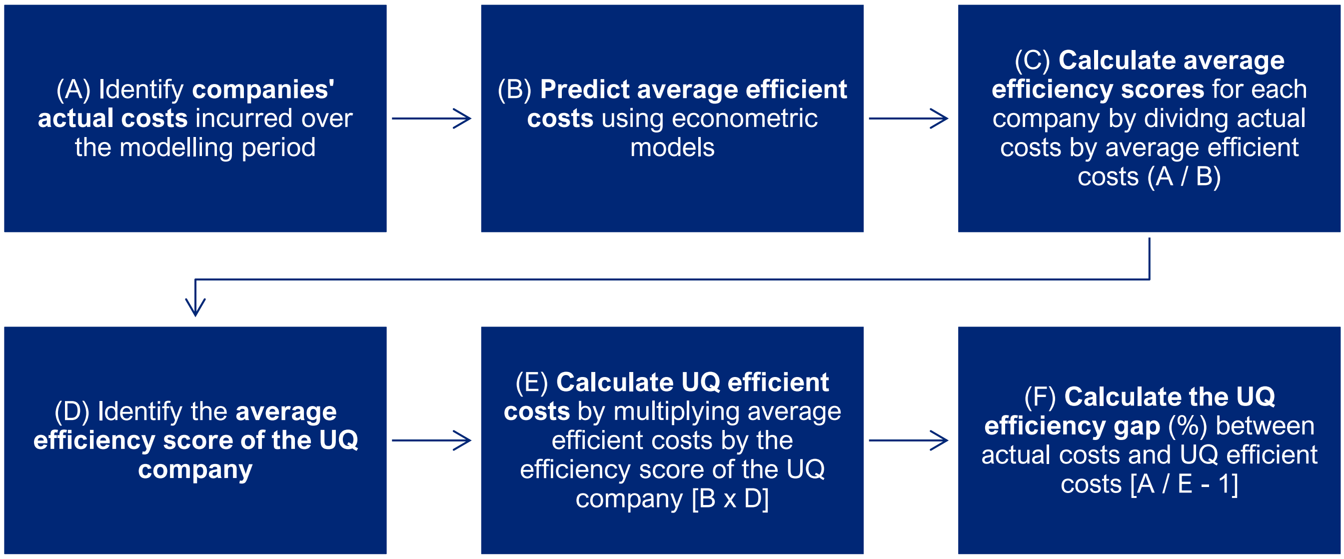
6. EFFICIENCY ANALYSIS BEFORE APPLICATION OF SPECIAL COST FACTORS

The tables and figures below summarise NI Water's efficiency results based on the econometric benchmarking models described in the sections above. In the context of this report, we define an efficiency gap as the expenditure distance between upper quartile (UQ) efficient company and NI Water in percentage terms.[17] In other words, we define the amount to which NI Water would need to reduce or increase its costs to reach the UQ efficient company.

We apply the UQ benchmark as it has been used by UK regulators such as the UR, Ofwat and Ofgem when conducting relative efficiency analysis in recent price controls. It is important to note, however, that the UR has not decided on the efficiency benchmark it will apply when assessing the relative efficiency of NI Water for PC21.

The upper quartile efficiency gap is calculated as follows:

Figure 6.1: Efficiency gap calculation before application of special cost factors



This means that an efficiency gap of 5% would indicate that NI Water's costs are 5% lower than the costs that would have been incurred by the UQ efficient company. Conversely, a gap of -5% would indicate the company's costs are 5% higher than the UQ efficient company.

An illustrative example is provided in Table 6-1 to show how NI Water's UQ efficiency gap has been calculated for each model. In this example, the efficiency gap is -15%, which means that the company would need to reduce its costs by 15% to reach a similar performance level to the UQ company. We have not accounted for special cost factors when conducting the efficiency gap analysis presented in this section. Special cost factors and the resulting adjusted efficiency gaps are considered in section 7.

[17] The upper quartile is equivalent to the company placed 5.25 out of 18 wholesale water companies in the weighted average efficiency gap calculations. The upper quartile is equivalent to the company placed 3.5 out of 11 wholesale sewerage companies in the weighted average efficiency gap calculations.

Table 6-1: Illustrative efficiency gap calculation before special cost factors

Column	Item	Calculation	Example
A	Actual Cost (excluding atypical costs)		£100m
B	Predicted Average		£89.5m
C	Efficiency Score of UQ Company		0.95
D	UQ Predicted Costs (before special cost factors)	B * C	£85m
E	**Efficiency Gap to UQ (£m)**	**D – A**	**- £15m**
F	**Efficiency Gap to UQ (%)**	**E / A**	**- 15%**

Source: CEPA analysis

6.1. Wholesale water efficiency results

The tables below present, by model, the efficiency gap results from the wholesale water models.[18]

Opex efficiency

Table 6-2: NI Water wholesale water efficiency gap to upper quartile, opex

	Model 1	Model 2	Model 3
2013/14	0.6%	2.1%	-3.2%
2014/15	0.4%	1.1%	-0.3%
2015/16	2.7%	-1.5%	-2.6%
2016/17	0.8%	-1.0%	-6.1%
2017/18	-3.0%	-3.7%	-8.8%
2018/19	-2.1%	0.4%	-3.2%
Weighted Average	5.5%	0.6%	-2.2%

Source: CEPA analysis

Capital maintenance efficiency

Table 6-3: NI Water wholesale water efficiency gap to upper quartile, capital maintenance

	Model 1	Model 2	Model 3	Model 4
2013/14	-3.0%	0.4%	-3.7%	-0.2%
2014/15	-16.3%	-12.5%	-16.8%	-17.8%
2015/16	-10.2%	-14.1%	-10.4%	-18.6%
2016/17	-9.6%	-11.8%	-9.8%	-15.8%
2017/18	16.7%	11.2%	16.2%	5.8%
2018/19	14.1%	13.0%	13.7%	8.8%
Weighted Average	1.6%	2.8%	0.9%	-0.9%

Source: CEPA analysis

We focus our analysis on the weighted average rather than the yearly efficiency gap results as it is less likely to be affected by regulatory cycle and accounting differences between NI Water and E&W companies. This mirrors the

[18] NI Water's upper quartile efficient costs that are used to calculate the efficiency gaps are provided in Appendix D.

approach taken by Ofwat at PR19 to calculate efficiency gaps which is calculated based on the sum of actual and predicted costs over the modelling period.

NI Water's wholesale water opex efficiency gap to the UQ ranges from **-2.2% to 5.5%** based on a weighted average calculation and appears more efficient than an UQ company in two out of three models. Across the three models there does not appear to be a clear indication of whether NI Water are becoming more or less efficient over time.

NI Water's wholesale water capital maintenance efficiency gap to the UQ ranges from **-0.9% to 2.8%** based on a weighted average calculation and it appears more efficient than an UQ company in three out of four models. There is some evidence that NI Water is becoming more efficient over time with respect to capital maintenance, which the UR may want to consider when assessing whether NI Water's wholesale water opex expenditure is efficient.

6.2. Wholesale sewerage efficiency results

The tables below present the efficiency gap results for the selected wholesale sewerage models.[19]

Opex efficiency

Table 6-4: NI Water wholesale sewerage efficiency gap to upper quartile, opex

	Model 1	Model 2
2012/13	-15.2%	-13.2%
2013/14	-15.7%	-16.8%
2014/15	-11.2%	-10.4%
2015/16	-3.8%	-6.3%
2016/17	-1.4%	-3.1%
2017/18	-3.5%	-3.8%
2018/19	1.8%	3.5%
Weighted Average	-7.3%	-7.0%

Source: CEPA analysis.

Capital maintenance efficiency

Table 6-5: NI Water wholesale sewerage efficiency gap to upper quartile, capital maintenance

	Model 1	Model 2
2012/13	-10.3%	-7.5%
2013/14	-22.9%	-19.6%
2014/15	-3.7%	0.1%
2015/16	-13.2%	-11.2%
2016/17	-12.2%	-9.6%
2017/18	-2.6%	-3.5%
2018/19	-13.7%	-13.1%
Weighted Average	-5.2%	-2.6%

Source: CEPA analysis.

[19] NI Water's upper quartile efficient costs that are used to calculate the efficiency gaps are provided in Appendix D.

As above, we focus our analysis on the weighted average rather than the yearly efficiency gap results as it is less likely to be affected by regulatory cycle and accounting differences between NI Water and E&W companies.

NI Water's wholesale sewerage opex efficiency gap to the UQ ranges from **-7.3% to -7.0%** based on a weighted average calculation and it appears less efficient than the UQ company in both models. There is some evidence that NI Water is becoming more efficient over time with respect to opex, which the UR may want to consider when assessing whether NI Water's wholesale sewerage opex is efficient.

NI Water's wholesale sewerage capital maintenance efficiency gap to the UQ ranges from **-5.2% to -2.6%** based on a weighted average calculation and it appears less efficient than the UQ company in both models. In this case, there does not appear to be a clear trend over time.

7. SPECIAL COST FACTOR ANALYSIS

The econometric models presented in this report are intended to capture the key drivers of costs for a water and sewerage company. The models are then used to assess the relative efficiency of NI Water with water and sewerage companies in England and Wales.

However, no econometric model perfectly captures all factors that drive differences in costs; the results will include a degree of inaccuracy. It may therefore be justifiable to adjust results for factors that are not adequately captured in the models – we define these as Special Cost Factors (SCFs). In this context, SCFs are variables that are:

- outside management control;
- have not been adequately captured in the modelling; and
- have a material impact in that ignoring them would result in NI Water having materially higher or lower costs than the predicted costs from the model.

Based on the approach taken in previous price controls, discussions as part of CAWG meetings, and UR's PC21 information requirements document[20], we identified three SCFs that potentially meet the criteria listed above and are quantifiable. These are:

- **Electricity prices.** Power prices have historically been higher in Northern Ireland when compared to the rest of the UK. NI Water has previously cited the lack of supplier competition locally compared to E&W dependence on gas, a lack of indigenous fuels and regulated charges and tariff structures as some of the reasons for the difference. We apply an electricity price SCF adjustment to wholesale water and sewerage modelled opex.
- **Regional wages.** Companies operating in Northern Ireland typically find themselves with an advantage over England and Wales water companies because they operate in a lower wage economy. Our regional price adjustment (RPA) analysis found that median hourly wages (excluding overtime) for a water company operating in Northern Ireland was around 12% lower than a typical water company operating in the UK.[21] We apply a regional wage SCF adjustment to wholesale water and sewerage modelled opex.
- **Capital maintenance regional price adjustment (RPA).** A SCF adjustment is made to take into account regional price differences in capital maintenance between a typical water company in Northern Ireland and the rest of the UK that are not captured in the econometric models.

This is not an exhaustive list of SCFs; we have focused our analysis on factors that are clearly not captured in the modelling and can be quantified. This approach is in line with the approach taken by NI Water, which considers that the suite of econometric cost models developed by CEPA for this price control remove certain factors which resulted in SCF adjustments previously (e.g. rurality)[22].

SCFs that have not been explicitly identified in this report could have a positive or negative impact on NI Water's opex and/or capital maintenance efficiency gap. For example, the Northern Ireland Environment Agency (NIEA) plans to transition to a Mature Wastewater Compliance Model, which will align the reporting of wastewater compliance at the treatment works and in the sewer network with the rest of the UK. This will be delivered through a significant programme spanning both PC21 and PC27 and will capture operational policy changes to both consenting discharges and the assessment of compliance. NI Water has estimated that the transition to the mature

[20] PC21 Information Requirements. Chapter 2 – Operational Costs and Efficiency (issued 15 March 2019 – Version 02). The intended approach to PC21 by the UR is largely unchanged from their PC15 approach, which in turn is based upon their regulatory letter "WR18" issued at PC13, following in general terms their approach at PC10.

[21] Source: CEPA (2020). PC21 Regional Price Adjustment.

[22] Source: NI Water (January 2020). NI Water PC21 Business Plan. Chapter 5 Annex 2.2 Special Factors and Atypicals.

compliance model will lead to a €2 million increase in opex per annum during PC21. Arguably, this could be applied as a negative special cost factor as these are costs that are required to align wastewater compliance with England and Wales water companies, which implies that NI Water is currently incurring lower wastewater compliance costs relative to a comparable company in England and Wales. We take a conservative view and do not apply wastewater compliance as a negative special cost factor because there may be water companies in England and Wales who are also non-compliant.

As briefly discussed in section 6, we apply the SCF adjustments by making post-modelling adjustments to the predicted costs from the models (i.e. after the econometric models have been estimated). A negative (positive) adjustment reduces (increases) NI Water's predicted costs from the models, which reflects the fact that the SCF is expected to make the operation of NI Water less (more) costly relative to the average water and sewerage company in the sample.

