On the inclusion of water volume variables in econometric cost models

Prepared for Southern Water Ltd

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Executive summary

For the PR19 price review, Ofwat has released a consultation document examining econometric cost models developed by itself and the industry.[1] While Ofwat has observed general concerns with the use of potential endogenous[2] drivers, and has avoided water volume measures as scale drivers in its models generally,[3] some companies have submitted models that control for distribution input (DI) or other water volume variables. This note contains a response to those models as well as a quantification of bias resulting from the use of such variables in cost models for Southern Water (SRN).

Including water volume measures in econometric cost models can be problematic from both an operational and a statistical perspective. This is because:

- endogenous variables, such as DI, can generate a bias in the estimated coefficients;[4]
- such variables can provide perverse incentives on water leakage and efficiency.

[1] Ofwat (2018), 'Cost assessment for PR19: a consultation on econometric cost modelling' March, https://www.ofwat.gov.uk/wp-content/uploads/2018/03/Cost-assessment-for-PR19-A-consultation-on-econometric-cost-modelling.pdf.
[2] That is, within management control, as opposed to exogenous drivers, which tend to be the focus in regulatory cost models.
[3] With the exception of Water Treatment models.
[4] This is the so-called endogeneity bias, which amounts to a two-way causality between the dependent variable (costs) and the independent variables (here, DI) considered.

The latter point is particularly relevant, given the UK government's targets for water usage and water efficiency.[5] SRN has undertaken actions to improve water efficiency in line with the government objectives, and tends to abstract, treat and deliver a lower level of water per property than the industry on average.[6] As a consequence, SRN performs worse in econometric models that control for water volume measures, as these underestimate SRN's scale of operation compared with equivalent models that control for scale measures such as connected properties, population served, and length of mains.

Based on the data that Ofwat has published in the modelling consultation, we have estimated a downward bias for SRN resulting from the inclusion of water volume variables. The approaches we have followed are:

- **observed differences**: quantifying the difference in SRN's cost predictions in models submitted by companies and Ofwat with and without water volume variables;
- **model modification**: amending Ofwat's scale driver in its BOTEX models to a water volume variable, and comparing these against Ofwat's original models.[7]

Owing to the nature of top-down modelling, we consider that this approach provides a practical way of quantifying a cost adjustment claim, and is similar to the approach considered by Ofwat in the past.[8]

The figure below outlines the logical steps that we have followed to quantify the bias in some of the models.

Steps followed in the quantification of bias

Step 1: Identification of water volume variables used in Ofwat's and company models

Ofwat's models: total water treated is considered in five of the water treatment models
Company-submitted models: DI used as scale variable by Anglian Water, Wessex Water, Severn Trent Water and South East Water in granular and aggregate models

Step 2: Assessment of SRN's performance in models with and without water volume measures

Observed differences: compare SRN's performance in Ofwat's and company models that control for water volume with like-for-like models that do not
Quantification of impact: variance in predictions is approximately £18m over an AMP (8% of water treatment BOTEX modelled costs) in Ofwat's models, and in the range of £39m–£41m (7% of wholesale BOTEX modelled costs) in company models

Step 3: Inclusion of water volume measures in Ofwat's cost models

Model modification: replacement of the scale driver with a water volume measure in Ofwat's overall BOTEX models
Quantification of impact: the variance in predictions between Ofwat's original BOTEX models and amended Ofwat models controlling for water volume is approximately £89m (14% of wholesale BOTEX modelled costs)

Assessment of materiality

Efficient cost adjustment: given models of varying quality and the need for further work on the appropriate benchmark, the estimated cost variance was assessed at average efficiency
Materiality assessment: currently not proposed as a cost adjustment claim. Assessment against modelled BOTEX cost (defined as such in Ofwat's models)
Estimated bias is indicative and requires updating once business plan information and additional data/modelling refinements are considered

[5] Department for Environment Food & Rural Affairs (2017), 'The government's strategic priorities and objectives for Ofwat', September, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/661803/sps-ofwat-2017.pdf, p. 4.
[6] See Department for Environment Food & Rural Affairs (2017), op. cit., for a description of its initiatives (section 2).
[7] Alternative methods of controlling for water volume exist, such as appending a composite variable such as DI per property to the original models. This can be a useful alternative if a scale variable is supposed to capture non-scale characteristics that may be lost if the scale variable is replaced. However, appending a variable could increase model complexity and lead to over-fitting.
[8] For example, in the consideration of special cost factor analysis in the context of Fawley oil refinery for Sembcorp Bournemouth at PR14.

Source: Oxera.

The results from the analysis are presented in the table below.

Results summary

Method	Models by:	Estimated impact*, £m; (as a percentage of BOTEX**)		
		Water treatment	**Network plus**	**Wholesale water**
Observed differences	Ofwat	18 (8%)	-	-
Observed differences	South East Water, Severn Trent Water	-	40 (7%)	-
Observed differences	South East Water	-	-	45 (7%)
Model modification	Ofwat	-	-	89 (14%)

Note: All costs are in 2016/17 prices. * This is the difference in model predictions for SRN over an AMP (five years) between models that control for a water volume measure and those that do not. We have not used an alpha correction in this note, to translate predictions in logarithm to levels, as considered by Ofwat at PR14. ** The estimated percentage impact (within brackets) is relative to BOTEX appropriate for the business unit excluding uncontrollable items that Ofwat has excluded from the analysis.

Source: Oxera analysis.

The general conclusions from the analysis are that:

- if water volume measures are included in econometric models, the estimated baseline cost for some companies tend to be distorted, particularly for SRN;
- the estimated impact is material for SRN, given its unique characteristics, and is contingent on the model specification.

While a cost claim for DI has not been made, there might be a need for one should Ofwat consider models that control for DI or volume measures in its final suite of models. In such a case, the materiality of the cost adjustment claim should be assessed relative to SRN's business plan TOTEX and consider an efficiency adjustment as noted in Ofwat's cost claim guidance. The numbers in this note should be seen as directional and indicative of the potential bias from the use of volume measures, and will require updating once business plan information and additional data/modelling refinements are considered.

1 Introduction

In March 2018, Ofwat released a consultation document setting out cost models developed by itself and water companies.[9] While volume of water was not explicitly controlled for as a scale measure in the majority of Ofwat's models, some companies have developed models that control for either volume of water delivered or DI. They include the following.

[9] Ofwat (2018), 'Cost assessment for PR19: a consultation on econometric cost modelling', March, https://www.ofwat.gov.uk/wp-content/uploads/2018/03/Cost-assessment-for-PR19-A-consultation-on-econometric-cost-modelling.pdf.

- **Anglian Water**. DIs from different water sources are used as scale drivers in its water resources models.
- **Wessex Water**. DI is used as a scale driver in all water resources plus models.
- **Severn Trent Water (SVT)**. DI is used as a scale variable in two network plus models.
- **South East Water (SEW)**. DI is the scale variable in one network plus, one wholesale water, and three TOTEX (growth) models.

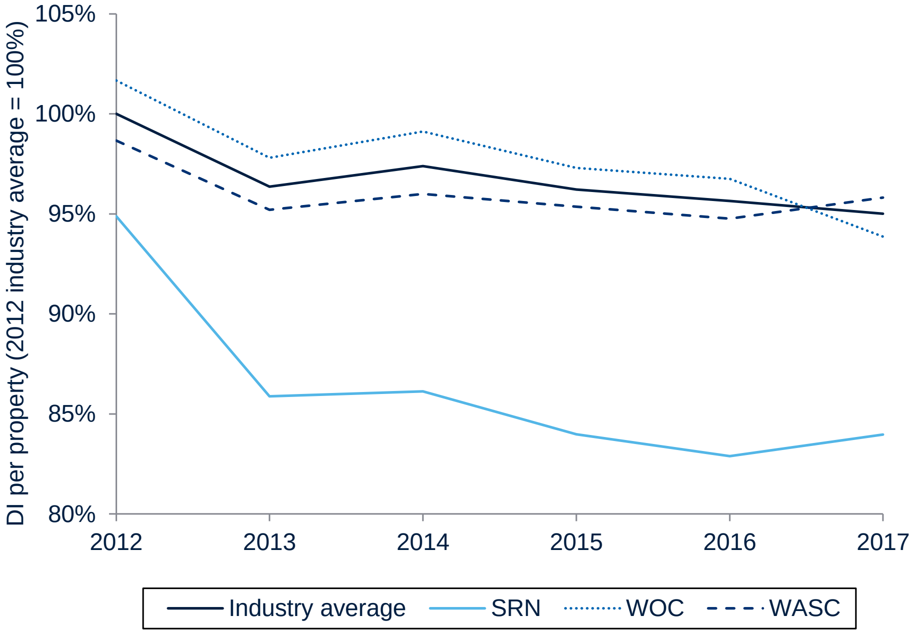
In addition, Ofwat's final modelling suite may include models that use volume measures as scale drivers, supporting the need for this note.