The remainder of this section is organised as follows:

- Electricity price SCF
- Regional wage SCF
- Regional price adjustment SCF
- Efficiency results after special cost factors

7.1. Electricity price SCF

To estimate the electricity price SCF we adopt a similar approach to that used by the UR in PC15, which aims to reflect electricity price differences between NI Water and a comparable company in England and Wales. As part of the UR's regular Retail Market Monitoring Transparency Reports, electricity prices in Northern Ireland are estimated using a methodology consistent with data published by Eurostat for a range of EU countries.[23] A weighted average of electricity price differentials between Northern Ireland and the UK across Industrial and Commercial (I&C) consumption bands is used. This is to reflect that different NI Water sites consume power at different levels.[24]

We use the data provided in the Transparency Reports for the two halves of each calendar year. In order to provide a proxy for the price differential for financial year Y1/Y2, we take an unweighted average of the second half of year one and the first half of year two.

Table 7-1 details the price differential calculated between Northern Ireland and the UK at different electricity consumption bands, while Table 7-2 summarises NI Water's electricity consumption as used to calculate a weighted average price differential.[25]

[23] Quarterly and Annual Transparency Reports are available at: https://www.uregni.gov.uk/market-information

[24] The UR has provided evidence to confirm that NI Water's electricity bills are split between sites and vary according to the electricity needs of each site.

[25] Source: NI Water (January 2020). NI Water PC21 Business Plan. Chapter 5 Annex 2.2 Special Factors and Atypicals.

Table 7-1: Annual electricity prices, excluding VAT and including other taxes, p/kWh (nominal prices)[26]

Consumption size band	Column	Calculation	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19
Northern Ireland									
Very small	A		✂	✂	✂	✂	✂	✂	✂
Small	B		✂	✂	✂	✂	✂	✂	✂
Small / medium	C		✂	✂	✂	✂	✂	✂	✂
Medium	D		✂	✂	✂	✂	✂	✂	✂
Large & very large	E		✂	✂	✂	✂	✂	✂	✂
UK									
Very small	F		✂	✂	✂	✂	✂	✂	✂
Small	G		✂	✂	✂	✂	✂	✂	✂
Small / medium	H		✂	✂	✂	✂	✂	✂	✂
Medium	I		✂	✂	✂	✂	✂	✂	✂
Large & very large	J		✂	✂	✂	✂	✂	✂	✂
Price differential (%)									
Very small	K	(A – F) / A	12.0%	10.6%	-1.4%	3.7%	-5.0%	-7.0%	0.9%
Small	L	(B – G) / B	17.2%	14.9%	-1.6%	0.8%	-2.1%	0.8%	-3.6%
Small / medium	M	(C – H) / C	21.2%	15.1%	6.9%	0.5%	-2.8%	2.1%	1.5%
Medium	N	(D – I) / D	17.3%	10.7%	0.0%	-9.3%	-15.8%	-11.7%	-7.1%
Large & very large	O	(E – J) / E	14.4%	6.2%	-11.0%	-27.8%	-33.1%	-25.6%	-15.0%

Source: UR Quarterly Transparency Reports, 2012-2018

Table 7-2: Annual NI Water electricity consumption, MWh

Consumption size band	Column	Calculation	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19
Very small	A		✂	✂	✂	✂	✂	✂	✂
Small	B		✂	✂	✂	✂	✂	✂	✂
Small / medium	C		✂	✂	✂	✂	✂	✂	✂
Medium	D		✂	✂	✂	✂	✂	✂	✂
Large & very large	E		✂	✂	✂	✂	✂	✂	✂
Total consumption	F		✂	✂	✂	✂	✂	✂	✂
Very small	G	A / F	4.7%	0.4%	0.4%	0.5%	0.7%	0.6%	0.6%
Small	H	B / F	19.3%	13.8%	11.8%	12.3%	11.3%	11.4%	9.9%
Small / medium	I	C / F	19.0%	35.4%	35.6%	36.3%	35.2%	36.1%	37.0%
Medium	J	D / F	32.1%	25.7%	25.6%	25.4%	25.6%	23.9%	25.7%
Large & very large	J	E / F	24.9%	24.8%	26.5%	25.4%	27.3%	27.9%	26.9%

[26] ✂ This symbol denotes redacted material which is likely to be classified 'Commercial in Confidence' such that publication may adversely affect NI Water's subsequent ability to secure best VFM in the marketplace.

Source: NI Water

Table 7-3 shows that in 2012/13 and 2013/14 NI Water had a positive price differential (i.e. electricity was on average more expensive for NI Water), but in recent years this has turned negative. In 2018/19 a UK water company with the same consumption profile as NI Water would have faced an electricity price 5.6% higher than NI Water.

To calculate the SCF adjustment in monetary terms, we apply the estimated energy price differential between Northern Ireland and the UK as a whole (based on the energy consumption profile of NI Water) to the annual electricity costs incurred by NI Water. Hence, this adjustment only applies to opex as electricity expenditure is not relevant to capital maintenance. As shown in Table 7-3, this leads to a:

- Wholesale water opex SCF adjustment ranging from -£1.8 million in 2016/17 to £2.8 million in 2012/13.
- Wholesale sewerage opex SCF adjustment ranging from -£2.0 million in 2016/17 to £3.1 million in 2012/13.

We note that the calculated electricity price SCF is in line with the electricity price SCF calculated by NI Water.

Table 7-3: Electricity price SCF opex adjustment, £ million (2017/18 prices)

Consumption size band	Column	Calculation	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19
Weighted price differential (%)									
Very small	A		0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Small	B		3.3%	2.1%	-0.2%	0.1%	-0.2%	0.1%	-0.4%
Small / medium	C		4.0%	5.3%	2.5%	0.2%	-1.0%	0.8%	0.6%
Medium	D		5.6%	2.7%	0.0%	-2.4%	-4.0%	-2.8%	-1.8%
Large & very large	E		3.6%	1.5%	-2.9%	-7.1%	-9.0%	-7.1%	-4.0%
Weighted differential	F	Sum (A : E)	17.0%	11.7%	-0.7%	-9.1%	-14.3%	-9.1%	-5.6%
NI Water power costs									
Wholesale water	G		16.5	15.4	15.1	13.2	12.6	13.2	15.6
Wholesale sewerage	H		18.0	17.9	16.3	17.1	14.1	13.6	14.6
SCF adjustment									
Wholesale water	I	F x G	2.8	1.8	-0.1	-1.2	-1.8	-1.2	-0.9
Wholesale sewerage	J	F x H	3.1	2.1	-0.1	-1.6	-2.0	-1.2	-0.8

Source: CEPA analysis

We assess the impact of applying the calculated electricity price SCF on NI Water's opex efficiency gap in Section 7.4 below.

7.2. Regional wage SCF

Labour costs in Northern Ireland are lower than in the rest of the UK. Hence, the regional wage SCF aims to reflect the advantage NI Water obtains from operating in a lower wage cost region of the UK. We adopt a similar approach to that used by the UR in PC15 to estimate the magnitude of the SCF, adjusted to ensure the methodology remains consistent with the approach taken in our Regional Price Adjustment (RPA) report.[27]

[27] CEPA (March 2020), *"Regional Price Adjustments, PC21"*, to be published.

The approach involves calculating the regional wage differential between a water company operating in Northern Ireland compared with a typical water company operating in the UK using data from the Annual Survey of Hours and Earnings (ASHE). The regional wage SCF is then calculated based on the regional wage differential between Northern Ireland and the UK and the proportion of opex attributable to labour costs.

Hence, the regional wage adjustment SCF is calculated in two steps:

- Calculation of regional wage adjustment factors between Northern Ireland and the UK; and
- Calculation of the regional wage SCF adjustment.

Each step is discussed in further detail below:

Regional wage adjustment factors

Table 7-4 presents the regional wage adjustment factors between 2012/13 and 2018/19 that are presented in our RPA report. In 2018/19, the regional wage adjustment for NI Water relative to a water and sewerage company in the rest of the UK is estimated to be -11.7%. This implies that the labour costs of NI Water in 2018/19 were 11.7% lower than a comparable water and sewerage company operating in the rest of the UK.

Table 7-4: Regional wage adjustment – Northern Ireland relative to the UK

	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19
Regional wage adjustment	-12.0%	-14.5%	-11.5%	-11.7%	-11.8%	-10.6%	-11.7%

Source: CEPA analysis

As detailed in our RPA report, regional wage adjustment factors have been calculated using data from the Annual Survey of Hours and Earnings (ASHE) based on the assumptions below. We highlight differences and similarities between the approach we have taken and the approach taken by NI Water:

- **Hourly versus weekly wages**. We use hourly wages excluding overtime to calculate the regional wage adjustment. We use hourly wages since weekly wages may capture other elements of company policy, such as differences in working hours both within and between different regions. This assumption is in line with the approach taken by NI Water.
- **Median versus mean wages**. We use median rather than mean wages to calculate the regional wage adjustment as they are less likely to be affected by extreme values. This assumption is in line with the approach taken by NI Water.
- **All employees versus full-time employee wages**. We use all employee estimates to calculate the regional wage adjustment. Companies employ a mix of full-time and part-time staff because any bias that may be introduced from part-time staff working fewer hours may be mitigated by using hourly wages. This assumption differs to the approach taken by NI Water; it has based its adjustment on full-time employees only.
- **Standard Occupational Classification (SOC) code level and occupational mix**. We use 2-digit SOC codes rather than the more detailed 3-digit and 4-digit categories to calculate the regional wage adjustment as these are more reliable than more granular occupational data given the larger sample size at digit level. We calculate a composite occupational wage split that reflects the mix of labour resources used in NI Water's activities (SOC codes in brackets):
    - Skilled construction (53) – 56%
    - Plant and machine operatives (81) – 16%
    - Science, research, engineering and technical professionals (21) – 10%
    - Elementary trades and related occupations (91) – 8%

- Science, engineering and technical associate professional (31) – 4%
- Corporate managers and directors (11) – 4%
- Administrative (41) – 2%

NI Water has based its regional wage adjustment on all employees, meaning that a decision on the SOC code level or occupational mix is not required. But it does mean that the adjustment calculated by NI Water is reflective of the Northern Ireland wage differential for the whole economy rather than being specific to a typical water company.

- **Calculation of NI Water's wage differential** is based on the percentage wage differential between Northern Ireland and the UK. This assumption differs to the approach taken by NI Water, which excludes London and Scotland from its differential calculation. We do not consider it necessary to exclude London and Scotland from the calculation given that our adjustment is based on labour costs incurred by a typical water company rather than based on labour costs incurred in the whole economy. This was the approach taken by the UR at PC15 within its RPA analysis. However, we have excluded London and Scotland as a sensitivity test, which leads to reduction in the wage differential of between 1.5 and 2.1 percentage points over the sampling period. We also demonstrate the impact of excluding London and Scotland from the wage differential calculation to NI Water's efficiency gap in Section 7.4. It is important to note that when the regional wage differential is based on the whole economy (i.e. NI Water approach) then the impact of excluding London and Scotland from the wage differential is much greater – a reduction in the wage differential of between 4.1 and 4.8 percentage points over the sampling period.

Regional wage SCF adjustment

The regional wage SCF adjustment is applied to wholesale water and sewerage modelled opex. The impact of the regional wage differential on capital maintenance costs is considered within the RPA adjustment in Section 7.3.

The regional wage SCF adjustment is calculated in two steps:

- **Estimate the value of opex attributable to labour costs**. We assume that 47% of water and sewerage opex costs are labour-related, which has been provided to us by the UR to ensure consistency with the notional input mix used within their frontier shift analysis. We multiply this percentage by wholesale water and sewerage modelled opex (as discussed in Section 3.1) to calculate the value of opex attributable to labour costs.
- **Labour opex is multiplied by the regional wage adjustment factor to calculate the SCF adjustment**:
  - The wholesale water regional wage SCF adjustment ranges from £3.4 million to £4.5 million.
  - The wholesale sewerage regional wage SCF adjustment ranges from £2.7 million to £4.1 million.

We set out the regional wage SCF adjustment in Table 7-8 below, and assess the impact of applying the regional wage SCF on NI Water's opex efficiency gap in Section 7.4 below.