It is our understanding that SRN has taken, and will continue to take, steps to improve water efficiency and therefore reduce water volume in the network. The UK government has outlined the need for improved water efficiency and reduced water usage in its strategic priorities for Ofwat:[10]

> We [Defra] expect Ofwat to promote ambitious action to reduce leakage and per capita consumption, where this represents best value for money over the long term, including exploring setting targets in future.

SRN's efforts to reduce leakage and water consumption can be seen in Figure 1.1, which shows the evolution of DI per property for SRN compared with the industry average.

Figure 1.1 DI per property over the modelled period



Note: The industry average refers to a simple (unweighted) average of DI per property. A weighted average may be dominated by large companies and therefore provide an inadequate comparison. WOC and WASC refer to the simple averages of DI per property for Water Only Companies, and Water And Sewerage Companies respectively.

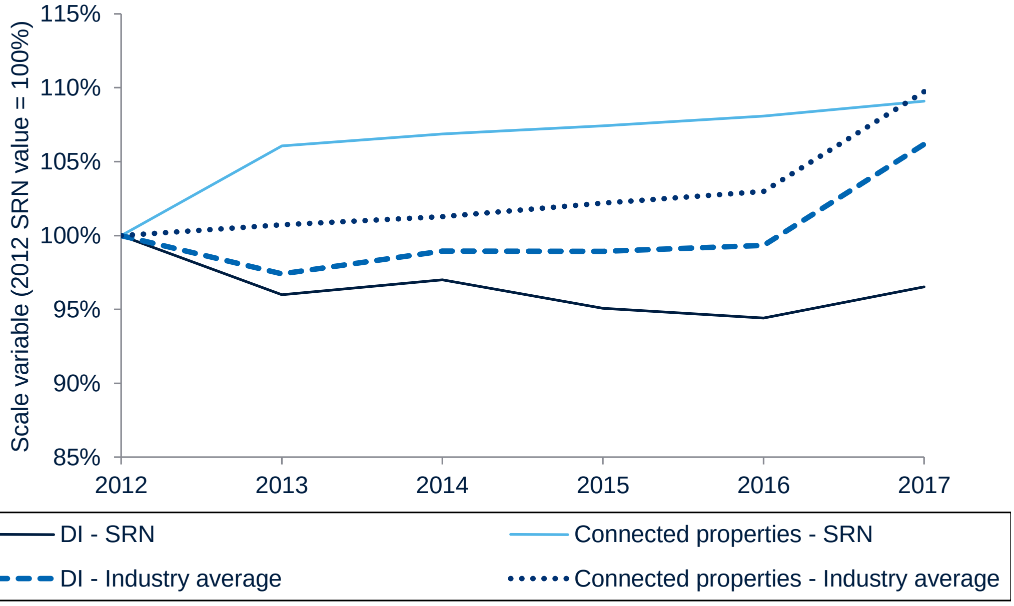
[10] Department for Environment, Food & Rural Affairs (2017), 'The government's strategic priorities and objectives for Ofwat', September, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/661803/sps-ofwat-2017.pdf, p. 4.

Source: Oxera analysis.

Starting from a position that is better than the industry average in 2012, SRN has managed to reduce DI per property at a faster pace. This observation is consistent when comparing SRN with WOCs as well as WASCs separately.

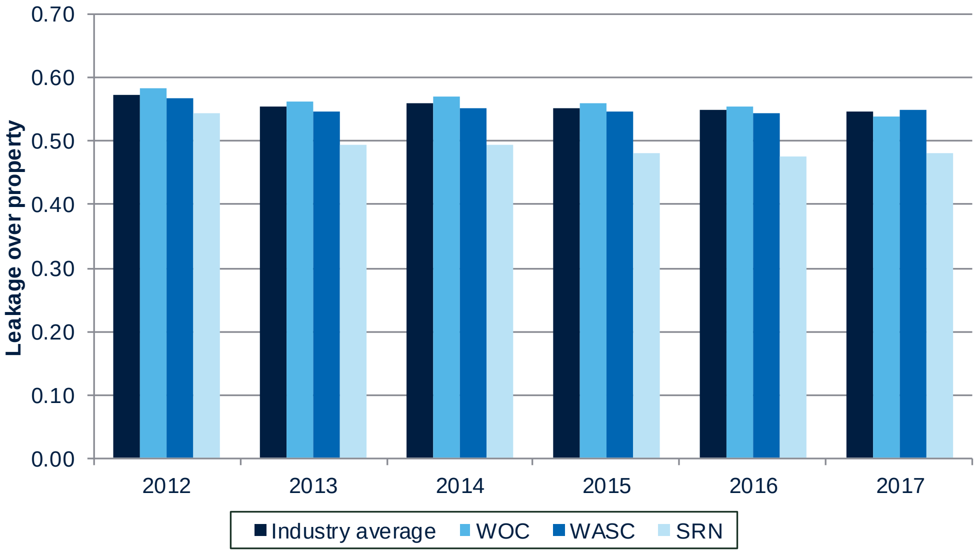
Figure 1.2 and 1.3 show the evolution of DI, connected properties and leakage per property for SRN and the industry over the modelled period. The reduction in DI, despite a general upward trend in connected properties, indicates that SRN is improving water efficiency and reducing usage among its customers. SRN has also been managing leakage below the industry average over the period.

Figure 1.2 Alternative scale variables over the modelled period



Source: Oxera analysis.

Figure 1.3 Leakage per property over the modelled period



Source: Oxera analysis.

SRN has asked Oxera to prepare a short note summarising some of the issues associated with the use of water volume variables in statistical models, and quantifying the impact of their inclusion on SRN's cost predictions. The remainder of this note is structured as follows:

- section 2 provides an operational argument for why water volume measures may be inappropriate in cost models;
- section 3 attempts to quantify the impact of including these measures on SRN's performance;
- section 4 concludes.

2 Public policy and operational implications

While focusing purely on exogenous variables may be impractical in a cost modelling framework, the CMA, Ofwat and other regulators have expressed caution when controlling for variables within management control in econometric models. Not only can controllability lead to biased estimates of the coefficients, it can also result in perverse incentives.

DI and other water volume measures are generally driven by consumer demand, but there is an element of controllability at the margin. While it may be unreasonable to suggest that companies will actively leak water to increase their efficient cost allowance, it might not be unreasonable to assume that companies are less incentivised to actively invest in their own leakage reduction, as well as encourage their customers to be more water efficient, through the use of water volume measures in models.

As noted earlier, the UK government has also outlined the need for improved water efficiency and reduced water usage in its strategic priorities for Ofwat.[11] Ofwat is explicit about this in its most recent consultation document:[12]

> the volume of water abstracted is to some extent under management control. Management can reduce leakage, promote demand side efficiency etc. A model that uses the volume of water abstracted to explain variation in costs due to scale, will have a positive coefficient and may be deemed to provide a perverse incentive – for two otherwise identical companies, the model will imply higher costs for the company that is less water efficient (and therefore abstracts more water).

Some of Ofwat's models have included variables that are potentially within management control. For example, the proportion of mains renewed/relined is considered as a maintenance driver. The impact of such variables requires consideration in the process of further model development and can be the subject of future work.