Table 7-5: Regional wage opex adjustment SCF, £ million (2017/18 prices)

Description	Column	Calculation	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19
Regional wage adjustment	A		-12.0%	-14.5%	-11.5%	-11.7%	-11.8%	-10.6%	-11.7%
Labour opex calculation									
Modelled opex (water)	B		69.2	65.9	65.8	63.5	66.1	68.4	70.0
Modelled opex (sewerage)	C		60.1	60.3	58.5	57.7	56.6	54.0	54.3
Labour as share of opex	D		47%	47%	47%	47%	47%	47%	47%
Labour opex (water)	E	B x D	32.5	31.0	30.9	29.9	31.1	32.2	32.9
Labour opex (sewerage)	F	C x D	28.1	28.1	27.3	26.9	26.4	25.2	25.4
SCF adjustment									
Wholesale water	G	E x A	-3.9	-4.5	-3.5	-3.5	-3.7	-3.4	-3.8
Wholesale sewerage	H	F x A	-3.4	-4.1	-3.1	-3.2	-3.1	-2.7	-3.0

Source: CEPA analysis

The regional wage adjustment SCF we present above is substantially greater than the regional wage adjustment SCF calculated by NI Water. This is for two main reasons:

- NI Water's regional wage adjustment factor is calculated based on the whole economy wage data rather than wage data specific to occupations present in the water sector and excludes London and Scotland wage data. This leads to a regional wage adjustment of between -7.8% and -4.2% compared to a regional wage adjustment of between -14.5% and -10.6% based on our approach.
- NI Water applies the regional wage adjustment to a lower level of labour opex. We assume a labour share of opex of 47%, which has been provided by the UR to ensure consistency with the notional input mix used in its frontier shift analysis. But NI Water assumes a labour share of opex of 34%.

Overall, we consider the assumptions we have applied to calculate the regional wage SCF adjustment are well justified. However, for completeness, in Section 7.4 we assess how NI Water's efficiency gap changes after applying two sensitivity tests:

- Excluding London and Scotland from the regional wage adjustment calculation.
- Apply the SCFs calculated by NI Water.

The UR could use the results of these sensitivity tests in collaboration with the other results presented in this report to decide on an appropriate opex efficiency challenge.

7.3. Capital maintenance RPA SCF

A Regional Price Adjustment (RPA) can be applied to control for regional differences in costs faced by regulated companies.[28] Costs may vary as a result of:

- regional wage differences;
- local differences in material prices; or
- differences in transportation costs.

[28] CEPA (March 2020), *"Regional Price Adjustments, PC21"*, to be published.

As detailed in our RPA report[29], we have developed a model to estimate regional price differences in capital expenditure (capex) between a typical water company in Northern Ireland and the rest of the UK. The baseline aggregated RPA adjustment suggests that the overall price differential between NI Water and other UK companies is 8% for wholesale water and 9% for wholesale sewerage. This implies that the cost of a typical wholesale water (sewerage) capex project is 8% (9%) lower in Northern Ireland than a comparable water company operating in the rest of the UK.

We calculate the capital maintenance RPA SCF adjustment in Table 7-6 below based on the baseline aggregated RPA adjustment, and we assess the impact of applying the RPA SCF on NI Water's capital maintenance efficiency gap in Section 7.4 below.

Table 7-6: Capital maintenance RPA SCF, £ million (2017/18 prices)

Description	Column	Calculation	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19
Wholesale Water RPA	A		-8%	-8%	-8%	-8%	-8%	-8%	-8%
Wholesale Sewerage RPA	B		-9%	-9%	-9%	-9%	-9%	-9%	-9%
Wholesale water capital maintenance	C		43.3	42.8	43.9	36.4	44.7	38.7	38.0
Wholesale sewerage capital maintenance	D		55.6	60.4	40.6	54.5	58.7	53.0	56.0
Wholesale water	E	C x A	-3.7	-3.6	-3.7	-3.1	-3.8	-3.3	-3.2
Wholesale sewerage	F	D x B	-5.2	-5.6	-3.8	-5.1	-5.5	-4.9	-5.2

Source: CEPA analysis

[29] CEPA (March 2020), *"Regional Price Adjustments, PC21"*, to be published.

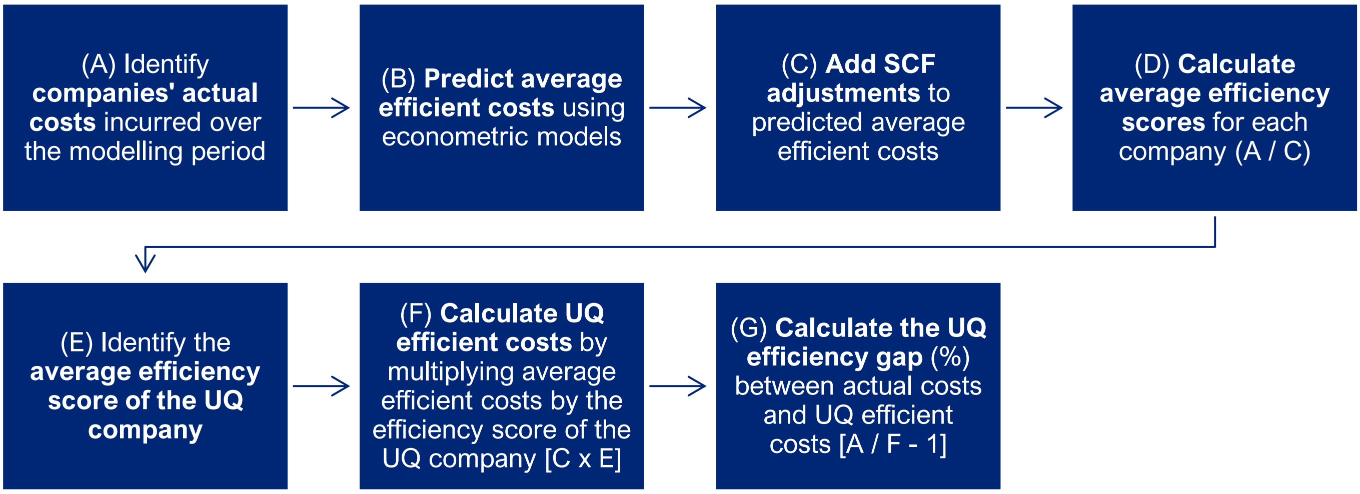
7.4. Efficiency results after special cost factors

The tables below summarise NI Water's efficiency results after application of the three special cost factors discussed above – electricity price SCF, regional wage SCF, and RPA SCF. [30]

As discussed in Section 6, we define the efficiency gap as the distance (in terms of expenditure) between upper quartile (UQ) efficient company and NI Water in percentage terms.

The upper quartile efficiency gap after application of SCFs is calculated as follows:

Figure 7.1: Efficiency gap calculation after application of SCFs



This means that an efficiency gap of 5% would indicate that NI Water's costs are 5% lower than the costs that would have been incurred by the UQ efficient company. Conversely, a gap of -5% would indicate the company's costs are 5% higher than the UQ efficient company.

An illustrative example is provided in Table 6-1 to show how NI Water's UQ efficiency gap has been calculated for each model after the application of special cost factors. In this illustrative example, the efficiency gap is -9.8%, which means that the company would need to reduce their costs by 9.8% to reach the UQ company. But the efficiency gap has reduced from -15% (see Table 6-1) to -9.8% after taking into account the SCFs.

Table 7-7: Illustrative efficiency gap calculation after special cost factors

Column	Item	Calculation	Example One
A	Actual Cost (excluding atypicals)		£100m
B	Predicted Average		£89.5m
C	Special Cost Factors (SCFs)		£5.5m
D	Predicted Average + SCFs	B + C	£95.0m
E	Efficiency Score of UQ Company		0.95
F	UQ Predicted Costs (after SCFs)	D * E	£90.2m
G	**Efficiency Gap to UQ (£m)**	**F – A**	**- £9.8m**
F	**Efficiency Gap to UQ (%)**	**G / A**	**- 9.8%**

Source: CEPA analysis

[30] NI Water's upper quartile efficient costs that are used to calculate the efficiency gaps are provided in Appendix D.

Wholesale water opex efficiency results (after SCFs)

Table 7-8 presents NI Water's wholesale water efficiency gap to the upper quartile benchmark for the wholesale water opex models presented in Section 4 after taking into account the SCFs.

The SCF adjustment is negative (i.e. the environment NI Water operates in allows for lower efficient costs compared to the typical company in E&W). This leads to a widening of NI Water's efficiency gap compared to the unadjusted calculations presented in section 6.

NI Water's wholesale water opex efficiency gap to the UQ after taking SCFs into account ranges from **-8.3% to 0.2%** based on a weighted average calculation and appears less efficient than an UQ company in two out of three models. This compares to a wholesale water opex efficiency gap range of between -2.2% and 5.5% before application of SCFs.

Table 7-8: NI Water wholesale water efficiency gap to upper quartile (after SCFs), opex

	Model 1	Model 2	Model 3
2013/14	-1.0%	-1.0%	-7.0%
2014/15	-3.1%	-0.5%	-5.0%
2015/16	-3.0%	-6.9%	-9.2%
2016/17	-4.9%	-8.5%	-13.5%
2017/18	-8.4%	-9.8%	-14.8%
2018/19	-6.8%	-5.1%	-9.7%
Weighted Average	0.2%[31]	-3.0%	-8.3%

Source: CEPA analysis

As mentioned above, we assess how NI Water's efficiency gap changes after applying two sensitivity tests, which the UR may want to consider when deciding on an appropriate wholesale water opex efficiency challenge:

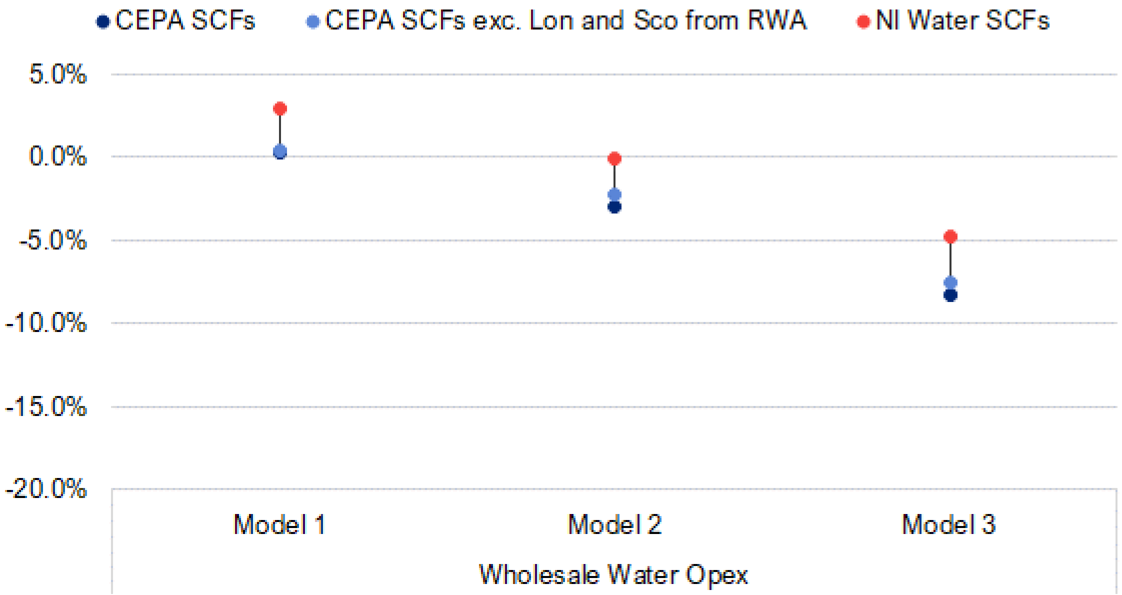
- **Excluding London and Scotland from the regional wage adjustment calculation** - NI Water's wholesale water opex efficiency gap to the UQ after excluding London and Scotland from the regional wage adjustment factor calculation ranges from -7.5% to 0.4%, which is not significantly different from baseline efficiency gap range in Table 7-8 above.
- **Apply the SCFs calculated by NI Water**[32] - NI Water's wholesale water opex efficiency gap to the UQ after taking into account the SCFs calculated by NI Water ranges from -4.8% to 2.9%.

Figure 7.2 below presents the range of NI Water's efficiency gap results for each wholesale water opex model based on our baseline (CEPA SCFs) and two sensitivity tests ('CEPA SCFs exc. Lon and Sco from RWA' and 'NI Water SCFs').

[31] The weighted average efficiency gap is positive because the catch-up efficiency challenge that is applied is much lower than on a year-by-year basis. This may be because of different spending patterns between water companies (e.g. high and low spending years may differ between water companies).

[32] NI Water (2020). PC21 Annex 5.2.2. Special Factor and Atypicals. The SCF adjustments calculated by NI Water are only provided up to 2017/18 and at a total wholesale level. We therefore apply the 2017/18 adjustment to 2018/19 as well. We allocate the SCF adjustments across wholesale water and sewerage based on the same allocation used within CEPA's SCF adjustments.

Figure 7.2: NI Water wholesale water opex upper quartile efficiency gap comparison



Source: CEPA analysis

Wholesale water capital maintenance efficiency results (after SCFs)

Table 7-9 presents NI Water's wholesale water efficiency gap to the upper quartile benchmark for the wholesale water capital maintenance models presented in Section 4 after taking into account the SCFs.

For wholesale water capital maintenance, the RPA SCF adjustment is negative, which leads to a widening of NI Water's wholesale water capital maintenance efficiency gap.

NI Water's wholesale water capital maintenance efficiency gap to the UQ after applying the RPA SCF ranges from **-7.6% to -2.3%** based on a weighted average calculation and it appears less efficient than the UQ company in all four models. This compares to a wholesale water capital maintenance efficiency gap range of between -0.9% and 2.8% before application of the RPA SCF.

Table 7-9: NI Water wholesale water efficiency gap to upper quartile (after SCFs), capital maintenance

	Model 1	Model 2	Model 3	Model 4
2013/14	-10.5%	-5.4%	-11.2%	-8.1%
2014/15	-22.8%	-19.4%	-23.3%	-24.6%
2015/16	-15.7%	-19.5%	-16.0%	-24.0%
2016/17	-16.2%	-18.5%	-16.5%	-22.5%
2017/18	9.4%	3.8%	8.9%	0.0%
2018/19	7.2%	6.3%	6.9%	2.8%
Weighted Average	-2.6%	-2.3%	-3.1%	-7.6%

Source: CEPA analysis

Wholesale sewerage opex efficiency results (after SCFs)

Table 7-10 presents NI Water's wholesale sewerage efficiency gap to the upper quartile benchmark for the wholesale sewerage opex models presented in Section 5 after taking into account the SCFs.

The SCF adjustments applied to NI Water's wholesale sewerage opex are negative overall. Hence, application of the SCFs widens NI Water's efficiency gap to an UQ company.

NI Water's wholesale sewerage opex efficiency gap to the UQ after applying the SCFs ranges from **-12.8% to -12.5%**, meaning that NI Water appears less efficient than the UQ company in both wholesale sewerage opex models. This compares to a wholesale sewerage opex efficiency gap range of between -7.3% and 7.0% before application of SCFs.

Table 7-10: NI Water wholesale sewerage efficiency gap to upper quartile (after SCFs), opex

	Model 1	Model 2
2012/13	-15.7%	-13.7%
2013/14	-18.8%	-19.8%
2014/15	-16.4%	-15.6%
2015/16	-11.8%	-14.2%
2016/17	-9.7%	-12.0%
2017/18	-10.1%	-10.5%
2018/19	-1.5%	-1.2%
Weighted Average	-12.8%	-12.5%

Source: CEPA analysis.

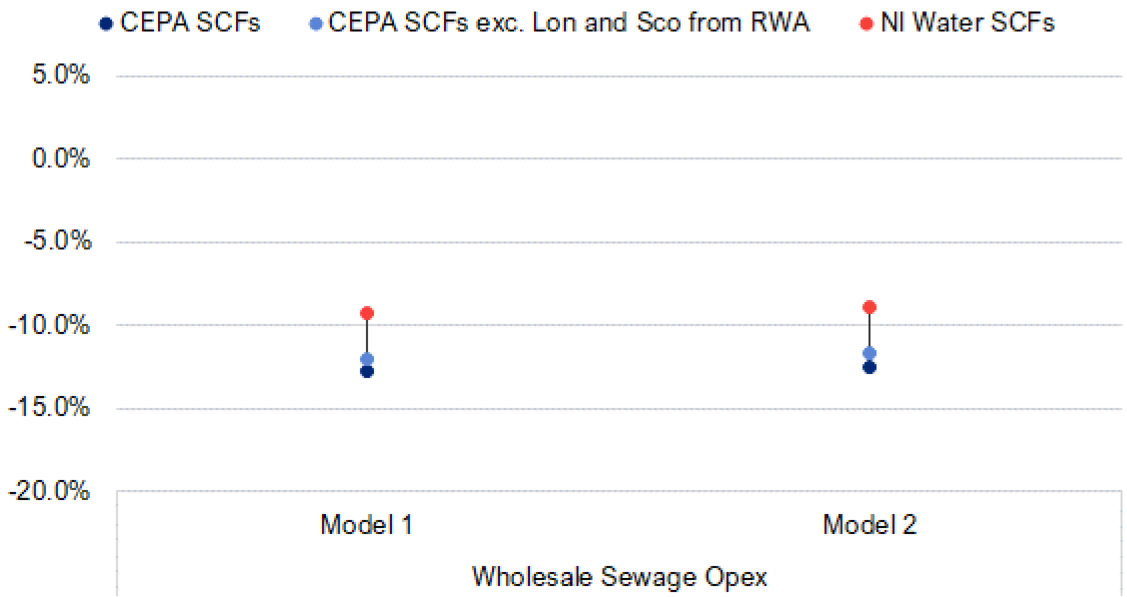
As mentioned above, we assess how NI Water's efficiency gap changes after applying two sensitivity tests, which the UR may want to consider when deciding on an appropriate wholesale water sewerage efficiency challenge:

- **Excluding London and Scotland from the regional wage adjustment calculation** - NI Water's wholesale sewerage opex efficiency gap to the UQ after excluding London and Scotland from the regional wage adjustment factor calculation ranges from -12.0% to -11.7%, which is close to the baseline efficiency gap range in Table 7-10 above.
- **Apply the SCFs calculated by NI Water**[33] - NI Water's wholesale sewerage opex efficiency gap to the UQ after taking into account the SCFs calculated by NI Water ranges from -9.2% to -8.9%.

Figure 7.3 below presents the range of NI Water's efficiency gap results for each wholesale sewerage opex model based on our baseline (CEPA SCFs) and two sensitivity tests ('CEPA SCFs exc. Lon and Sco from RWA' and 'NI Water SCFs').

[33] NI Water (2020). PC21 Annex 5.2.2. Special Factor and Atypicals. The SCF adjustments calculated by NI Water are only provided up to 2017/18 and at a total wholesale level. We therefore apply the 2017/18 adjustment to 2018/19 as well. We allocate the SCF adjustments across wholesale water and sewerage based on the same allocation used within CEPA's SCF adjustments.

Figure 7.3: NI Water wholesale sewerage opex upper quartile efficiency gap comparison



Source: CEPA analysis

Wholesale sewerage capital maintenance efficiency results (after SCFs)

Table 7-11 presents NI Water's wholesale sewerage efficiency gap to the upper quartile benchmark for the wholesale sewerage capital maintenance models presented in Section 5 after taking into account the SCFs.

The RPA SCF adjustment applied to NI Water's wholesale sewerage capital maintenance is also negative. Hence, application of the SCF widens NI Water's efficiency gap to an UQ company.

NI Water's wholesale sewerage capital maintenance efficiency gap to the UQ after applying the RPA SCF ranges from **-13.8% to -11.6%**, meaning that NI Water appears less efficient than the UQ company in both wholesale sewerage capital maintenance models. This compares to a wholesale sewerage capital maintenance efficiency gap range of between -5.2% and -2.6% before application of the RPA SCF.

Table 7-11: NI Water wholesale sewerage efficiency gap to upper quartile (after SCFs), capital maintenance

	Model 1	Model 2
2012/13	-18.8%	-16.2%
2013/14	-30.8%	-27.9%
2014/15	-6.8%	-3.3%
2015/16	-21.1%	-19.4%
2016/17	-20.8%	-18.6%
2017/18	-10.8%	-12.2%
2018/19	-21.8%	-21.5%
Weighted Average	-13.8%	-11.6%

Source: CEPA analysis.

8. CONCLUSION

Through this project we have developed a range of wholesale water and sewerage econometric benchmarking models, in order to assess the efficiency of NI Water's opex and capital maintenance expenditure relative to companies in England and Wales.

The econometric benchmarking models presented in this report perform well against our model selection criteria with no major concerns identified. Our opex models perform somewhat better than the capital maintenance models, reflecting the fact that the latter is inherently lumpy in nature.

Efficiency results are mixed across the wholesale water and sewerage models, with NI Water appearing relatively more efficient in wholesale water than sewerage.

Based on the weighted average efficiency results before SCF adjustments:[34]

- **Wholesale Water**: NI Water's wholesale water opex efficiency gap to the UQ ranges from **-2.2% to 5.5%**. NI Water's wholesale water capital maintenance UQ efficiency gap ranges from **-0.9% to 2.8%**.
- **Wholesale Sewerage**: NI Water's wholesale sewerage opex efficiency gap to the UQ ranges from **-7.3% to -7.0%**. NI Water's wholesale sewerage capital maintenance efficiency gap to the UQ ranges from **-5.2% to -2.6%**.

Based on the weighted average efficiency results after SCF adjustments: [35]

- **Wholesale Water**: NI Water's wholesale water opex efficiency gap to the UQ ranges from **-8.3% to 0.2%**. NI Water's wholesale water capital maintenance UQ efficiency gap ranges from **-7.6% to -2.3%**.
- **Wholesale Sewerage**: NI Water's wholesale sewerage opex efficiency gap to the UQ ranges from **-12.8% to -12.5%**. NI Water's wholesale sewerage capital maintenance efficiency gap to the UQ ranges from **-13.8% to -11.6%**.

When deciding how to use the results in this report to assist in setting opex and capital maintenance allowances the UR should note that the accounting dummy variable included in the models does not perfectly capture companies' reactions to the accounting change discussed in Section 3.4; it only captures an average effect.

Overall, however, we are satisfied that the dummy variable captures companies' reactions to the accounting change well enough to enable the model results to be utilised by the UR when setting NI Water's allowances but recommend they are not applied mechanistically. In addition, while we present the results in this report to one decimal place we do not intend the results to be applied to that level of precision. Instead, we suggest that the UR triangulate between the results presented in this report with other analysis, such as the botex model results presented in Appendix B and Appendix C, when setting NI Water's opex and capital maintenance PC21 allowances.

[34] For illustration purposes only:

- NI Water's wholesale (water plus sewerage) opex weighted average efficiency gap to the UQ would be -2.6% if equal weights were applied to each opex model (before SCF adjustments).
- NI Water's wholesale (water plus sewerage) capital maintenance weighted average efficiency gap to the UQ would be -1.7% if equal weights were applied to each capital maintenance model (before SCF adjustments).

[35] For illustration purposes only:

- NI Water's wholesale (water plus sewerage) opex weighted average efficiency gap to the UQ would be -7.8% if equal weights were applied to each opex model (after SCF adjustments).
- NI Water's wholesale (water plus sewerage) capital maintenance weighted average efficiency gap to the UQ would be -8.9% if equal weights were applied to each capital maintenance model (after SCF adjustments).

Appendix A DETAILED PC21 MODEL SELECTION CRITERIA

Description	Level of importance	Comment
Robustness of models		
Statistical significance of individual parameters (t-test)	Medium	• If one or more of the coefficients in the model fails this test, we cannot rule out that the relationship being identified between the driver of cost and costs under consideration is not spurious (i.e. the coefficient could be zero). • Parameters could fail this test because there is no relationship between the driver of cost and the costs but also due to limitations in the data. The small size and poor quality of some of the components in the sample could make it difficult, if not impossible, to identify clearly the relationship between the variables and, therefore, we are unable to reject the null hypothesis that the coefficient is significantly different from zero. • While statistical significance of the estimated parameters is important, it is also important we can capture as many of the drivers of cost as possible. This issue highlights the trade-off between parsimony and avoiding omitted variable bias, which is common in econometric modelling, but perhaps comes under greater scrutiny in the regulatory context. • As a result, it would be possible to include variables that are statistically insignificant if they reflect relationships that are well set in engineering and/or economic literature. In those cases, we can be certain that the relationship exists even when there is not enough data or of enough quality to identify it robustly enough. • Furthermore, this would need to be compared with the F-test discussed below. Even when individual variables are insignificant, it is possible that they are jointly considering relevant effects. • One topic to be considered is whether this result is caused by the existence of multi-collinearity (i.e. high correlation between explanatory variables). If that is the case, one could decide to keep both variables but recognising that they are both measuring similar effects.
Jointly statistically significant (F-test)	Very high	• If the equation fails this test, it could suggest that the joint effect of all parameters is not statistically different from zero. • Therefore, if a model fails this test, it is not possible to determine whether there is an actual relationship between explanatory variables and the dependent variable. • There are different reasons that could justify this result (e.g. poor data quality or wrong specification of the model) but they all seem to indicate that there is a lack of statistical robustness that will make the result easy to challenge.
Underlining assumptions tests		
Linearity	Low	• This test aims to determine whether one could expect a linear relationship between the driver of cost and the costs under consideration. The linear assumption might be a reasonable assumption in some cases whereas in others it may not.