As noted, sometimes including controllable variables cannot be avoided. The CMA stated in the Bristol appeal:[13]

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[11] Department for Environment, Food & Rural Affairs (2017), 'The government's strategic priorities and objectives for Ofwat', September, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/661803/sps-ofwat-2017.pdf, p. 4.

[12] Ofwat (2018), 'Cost assessment for PR19: a consultation on econometric cost modelling', March, https://www.ofwat.gov.uk/wp-content/uploads/2018/03/Cost-assessment-for-PR19-A-consultation-on-econometric-cost-modelling.pdf, p. 10.

[13] Competition and Markets Authority (2015), 'Bristol Water plc: A reference under section 12(3)(a) of the Water Industry Act 1991, Appendices 1.1-4.3', March, https://assets.publishing.service.gov.uk/media/5627995aed915d101e000001/Appendices_1.1_-_4.3.pdf, p. A4(1)-41.

in some cases at least, including explanatory variables that are inputs and under management control may be better than a strict approach of excluding such factors. In principle, there would be merit in using alternative explanatory variables or data sources that could capture the same underlying factors with less of a link to a company's inputs and asset management approach, but such data sources may not be available.

If water volume is intended to capture only the scale of operation, then a range of alternatives exist such as connected properties, population served, and length of mains (where appropriate[14]). Some of these alternative scale measures may also capture non-scale operational characteristics, such as density or sparsity of the service area. The 'composite' nature of these variables in top-down modelling can allow multiple effects to be captured in a simpler model.[15]

3 Quantifying the impact

In this section, we explore the following two approaches to quantify the impact of water volume variables on SRN's efficient cost predictions.

- **Observed differences**. Observing the difference in SRN's performance in models that control for volume of water compared with models that do not.
- **Model modification**. Replacing the scale driver with a water volume measure in the existing models.

The results from econometric modelling are shown without an additional efficiency challenge (i.e. at average efficiency). This is because the choice of benchmark can be ad hoc at this stage, and is dependent on model quality. Moreover, the CMA had considered an average benchmark to be appropriate for the top-down econometric models that it developed in the Bristol price appeal inquiry. As such, at this stage, the analysis presented in this note estimates the impact of water volume variables for SRN at average efficiency.

Additional work is required to determine the efficiency challenge that is appropriate for the final set of models that Ofwat uses for cost-setting purposes.

3.1 Observed differences

The impact of including water volume variables on SRN's performance can be obtained by comparing SRN's performance in models that control for water volume with similar models that do not.

This could have an advantage over the other methods in that we are not amending any of the model specifications that may have undergone due model development and validation by Ofwat and the companies. However, this limits the scope of the analysis to a handful of models, as most models are not directly comparable (i.e. in terms of isolating the impact of DI).

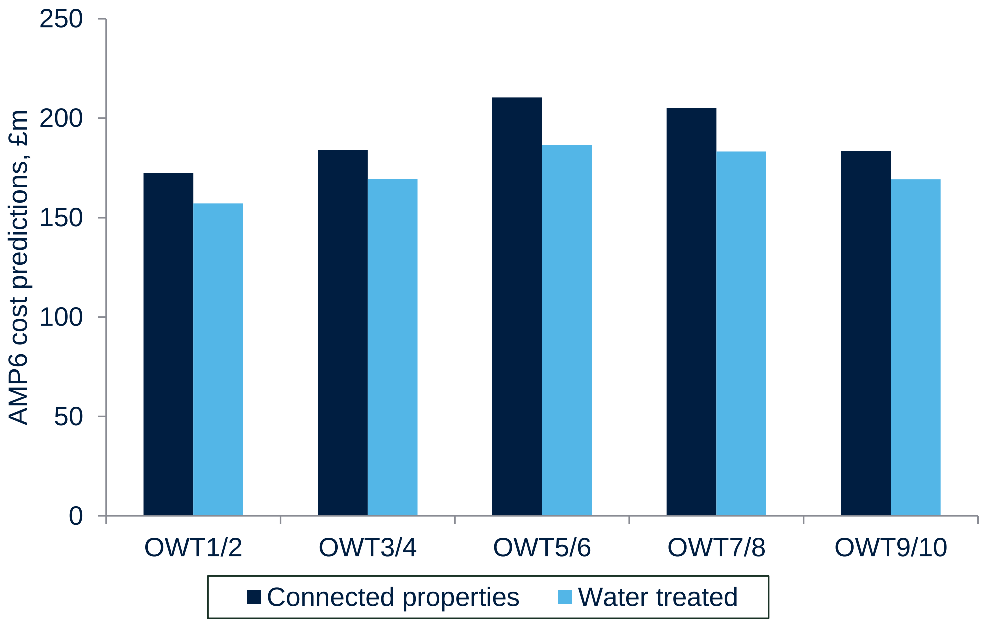
[14] Length of mains may, to a limited degree, also be within management control. It can be an appropriate scale variable in models where treated water distribution is dominant, such as treated water distribution or network plus models.
[15] Ofwat (2018), 'Cost assessment for PR19: a consultation on econometric cost modelling. Appendix 1: Modelling results', March, https://www.ofwat.gov.uk/wp-content/uploads/2018/03/Appendix-1-Modelling-results_Final.pdf. p. 11.