Description	Level of importance	Comment
		• Failing this test seems to indicate that the data could be better fitted using a different functional form (e.g. quadratic). However, this is not to say that a linear assumption is automatically wrong but that other options could be better. The introduction of alternative functional forms, however, could increase the complexity of the models which would be linked to additional data requirements. • Given the need to develop transparent models and the limitations in the data available, the UR could still use models that fail this test. However, it will be important to consider whether additional adjustments need to be introduced in the results to account for the lack of linearity (e.g. introduction of quadratic terms or other explanatory variables).
Homoscedasticity	Low	• Ensuring that OLS is BLUE (Best Linear Unbiased Estimator) requires that the residuals of the equation are normally distributed with an average of zero and a variance equal for all of them. If this assumption is violated, the results are still unbiased although they could lose some other properties. Heteroscedasticity can be detected by inspecting the residuals in addition to formal testing procedures. • If a model fails the homoscedasticity test, it means that the variance of the errors is not equal for all observations. Different measures can be introduced to address this issue (e.g. use cluster robust standard errors). However, if the effect persists, the model could still be used as the results are robust.
Normality	Low	• The impact of non-normality only has implications in small samples. As the sample size increases, the sampling distributions are approximately normally distributed. This means we can apply standard inference based on asymptotic approximations, and as a result normality is not a great concern.[36]
Multicollinearity	Low	• When two or more explanatory factors are closely linearly related and used in the same model, it can cause estimates for the impact of those variables to be very imprecise. When variables are perfectly collinear, it is impossible to linearly estimate the model in question. • CEPA considers a variable inflation factor (VIF) of greater than 10 to indicate a high degree of multicollinearity. While in this case the estimates of some parameters may be less precise, they remain unbiased. Where a variable and its squared term are both included in a model this will inherently generate a degree of multicollinearity, and so failing this test is even less of a concern.
Tests of pooled OLS versus random effects models - Breusch-Pagan LM test for random effects	Medium	• Both OLS and Random Effects assume that the individual firm effect is uncorrelated with the regressors. Thus, the main difference between OLS and a Random Effect estimation is the assumptions that are made about the structure of the error term. • If the model fails this test, then OLS is unbiased but not the most efficient estimator assuming the aforementioned assumption holds (i.e. larger standard errors compared to other estimators). In other words, in these circumstances

[36] Even in small samples, the lack of normality only has implications for the inference of t- and F-test statistics and not the unbiasedness and consistency of parameter estimates.

Description	Level of importance	Comment
		Random Effects is more likely to produce a more accurate estimate. However, we can still use OLS to produce unbiased parameter estimates.[37]
Hausman test for fixed effects	Medium	• If the unobserved fixed effects are uncorrelated with the regressors then both OLS and Random Effects estimation produce unbiased results. However, if the unobserved fixed effects are correlated with the regressors only Fixed Effects estimation produce unbiased results. • The Hausman test can be used to test whether the unobserved fixed effects are correlated with the regressors. If the difference in the estimated coefficients between Fixed and Random Effects estimation is statistically significant, this is evidence that the regressors are correlated with the unobserved fixed effects. In this case we will need to consider whether fixed effects estimation is more appropriate and/or whether there are any omitted but available time invariant explanatory variables we could test in the random effects model. • Nevertheless, while Fixed Effects estimation has useful statistical properties it is rarely used in efficiency analysis because of two reasons. Firstly, it is difficult to distinguish between inefficiency and company heterogeneity. Secondly, due to the relatively small datasets, fixed effects estimation tends to produce very wide standard errors. As a result, OLS or random effects estimation, while biased, is often preferred to fixed effects estimation within an efficiency analysis exercise.
Sensitivity of results		
Chow test - Sensitivity to removal / addition of a year / company	Medium	• This test would consider whether there is any data that does not fit with the rest of the data set (i.e. a company or a year presenting different characteristics than the rest of the data set). There are several reasons that could justify this distinction such as structural break in the data (different across years) or the presence of an outlier in the data. • Therefore, before taking a specific decision it will be important to evaluate the rationale that could justify these differences. For example, if a company has a very different cost structure than the rivals for, for example, historic reasons outside of the control of the company, it could require that that company is excluded from the analysis.
Sensitivity to inclusion / exclusion of explanatory variables	Medium	• A key part of our model development approach is deciding the most appropriate explanatory variables to include or exclude. When considering the merits of a given variable, we consider the potential effect on the efficiency rankings for a company or group of companies of including/excluding an explanatory variable. This allows us to identify whether the model produces consistent efficiency rankings/scores. • There are reasons that could justify these changes in efficiency rankings/scores. Therefore, the impact of inclusion / exclusion will need to be carefully evaluated.

[37] Assuming the individual fixed effects are not correlated with the regressors.

Description	Level of importance	Comment
Predictive Power		
Overall goodness of fit (Adjusted R-squared)	Very high	• If a model fails to explain a significant variation in the costs of the industry, it would be inappropriate to use it for the estimation of the costs going forward (for models in log-terms the R-squared relates to the log of costs). Therefore, we would expect that only models with a high explanatory power should be used as the base of the cost assessment methodology (e.g. above 80%).
Within sample forecast power of the models	Medium	• Similarly, if a particular model does not have significant forecasting power this would also be a concern. We have tested this by evaluating whether a selected model estimated using only 5 years of historical data (2012/13 – 2016/17) for wholesale water models, or only 4 years (2013/14 – 2016/17) for wholesale sewerage models, has sufficient power to accurately forecast 2017/18 expenditure.
Transparency		
Transparency of results / ease of interpretation	High	• To facilitate their use during PC21, the models should be understandable and intuitive. However, there would need to be a balance between simplicity and complexity if the latter brings a significant improvement in the performance of the model.
Data availability	High	• To ensure that NI Water can challenge the models, it is important that they have access to the data used in developing the models. • To reduce this risk CEPA propose that the final consolidated data set could be shared with NI Water.
Software transparency	Very High	• We use Stata to conduct our econometric analysis, which is an internationally recognised standard software for applied econometrics analysis. • In addition, our final model selection is replicated in Excel to ensure that the UR can re-run the analysis on an annual basis.
Economic and technical rationale		
Are any important explanatory variables omitted?	Medium	• By omitting important explanatory variables, the model would fail to incorporate some of the drivers into the analysis. In some cases, it will not be possible to incorporate these variables as the model already includes a significant number of drivers of cost given the data available, or no robust variable has been found to cover this specific cost driver. • Engineering and econometric experts will be used to minimise this risk. However, if it were to arise this would be flagged and potential off-model adjustments would need to be incorporated into the results to account for these effects.
Consistency with a priori expectations of magnitude and signs	High	• Ahead of running a regression CEPA will have an expected sign for the coefficients. In some cases, the economic and technical literature will also be able to offer an expected size for the parameter.

Description	Level of importance	Comment
of estimated coefficients		• Estimated coefficients that significantly differ from our a priori expectations of magnitude and signs could be a cause for concern. However, there are good reasons that could justify this effect. For example, the variable could be picking up some additional effect for which the explanatory variable is only an imperfect proxy. if any variable would fail this test, it would need to be considered carefully and a good explanation developed before putting forward the model.
Consistency with policy in other parts of the price control	Very high	• Models that produce coefficients that are inconsistent with policy in other parts of the price control would be automatically rejected, e.g. inclusion of costs that are dealt with in other parts of the price control.
Stability of relative efficiency		
Stability of efficiency gap	High	• CEPA will conclude that a model fails to provide a consistent efficiency range if the efficiency gap for NI Water is outside of a range of +/- 5 percentage points around the average efficiency gap for NI Water when considering all the selected models.

Source: CEPA

CEPA economics matters

Appendix B SENSITIVITY TESTING

In this appendix we present the full results of our sensitivity and robustness testing. For completeness, we also present analysis for additional model specifications that were considered but were not included in our final model selection. Note that the analysis in this appendix does not include any consideration of special cost factors.

In addition to the opex and capital maintenance models, we also present wholesale water and sewerage 'botex' models. These models use the combination of opex and capital maintenance and the dependent variable. This means we do not need to include a dummy variable for the accounting change.

B.1. WHOLESALE WATER SENSITIVITY RESULTS

B.1.1. Opex sensitivity results

Table B.1: Wholesale water sensitivity results, opex

	Model 1	Model 2	Model 3
Length of mains	1.006***	0.970***	1.000***
Number of booster pumping stations per length of mains	0.306**	0.290*	0.216
% of water treated in complexity bands 4 to 6	0.004***		
Weighted average treatment complexity		0.396**	
% of water input from pumped reservoirs			0.004***
Connections per length of mains	-3.238*	-4.000**	-2.742**
Connections per length of mains squared	0.490**	0.586***	0.425**
Post-2014/15 UK GAAP accounting treatment	0.187***	0.193***	0.196***
Constant	0.402	1.843	-0.647
Overall predictive power	97.0%	96.8%	97.1%
Number of observations	111	111	109
Model robustness tests[38]	**Model 1**	**Model 2**	**Model 3**
Jointly statistically significant (F-test)	✓	✓	✓
Linearity	×	×	×
Homoscedasticity	✓	✓	✓
Normality	×	×	✓
Chow / Pooling test	✓	✓	✓
Test of pooled OLS versus RE	RE	RE	RE
Hausman test for FE	RE	RE	RE
Consistency with a priori expectations of magnitude / signs	✓	✓	✓
Consistency with other parts of the price control	✓	✓	✓
Is the mean VIF less than 10?	×	×	×
Is the max VIF less than 10?	×	×	×
Joint significance of quadratic term	✓	✓	✓

[38] Unless otherwise stated (see Appendix A), statistical robustness tests are assessed at the 1% significance level

	Model 1	Model 2	Model 3
Sensitivity of estimated coefficients to removal of least efficient company	✓	✓	✓
Sensitivity of estimated coefficients to removal of most efficient company	✓	✓	✓
Sensitivity of estimated coefficients to removal of individual years	✓	✓	✓
Within sample forecasting power	✓	✓	✓
Stability of NIW efficiency score	✓	✓	✓
Efficiency gaps	**Model 1**	**Model 2**	**Model 2**
2013/14	0.6%	2.1%	-3.2%
2014/15	0.4%	1.1%	-0.3%
2015/16	2.7%	-1.5%	-2.6%
2016/17	0.8%	-1.0%	-6.1%
2017/18	-3.0%	-3.7%	-8.8%
2018/19	-2.1%	0.4%	-3.2%
Weighted average	5.5%	0.6%	-2.2%

*Note: Significant at the * 10% level, ** 5% level, *** 1% level. Ticks (crosses) indicate that the model passes (fails) that specific model robustness test.*

B.1.2. Capital maintenance sensitivity results

Table B.2: Wholesale water sensitivity results, capital maintenance

	Model 1	Model 2	Model 3	Model 4
Length of mains	1.190***	1.244***	1.191***	1.249***
Number of booster pumping stations per length of mains	0.528*	0.339	0.525*	0.305
% of water treated in complexity bands 4 to 6	0.011**	0.011**	0.011**	0.011***
% of mains after 1981		-0.019***		-0.019***
Connections per length of mains	0.943***	0.637**	1.076	1.992
Connections per length of mains squared			-0.016	-0.166
Post-2014/15 UK GAAP accounting treatment	-0.209**	-0.173*	-0.210*	-0.179*
Constant	-9.962***	-9.302***	-10.248	-12.244
Overall predictive power	88.6%	90.0%	88.5%	89.9%
Number of observations	111	109	111	109
Model robustness tests	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Jointly statistically significant (F-test)	✓	✓	✓	✓
Linearity	✓	✓	✓	✓
Homoscedasticity	×	×	×	✓
Normality	✓	✓	✓	✓
Chow / Pooling test	✓	✓	✓	✓
Test of pooled OLS versus RE	RE	RE	RE	RE
Hausman test for FE	RE	RE	RE	RE
Consistency with a priori expectations of magnitude / signs	✓	✓	✓	✓
Consistency with other parts of the price control	✓	✓	✓	✓
Is the mean VIF less than 10?	✓	✓	×	×
Is the max VIF less than 10?	✓	✓	×	×
Joint significance of quadratic term	N/A	N/A	✓	✓
Sensitivity of estimated coefficients to removal of least efficient company	✓	✓	×	✓
Sensitivity of estimated coefficients to removal of most efficient company	✓	✓	✓	✓
Sensitivity of estimated coefficients to removal of individual years	✓	✓	✓	✓
Within sample forecasting power	×	✓	✓	✓
Stability of NIW efficiency score	✓	✓	✓	✓
Efficiency gaps	**Model 1**	**Model 2**	**Model 3**	**Model 4**
2013/14	-3.0%	0.4%	-3.7%	-0.2%
2014/15	-16.3%	-12.5%	-16.8%	-17.8%
2015/16	-10.2%	-14.1%	-10.4%	-18.6%
2016/17	-9.6%	-11.8%	-9.8%	-15.8%