3.1.1 Ofwat models

Only five models developed by Ofwat (for water treatment) control for water volume (total water treated) explicitly, with all other models using either connected properties or length of mains.[16]

In the consultation document, the water treatment models are displayed incrementally such that each even-numbered model is equivalent to the previous odd-numbered model, but uses total water treated as a scale variable instead of connected properties. The predictions for SRN from these models are displayed in Figure 3.1.

Figure 3.1 AMP (over five years) predictions: Ofwat water treatment models



Note: All costs are in 2016/17 prices and have been benchmarked to the average. We have not used a log-correction factor in this note as used by Ofwat in PR14.

Source: Oxera.

A like-for-like comparison of the models shows that controlling for the volume of water treated leads to a lower cost prediction for SRN in all models. The magnitude of the change in cost prediction is approximately £18m on average, or 8% for water treatment BOTEX, but there is significant variation across models, ranging from £14m in models OWT9/10 to £24m in models OWT5/6. Section 3.2 shows that the impact at the wholesale water BOTEX level is higher than on water treatment BOTEX alone.

3.1.2 Company models

In using company-submitted models, we have used Ofwat's dataset and modelled cost definitions. The models used in estimating SRN's costs in this section may differ from the models presented in the consultation document, due to the following.

[16] Ofwat (2018), 'Cost assessment for PR19: a consultation on econometric cost modelling. Appendix 1: Modelling results', March, https://www.ofwat.gov.uk/wp-content/uploads/2018/03/Appendix-1-Modelling-results_Final.pdf.

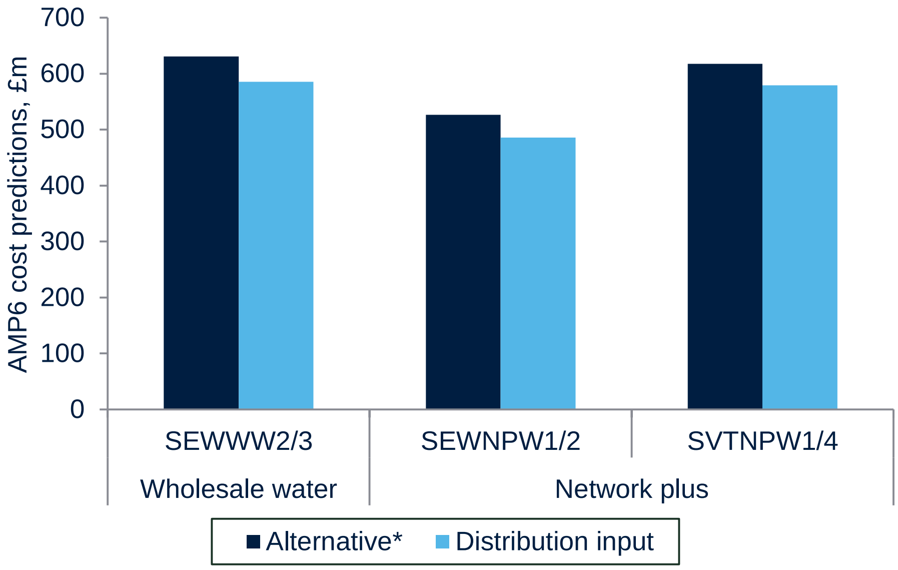
- **Data differences**. Companies may estimate the models using a version of the data that is different from that used by Ofwat.
- **Industry structure**. Some companies have modelled a 17-firm industry for the full time period, whereas Ofwat has modelled an 18-firm industry for the first four years and a 17-firm industry for the final year.
- **Variable definitions**. Some constructed variables such as density have not been explicitly defined in the consultation document, making exact replication difficult.