	Model 1	Model 2	Model 3	Model 4
2017/18	16.7%	11.2%	16.2%	5.8%
2018/19	14.1%	13.0%	13.7%	8.8%
Weighted average	1.6%	2.8%	0.9%	-0.9%

*Note: Significant at the * 10% level, ** 5% level, *** 1% level. Ticks (crosses) indicate that the model passes (fails) that specific model robustness test.*

B.1.3. Botex sensitivity results

Table B.3: Wholesale water sensitivity results, botex

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Length of mains	1.073***	1.095***	1.065***	1.087***	1.052***	1.017***	1.044***	1.004***
Number of booster pumping stations per length of mains	0.334**	0.265*	0.400**	0.325**	0.226	0.301**	0.306*	0.408***
% of water treated in complexity bands 4 to 6	0.006***	0.006***	0.006***	0.006***				
Weighted average treatment complexity						0.719***		0.758***
% of mains after 1981		-0.007*		-0.006*				
Connections per length of mains	0.903***	0.803***	-1.684	-1.393	0.956***	0.950***	-2.051	-2.944
Connections per length of mains squared			0.316	0.269			0.367	0.475*
Constant	-8.321***	-8.152***	-2.699	-3.381	-8.382***	-8.819***	-1.847	-0.382
Overall predictive power	96.6%	96.8%	96.8%	96.9%	95.5%	96.7%	95.6%	97.0%
Number of observations	111	109	111	109	111	111	111	111
Model robustness tests	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**
Jointly statistically significant (F-test)	✓	✓	✓	✓	✓	✓	✓	✓
Linearity	✓	×	✓	×	✓	×	✓	×
Homoscedasticity	✓	✓	✓	✓	✓	✓	×	✓
Normality	✓	✓	✓	✓	✓	✓	✓	✓
Chow / Pooling test	✓	✓	✓	✓	✓	✓	✓	✓
Test of pooled OLS versus RE	RE	RE	RE	RE	RE	RE	RE	RE
Hausman test for FE	FE	FE	FE	FE	FE	FE	FE	FE
Consistency with a priori expectations of magnitude / signs	✓	✓	✓	✓	✓	✓	✓	✓
Consistency with other parts of the price control	✓	✓	✓	✓	✓	✓	✓	✓
Is the mean VIF less than 10?	✓	✓	×	×	✓	✓	×	×
Is the max VIF less than 10?	✓	✓	×	×	✓	✓	×	×
Joint significance of quadratic term	N/A	N/A	✓	✓	N/A	N/A	✓	✓
Sensitivity of estimated coefficients to removal of least efficient company	✓	✓	×	✓	✓	✓	×	✓
Sensitivity of estimated coefficients to removal of most efficient company	✓	✓	✓	✓	✓	✓	✓	✓

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Sensitivity of estimated coefficients to removal of individual years	✓	✓	✓	✓	✓	✓	✓	✓
Within sample forecasting power	✓	✓	✓	✓	✓	✓	✓	✓
Stability of NIW efficiency score	×	×	✓	✓	✓	✓	×	×
Efficiency gaps	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**
2013/14	-13.1%	-12.4%	-3.1%	-3.7%	0.1%	-0.4%	-13.9%	-15.9%
2014/15	-16.9%	-18.4%	-7.2%	-8.2%	-6.5%	-3.0%	-19.2%	-19.6%
2015/16	-6.0%	-9.3%	1.0%	0.2%	-2.8%	-1.3%	-14.0%	-15.0%
2016/17	-7.3%	-10.5%	0.1%	-1.3%	-3.1%	-3.0%	-12.4%	-15.8%
2017/18	0.4%	1.5%	9.2%	10.6%	9.1%	4.1%	-2.8%	-6.7%
2018/19	2.2%	1.4%	10.6%	7.1%	1.5%	2.3%	-4.3%	-4.8%
Weighted average	-13.1%	-12.4%	-3.1%	-3.7%	0.1%	-0.4%	-13.9%	-15.9%

*Note: Significant at the * 10% level, ** 5% level, *** 1% level. Ticks (crosses) indicate that the model passes (fails) that specific model robustness test.*

B.2. WHOLESALE SEWERAGE SENSITIVITY RESULTS

B.2.1. Opex sensitivity results

Table B.4: Wholesale sewerage sensitivity results, opex

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Total length of sewers	1.017***	0.978***	0.900***	0.875***				
Total load					0.963***	0.927***	0.861***	0.835***
% of load treated in complexity bands 1 to 3	0.072***	0.063***			0.060***	0.056***		
% sewer laid or structurally refurbished post-2001		-0.009***		-0.011***		-0.009***		-0.010***
Connections per length of mains	-11.858*	-10.687**	-11.097	-10.445				
Connections per length of mains squared	1.550*	1.393**	1.429	1.339				
Post-2014/15 UK GAAP accounting treatment	0.167***	0.180***	0.166***	0.180***	0.181***	0.186***	0.168***	0.175***
Constant	16.351	14.726	17.579	16.748	-7.718***	-7.156***	-5.480***	-5.054***
Overall predictive power	94.8%	96.4%	91.7%	94.2%	96.0%	97.6%	93.5%	95.7%
Number of observations	77	76	77	76	77	76	77	76
Model robustness tests	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**
Jointly statistically significant (F-test)	✓	✓	✓	✓	✓	✓	✓	✓
Linearity	✓	✓	✓	×	✓	✓	✓	×
Homoscedasticity	✓	✓	✓	✓	✓	✓	✓	✓
Normality	✓	×	✓	✓	✓	✓	✓	✓
Chow / Pooling test	✓	✓	✓	✓	✓	✓	✓	✓
Test of pooled OLS versus RE	RE	RE	RE	RE	RE	FE	RE	RE
Hausman test for FE	RE	RE	RE	RE	FE	FE	FE	FE
Consistency with a priori expectations of magnitude / signs	✓	✓	✓	✓	✓	✓	✓	✓
Consistency with other parts of the price control	✓	✓	✓	✓	✓	✓	✓	✓
Is the mean VIF less than 10?	×	×	×	×	✓	✓	✓	✓
Is the max VIF less than 10?	×	×	×	×	✓	✓	✓	✓
Joint significance of quadratic term	✓	✓	×	×	N/A	N/A	N/A	N/A
Sensitivity of estimated coefficients to removal of least efficient company	✓	×	✓	×	✓	✓	✓	✓

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Sensitivity of estimated coefficients to removal of most efficient company	✓	✓	✓	✓	✓	✓	✓	✓
Sensitivity of estimated coefficients to removal of individual years	✓	✓	✓	✓	✓	✓	✓	✓
Within sample forecasting power	✓	×	×	×	✓	✓	✓	×
Stability of NIW efficiency score	✓	✓	✓	✓	✓	✓	✓	×
Efficiency gaps	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**
2012/13	-15.2%	-13.2%	-13.2%	-15.5%	-9.9%	-10.5%	-15.6%	-20.2%
2013/14	-15.7%	-16.8%	-13.9%	-15.2%	-8.9%	-11.2%	-13.6%	-17.6%
2014/15	-11.2%	-10.4%	-9.8%	-10.1%	-7.7%	-10.0%	-14.2%	-16.4%
2015/16	-3.8%	-6.3%	-7.2%	-11.9%	-2.9%	-5.6%	-4.8%	-10.3%
2016/17	-1.4%	-3.1%	-2.7%	-7.5%	-0.5%	-4.6%	-5.6%	-11.2%
2017/18	-3.5%	-3.8%	-3.5%	-5.3%	-2.7%	-4.0%	-4.6%	-8.7%
2018/19	1.8%	3.5%	1.3%	-1.5%	-2.7%	-7.3%	-5.4%	-11.9%
Weighted average	-7.3%	-7.0%	-7.0%	-10.2%	-3.0%	-6.2%	-8.7%	-13.5%

*Note: Significant at the * 10% level, ** 5% level, *** 1% level. Ticks (crosses) indicate that the model passes (fails) that specific model robustness test.*

B.2.2. Capital maintenance sensitivity results

Table B.5: Wholesale sewerage sensitivity results, capital maintenance

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Total length of sewers	0.695***	0.693***	0.695***					0.842***
Total load				0.676***	0.665***	0.661***	0.796***	
% sewer laid / structurally refurbished post-2001 per km sewers		-0.008				-0.007	-0.005	-0.006
% of load treated in complexity bands 1 to 3							0.049	0.052
Connections per length of sewers	-21.988***	-21.776***	1.100**	0.555	-18.115**	-17.939***	-23.266***	-28.189***
Connections per length of mains squared	2.796***	2.763***			2.263**	2.236***	2.911***	3.585***
Post-2014/15 UK GAAP accounting treatment	-0.196**	-0.178**	-0.229***	-0.215**	-0.189**	-0.172**	-0.178**	-0.186**
Constant	40.455***	40.248***	-7.051***	-6.167***	32.341**	32.214**	40.699***	50.870***
Overall predictive power	82.4%	84.2%	77.5%	79.3%	82.5%	84.1%	85.6%	86.0%
Number of observations	77	76	77	77	77	76	76	76
Model robustness tests	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**
Jointly statistically significant (F-test)	✓	✓	✓	✓	✓	✓	✓	✓
Linearity	✓	×	×	✓	×	×	×	✓
Homoscedasticity	✓	✓	✓	✓	✓	✓	✓	✓
Normality	✓	✓	✓	✓	✓	✓	✓	✓
Chow / Pooling test	✓	✓	✓	✓	✓	✓	✓	✓
Test of pooled OLS versus RE	RE	RE	RE	RE	RE	RE	RE	RE
Hausman test for FE	RE	RE	RE	RE	RE	RE	RE	RE
Consistency with a priori expectations of magnitude / signs	✓	✓	✓	✓	✓	✓	✓	✓
Consistency with other parts of the price control	✓	✓	✓	✓	✓	✓	✓	✓
Is the mean VIF less than 10?	×	×	✓	✓	×	×	×	×
Is the max VIF less than 10?	×	×	✓	✓	×	×	×	×
Joint significance of quadratic term	✓	✓	N/A	N/A	✓	✓	✓	✓
Sensitivity of estimated coefficients to removal of least efficient company	✓	✓	✓	✓	✓	✓	✓	✓

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Sensitivity of estimated coefficients to removal of most efficient company	✓	✓	✓	✓	✓	✓	✓	✓
Sensitivity of estimated coefficients to removal of individual years	✓	✓	✓	✓	✓	✓	✓	✓
Within sample forecasting power	✓	×	✓	✓	×	×	×	×
Stability of NIW efficiency score	✓	×	×	×	×	×	✓	✓
Efficiency gaps	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**
2012/13	-10.3%	-7.5%	-22.2%	-18.7%	-4.9%	-2.3%	-9.9%	-11.6%
2013/14	-22.9%	-19.6%	-37.0%	-32.2%	-20.4%	-16.0%	-16.6%	-18.8%
2014/15	-3.7%	0.1%	-17.4%	-11.6%	-2.7%	1.7%	4.4%	1.5%
2015/16	-13.2%	-11.2%	-33.2%	-30.4%	-15.6%	-14.1%	-8.9%	-13.8%
2016/17	-12.2%	-9.6%	-33.5%	-28.1%	-12.2%	-10.0%	-17.4%	-15.0%
2017/18	-2.6%	-3.5%	-13.5%	-15.2%	-6.1%	-7.2%	-10.3%	-11.0%
2018/19	-13.7%	-13.1%	-29.4%	-31.0%	-18.9%	-16.5%	-16.8%	-14.0%
Weighted average	-5.2%	-2.6%	-28.6%	-24.3%	-4.1%	-2.3%	-6.2%	-6.2%

*Note: Significant at the * 10% level, ** 5% level, *** 1% level. Ticks (crosses) indicate that the model passes (fails) that specific model robustness test.*

B.2.3. Botex sensitivity results

Table B.6: Wholesale sewerage sensitivity results, botex

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Total length of sewers	0.947***	0.920***			0.835***	0.946***
Total load			0.905***	0.878***		
% of load treated in complexity bands 1 to 3	0.066***	0.059***	0.065***	0.058***	0.029	0.084***
% sewer laid or structurally refurbished post-2001		-0.008*		-0.007*	-0.009*	-0.004
Volume of trade effluent as a % of volume of wastewater						0.073***
Connections per length of mains	-20.175***	-19.007***	-14.646***	-13.678***	0.895**	2.507***
Connections per length of mains squared	2.591***	2.438***	1.834***	1.709***		
Constant	34.308***	32.489***	22.754***	21.351***	-6.963***	-15.487***
Overall predictive power	94.6%	96.1%	95.2%	96.4%	92.5%	96.0%
Number of observations	77	76	77	76	76	76
Model robustness tests	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Jointly statistically significant (F-test)	✓	✓	✓	✓	✓	✓
Linearity	×	×	×	×	×	×
Homoscedasticity	×	✓	✓	✓	✓	✓
Normality	✓	✓	✓	✓	✓	✓
Chow / Pooling test	✓	✓	✓	✓	✓	✓
Test of pooled OLS versus RE	RE	RE	RE	RE	RE	RE
Hausman test for FE	RE	RE	RE	RE	RE	FE
Consistency with a priori expectations of magnitude / signs	✓	✓	✓	✓	✓	✓
Consistency with other parts of the price control	✓	✓	✓	✓	✓	✓
Is the mean VIF less than 10?	×	×	×	×	✓	✓
Is the max VIF less than 10?	×	×	×	×	✓	×
Joint significance of quadratic term	✓	✓	✓	✓	N/A	N/A
Sensitivity of estimated coefficients to removal of least efficient company	✓	✓	✓	✓	×	✓
Sensitivity of estimated coefficients to removal of most efficient company	✓	✓	✓	✓	✓	✓
Sensitivity of estimated coefficients to removal of individual years	✓	✓	✓	✓	✓	✓
Within sample forecasting power	✓	✓	✓	✓	×	✓
Stability of NIW efficiency score	✓	✓	✓	✓	×	✓
Efficiency gaps	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
2012/13	-6.9%	-9.9%	-4.9%	-6.3%	-21.3%	-27.4%
2013/14	-14.3%	-15.4%	-10.1%	-11.6%	-28.9%	-19.6%

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
2014/15	0.0%	-0.2%	1.1%	2.8%	-17.9%	1.0%
2015/16	-7.8%	-8.3%	-5.7%	-4.7%	-25.6%	-5.4%
2016/17	-7.8%	-7.0%	-8.1%	-5.5%	-23.9%	-4.7%
2017/18	0.3%	-1.5%	-2.4%	-0.3%	-18.7%	5.5%
2018/19	-0.9%	0.4%	-8.1%	-6.2%	-12.1%	0.0%
Weighted average	-5.8%	-4.4%	-4.6%	-4.5%	-22.6%	-6.0%

*Note: Significant at the * 10% level, ** 5% level, *** 1% level. Ticks (crosses) indicate that the model passes (fails) that specific model robustness test.*

Appendix C FURTHER BOTEX ANALYSIS

In the previous appendix we introduced botex modelling which combines both opex and capital maintenance expenditure as the dependent variable and is used as a cross-check sensitivity for the more disaggregated models.

In this appendix we provide further discussion of the botex results; compare the output of the botex models (e.g. model predicted costs) with the output from the separate opex and capital maintenance models; and compare the wholesale water botex model results with Ofwat's PR19 econometric cost models.

Based on the analysis presented, we conclude that the botex model results support the separate opex and capital maintenance model results discussed in the main report. However, the botex model results do not perform as well against the model sensitivity tests relative to the separate opex and capital maintenance models, and the wholesale water botex models have a larger efficiency score range relative to Ofwat's PR19 wholesale water botex models. For these reasons, we consider that the UR should focus on the separate opex and capital maintenance model results presented in the main report when setting NI Water's PC21 wholesale opex and capital maintenance allowances.

The remainder of this appendix is set out as follows:

- Botex model discussion
- Comparison to disaggregated models
- Comparison to Ofwat's PR19 modelling

C.1. BOTEX MODEL DISCUSSION

Overall, the wholesale water botex models presented in Table B.3 above perform well against our assessment criteria. But they do not perform as well against the model sensitivity tests relative to the separate opex and capital maintenance models. A summary of the findings is as follows:

- Botex models 1 to 4 broadly reflect the specifications of the preferred opex and capital maintenance models. Models 5 to 8 provide alternative sensitivities that consider complexity variables. The botex models do not include a dummy to reflect the accounting change as this is captured via the combination of opex and capital maintenance.
- The estimated coefficients on the explanatory variables all have a plausible sign and magnitude. Where an explanatory variable is included in both opex and capital maintenance models, the estimated magnitude in the botex models is generally within the range estimated by the disaggregated models. For example, the unweighted average magnitude for length of mains is 0.992 in the opex models, 1.219 in the capital maintenance models, and 1.055 across the botex models.
- Most explanatory variables are individually significant at least at the 10 percent significance level. The exceptions generally follow those discussed in section 4.3 i.e.:
    - The number of booster pumping stations per length of mains in Model 5.
    - 'Connections per length of mains' and 'connections per length of mains squared' are not individually significant when both included in a model (except in Model 8 where the squared term is individually significant at the 10% level). However, in all cases the variables are jointly statistically significant.
- All the models perform well in terms of goodness of fit, with an adjusted R-squared of over 95%. Most models also satisfy the within sample forecasting test, indicating the models could reasonably be used to predict wholesale botex allowances.

- However, the models do not perform as well against the sensitivity tests relative to the standalone opex and maintenance models. For example, two models are sensitive to the removal of the least efficient company, and efficiency results are unstable in four out of eight models.
- Models 2, 4, 6, and 8 fail the linearity test (RESET), which may indicate that a different functional form could perform better. For example, this may mean there is a more complicated relationship between botex and the age of the network. However, more complex functional forms increase complexity whilst not always producing better results.
- The models generally perform well against other tests, most of which we place low emphasis on. For example, all the models satisfy normality and pooling assumptions, and only Model 6 does not satisfy the homoscedasticity test.

Similarly, the wholesale wastewater botex models presented in Table B.6 generally perform well against our assessment criteria.

A summary of the findings is as follows:

- Botex models 1 to 2 broadly reflect the specifications of the preferred opex and capital maintenance models. Models 3 to 6 are sensitivities that consider a different possible volume variable or remove the quadratic term.
- The estimated coefficients on the explanatory variables all have a plausible sign and magnitude. They are all statistically significant to at least the 10% level, with the exceptions of the complexity variable in Model 5 and the network age variable in Model 6.
- The models perform well in terms of goodness of fit, with an adjusted R-squared consistently well over 90%, and as expected generally fall in between the goodness of fit of the opex and capital maintenance models.
- The models perform well against tests assessing the stability of results. All models except for Model 5 are stable to the removal of data points, satisfy within sample forecasting expectations and have efficiency scores that are stable in most models.
- The models generally perform well in the other tests. All pass the normality and pooling tests and only Model 1 fails to satisfy the homoscedasticity assumption. However, all models do not pass the linearity test, which may indicate that a different functional form could perform better. However, as discussed in the main report more complex functional forms increase complexity whilst not always producing better results.

C.2. Comparison to disaggregated models

Figure C.1 and Figure C.2 consider how similar the outputs of the two modelling approaches are to each other in terms of predicted costs. The darker blue bar reflects the sum of predicted average costs from the opex and capital maintenance models, while the lighter blue bar is the average expenditure the botex models predict for a typical water and wastewater company with NI Water's characteristics.[39] The red line reflects NI Water's actual expenditure in a given year.

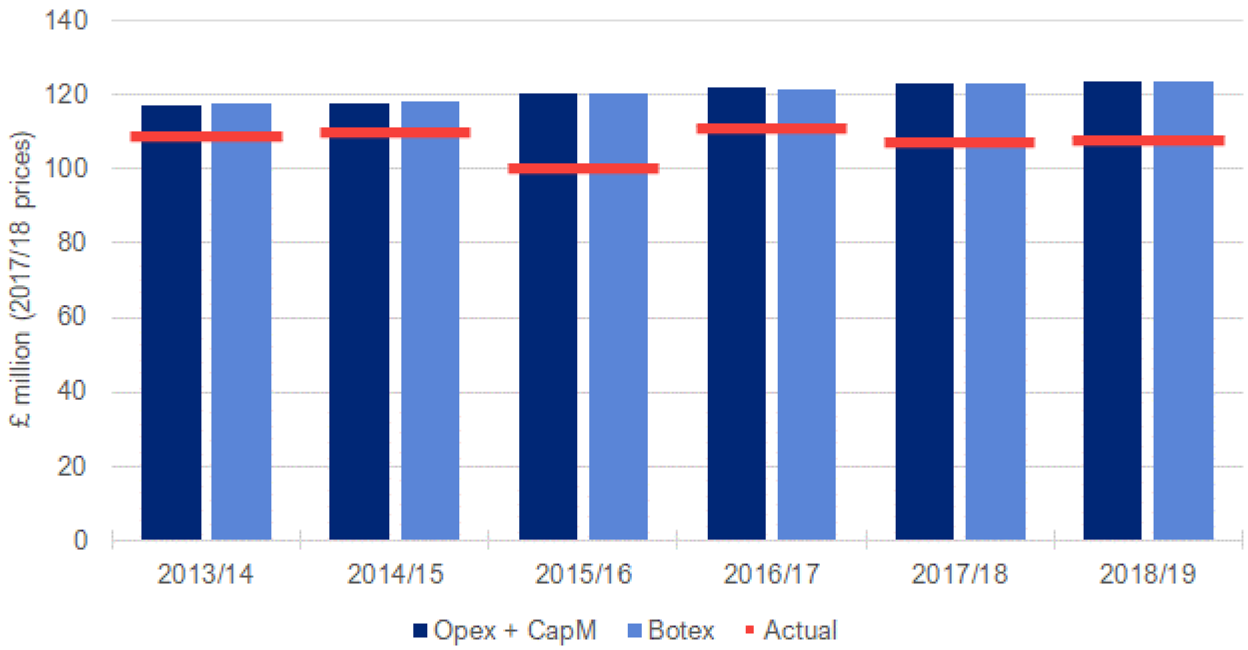
The figures show that the two approaches result in very similar final predicted costs. The figure also reflects the results found in Section 6 of the main report, which showed that NI Water generally appear more efficient in wholesale water than wholesale sewerage.

A comparison of the efficiency gaps implied by the different modelling approaches is challenging to do in a simple and consistent manner. Reasons for this include:

- botex model specifications are not always aligned with the opex and capital maintenance model specifications as each has been developed independently according to our model development process;
- the relative weight of opex and capital maintenance efficiency gaps must account for the changing levels of associated expenditure over time; and
- efficiency rankings may differ between opex, capital maintenance and botex models, leading to differences in the upper quartile company between the disaggregated modelling approach (i.e. separate opex and capital maintenance models) and botex modelling approach.

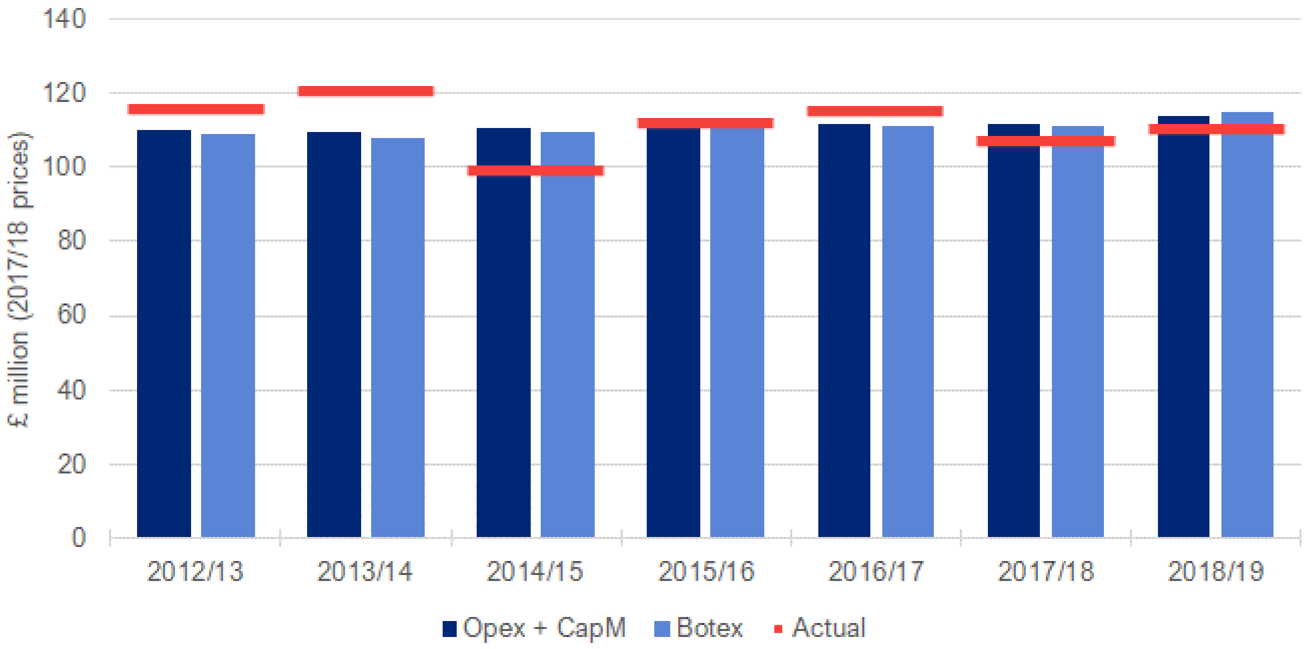
Overall, however, we believe the similarity in average predicted costs between the two approaches is sufficient to support the conclusion that the disaggregated opex and capital maintenance models are consistent with the botex model results.

Figure C.1: Comparison of disaggregated and botex models, wholesale water



[39] For illustration purposes only, we apply an equal weight to each selected opex, capital maintenance and botex model in order to compare results. We focus on average predicted costs rather than upper quartile predicted costs because the upper quartile benchmark may differ between the opex, capital maintenance and botex model results, which would make comparisons challenging.

Figure C.2: Comparison of disaggregated and botex models, wholesale sewerage



C.3. COMPARISON TO OFWAT PR19 COST MODELLING

It is challenging to make comparisons with Ofwat's PR19 cost modelling for several reasons:

- **Ofwat developed models at different levels of cost disaggregation**. For example, Ofwat did not develop combined sewage treatment and collection cost models. This means it is not possible to compare our botex sewerage model results with Ofwat's PR19 cost model results.
- **Ofwat included growth related enhancement capex** in their econometric base cost models for draft and final determinations. Whereas, growth related enhancement capex is not included in our botex models.
- **Model specifications are not always aligned**, which means it is not possible to make direct comparisons between results.
- **Different underlying time periods**. For example, our wholesale water botex models for PC21 were developed using data from 2013/14 to 2018/19. Whereas, Ofwat's PR19 botex models at the initial assessment of plans were developed using data from 2011/12 to 2017/18.
- **Data amendments**. Data amendments have been made since Ofwat published its initial assessment of business plans (IAP) econometric cost models.

We focus the comparison on the wholesale water botex models 3 and 8 presented in this report and Ofwat's IAP wholesale water botex models as we consider these make for the most meaningful comparison because the model specifications are reasonably comparable and the Ofwat IAP models exclude growth related enhancement capex. However, comparisons remain difficult to make due to some of the reasons listed above.

Table 8-1 presents selected CEPA PC21 wholesale water botex results and *Table 8-2 presents Ofwat's PR19 IAP wholesale water botex models. We include the econometric model results and average efficiency scores (actual costs divided by predicted costs) for the water companies included in the sample.*

Overall, there are some material differences between the two sets of results:

- The Ofwat IAP wholesale water models have a higher explanatory power and include explanatory variables that generally appear more statistically significant.
- The Ofwat IAP wholesale water models have a lower spread of average efficiency scores. For example, the largest efficiency score across both Ofwat wholesale water botex models is 1.17 (i.e. 17% less efficient that the average efficient company). This compares to the largest efficiency score across CEPA PC21 wholesale water botex models of 1.29 (i.e. 29% less efficient that the average efficient company).

If it is difficult to say with any confidence whether the differences between the two sets of results identified above are caused by the inclusion of NI Water into the dataset. However, there is some limited evidence that the inclusion of NI Water in the sample has widened the spread of efficiency scores between companies.

Table 8-1: Selected CEPA PC21 wholesale water botex results

	Model 3	Model 8
Length of mains	1.065***	1.004***
Number of booster pumping stations per length of mains	0.400**	0.408***
% of water treated in complexity bands 4 to 6	0.006***	
Weighted average treatment complexity		0.758***
Connections per length of mains	-1.684	-2.944
Connections per length of mains squared	0.316	0.475*
Constant	-2.699	-0.382
Overall predictive power	96.8%	97.0%
Number of observations	111	111
Actual Costs / Predicted Costs (2013/14 to 2018/19)		
Northern Ireland Water (NIW)	0.93	0.96
Affinity Water (AFW)	0.95	0.95
Anglian Water (ANH)	0.97	1.01
Bristol Water (BRL)	1.04	0.99
Dee Valley Water (DVW)	0.98	1.00
Northumbrian Water (NES)	0.86	0.94
United Utilities (NWT)	1.06	1.02
Portsmouth Water (PRT)	0.84	0.89
SES Water (SES)	1.20	1.18
South East Water (SEW)	0.97	0.93
Southern Water (SRN)	0.90	0.91
South Staffs Water (SSC)	0.87	0.88
Severn Trent Water (SVT)	0.93	1.08
South West Water (SWB)	1.08	0.97
Thames Water (TMS)	1.26	1.19
Dwr Cymru (WSH)	1.25	1.18
Wessex Water (WSX)	1.21	1.29
Yorkshire Water (YKY)	0.93	0.86

Source: CEPA analysis

Table 8-2: Ofwat PR19 initial assessment of plans wholesale water botex models

	Model 3	Model 8
Number of properties	0.993***	0.984***
Number of booster pumping stations per length of mains	0.515***	0.517***
% of water treated in complexity bands 3 to 6	0.003***	
Weighted average treatment complexity		0.371***
Connections per length of mains	-1.711***	-1.473***
Connections per length of mains squared	0.126***	0.109***
Constant	-1.273	-2.267**
Overall predictive power	98%	98%
Number of observations	124	124
Actual Costs / Predicted Costs (2011/12 to 2017/18)		
Affinity Water (AFW)	1.01	0.99
Anglian Water (ANH)	1.07	1.03
Bristol Water (BRL)	1.02	0.97
Dee Valley Water (DVW)	0.82	0.84
Northumbrian Water (NES)	0.97	0.96
United Utilities (NWT)	1.06	1.06
Portsmouth Water (PRT)	0.82	0.85
SES Water (SES)	1.11	1.11
South East Water (SEW)	1.01	1.01
Southern Water (SRN)	0.94	0.94
South Staffs Water (SSC)	0.99	0.97
Severn Trent Water (SVT)	1.00	1.02
South West Water (SWB)	0.98	0.99
Thames Water (TMS)	1.03	1.03
Dwr Cymru (WSH)	1.17	1.17
Wessex Water (WSX)	0.96	0.95
Yorkshire Water (YKY)	0.81	0.82

Source: Ofwat (https://www.ofwat.gov.uk/initial-assessment-of-business-plans-cost-assessment-models/)

Appendix D UPPER QUARTILE PREDICTED COSTS

This appendix presents NI Water's modelled upper quartile efficient costs (2017/18 prices) which are used to estimate NI Water's catch-up efficiency gap in Section 6 (before application of special cost factors) and Section 7.4 (after application of special cost factors).[40] In other words, this is our prediction of what NI Water's costs would be if the company were operating at the upper quartile benchmark.

An illustrative example is provided in Table 8-3 to show how we have calculated NI Water's UQ predicted costs for each model **before consideration of special cost factors (SCFs)**.

Table 8-3: Illustrative upper quartile predicted costs calculation before SCFs

Column	Item	Formula	Example
A	Actual Cost (excluding atypical costs)		£100m
B	Predicted Average Modelled Costs		£89.5m
C	Efficiency Score of UQ Company		0.95
D	Predicted UQ Modelled Costs (before SCFs)	B * C	£85m

Source: CEPA analysis

An illustrative example is provided in Table 8-4 to show how we have calculated NI Water's UQ predicted costs for each model **after consideration of SCFs**.

Table 8-4: Illustrative upper quartile predicted costs calculation after SCFs

Column	Item	Formula	Example
A	Actual Cost (excluding atypicals)		£100m
B	Predicted Average Modelled Costs		£89.5m
C	SCFs adjustment		£5.5m
D	Predicted Average Modelled Costs + SCFs	B + C	£95.0m
E	Efficiency Score of UQ Company		0.95
F	Predicted UQ Modelled Costs (after SCFs)	D * E	£90.2m

Source: CEPA analysis

[40] A multiplier of 1.0306 would need to be applied to convert costs from a 2017/18 price base to a 2018/19 price base.

D.1. Upper quartile predicted costs (before SCFs)

D.1.1. Wholesale water opex

Table 8-5: NI Water wholesale water UQ predicted costs £m 2017/18 prices – opex (before SCFs)

	Model 1	Model 2	Model 3
2013/14	66.3	67.3	63.8
2014/15	66.0	66.5	65.6
2015/16	65.2	62.6	61.9
2016/17	66.7	65.4	62.1
2017/18	66.4	65.9	62.4
2018/19	68.5	70.2	67.7
Weighted Average	70.3	67.0	65.1

Source: CEPA analysis

D.1.2. Wholesale water capital maintenance

Table 8-6: NI Water wholesale water UQ predicted costs £m 2017/18 prices - capital maintenance (before SCFs)

	Model 1	Model 2	Model 3	Model 4
2013/14	41.5	43.0	41.3	42.7
2014/15	36.7	38.4	36.5	36.1
2015/16	32.7	31.3	32.6	29.6
2016/17	40.4	39.4	40.3	37.6
2017/18	45.1	43.0	44.9	40.9
2018/19	43.3	42.9	43.2	41.3
Weighted Average	41.4	41.9	41.1	40.4

Source: CEPA analysis

D.1.3. Wholesale sewerage opex

Table 8-7: NI Water wholesale sewerage UQ predicted costs £m 2017/18 prices - opex (before SCFs)

	Model 1	Model 2
2012/13	51.0	52.2
2013/14	50.8	50.2
2014/15	51.9	52.4
2015/16	55.5	54.1
2016/17	55.8	54.8
2017/18	52.0	51.9
2018/19	55.3	56.2
Weighted Average	53.1	53.3

Source: CEPA analysis.

D.1.4. Wholesale sewerage capital maintenance

Table 8-8: NI Water wholesale sewerage UQ predicted costs £m 2017/18 prices - capital maintenance (before SCFs)

	Model 1	Model 2
2012/13	49.9	51.4
2013/14	46.5	48.5
2014/15	39.1	40.7
2015/16	47.3	48.4
2016/17	51.6	53.1
2017/18	51.6	51.1
2018/19	48.3	48.7
Weighted Average	51.3	52.7

Source: CEPA analysis.

D.2. Upper quartile predicted costs (after special cost factors)

D.2.1. Wholesale water opex

Table 8-9: NI Water wholesale water UQ predicted costs £m 2017/18 prices – opex (after SCFs)

	Model 1	Model 2	Model 3
2013/14	65.2	65.2	61.3
2014/15	63.8	65.4	62.5
2015/16	61.6	59.2	57.7
2016/17	62.9	60.5	57.2
2017/18	62.7	61.7	58.3
2018/19	65.2	66.4	63.2
Weighted Average	66.8	64.6	61.1

Source: CEPA analysis

D.2.2. Wholesale water capital maintenance

Table 8-10: NI Water wholesale water UQ predicted costs £m 2017/18 prices - capital maintenance (after SCFs)

	Model 1	Model 2	Model 3	Model 4
2013/14	38.3	40.5	38.0	39.4
2014/15	33.8	35.3	33.6	33.1
2015/16	30.7	29.3	30.6	27.7
2016/17	37.4	36.4	37.3	34.6
2017/18	42.3	40.2	42.1	38.7
2018/19	40.7	40.4	40.6	39.0
Weighted Average	39.7	39.8	39.5	37.6

Source: CEPA analysis

D.2.3. Wholesale sewerage opex

Table 8-11: NI Water wholesale sewerage UQ predicted costs £m 2017/18 prices - opex (after SCFs)

	Model 1	Model 2
2012/13	50.7	51.9
2013/14	49.0	48.3
2014/15	48.9	49.3
2015/16	50.9	49.5
2016/17	51.1	49.8
2017/18	48.5	48.3
2018/19	53.5	53.6
Weighted Average	50.0	50.2

Source: CEPA analysis.

D.2.4. Wholesale sewerage capital maintenance

Table 8-12: NI Water wholesale sewerage UQ predicted costs £m 2017/18 prices - capital maintenance (after SCFs)

	Model 1	Model 2
2012/13	45.2	46.6
2013/14	41.8	43.5
2014/15	37.8	39.3
2015/16	43.0	44.0
2016/17	46.5	47.8
2017/18	47.2	46.5
2018/19	43.8	44.0
Weighted Average	46.7	47.9

Source: CEPA analysis.

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