The following three types of company-submitted models were presented in such a way that they allow direct comparison.

- **South East Water wholesale water models**. SEWWW1, 2 and 3 vary in terms of the scale driver used, but are otherwise identical in model specification. Connected properties, population served, and DI are used in models SEWWW1, 2 and 3 respectively. For simplicity, we have focused on a comparison of models SEWWW2 and 3.
- **Severn Trent Water network plus models**. Severn Trent Water SVTNPW1 and SVTNPW4 are equivalent models, with SVTNPW1 controlling for network length and SVTNPW4 controlling for DI.
- **South East Water network plus models**. SEWNPW1 and SEWNPW2 are similar models, with SEWNPW1 controlling for connected properties and SEWNPW2 controlling for DI.

The results from the company-submitted models are shown in Figure 3.2.

Figure 3.2 AMP (over five years) predictions: company models



Note: All costs are in 2016/17 prices. * Alternative refers to population served in models SEWWW2/3 and SEWNPW1/2, and length of mains in models SVTNPW1/4. We have not used an alpha correction in this note, to translate predictions in logarithm to levels, as considered by Ofwat at PR14.

Source: Oxera analysis.

In SEW's wholesale water models, predicted costs over an AMP reduce by approximately £45m when DI is used relative to population served. For SEW's network plus models, the reduction is about £41m. The reduction in SRN's cost predictions is lower in SVT's models at £39m than in SEW's. As a percentage of BOTEX, these differences are reasonably consistent and centre around 7%.

3.2 Model modification

By modifying the overall BOTEX models developed by Ofwat such that they control for water volume as a scale variable (where an alternative scale measure is used), it is possible to estimate the impact of water volume measures on SRN's predictions.

As noted above, a scale driver in a model may be intended to capture more than just the scale of operation. For example, length of mains could capture aspects of scale and sparsity in the service area, and replacing length of mains with distribution input may limit the extent to which sparsity is captured for some companies in the industry. Appending a water volume per scale variable to Ofwat's original models may mitigate possible limitation in replacing the original scale driver with DI, but such models can increase complexity in isolating the incremental impact of DI.[17]

Table 3.1 shows SRN's performance in wholesale water models with these two approaches to model modification.

Table 3.1 AMP (over five years) predictions—Ofwat model modifications

	Ofwat original models*, £m	Water volume**, £m	Difference, £m
Model modification	734	644	89

Note: All costs are in 2016/17 prices. * Average cost prediction across all 12 models. ** For each Ofwat model, we replaced the scale driver with either water treated, water delivered or distribution input. The figure refers to the average cost prediction across all 36 of these modified models. We have not used an alpha correction in this note, to translate predictions in logarithm to levels, as considered by Ofwat at PR14.

Source: Oxera analysis.

While the impact of changing the scale driver is material and negative in all the models, the level of reduction varies considerably, which further highlights the importance of identifying model specifications that appropriately reflect company costs. For example, the replacement of the scale variable with the three alternative measures leads to a fall of SRN's AMP costs of £70m in model OWW9 and as much as £119m in model OWW10. The percentage impact on modelled BOTEX is about 14% on average.

While the alternative scale measure comes out with an intuitive coefficient, the model modification affects the outcome on some of the other variables in the specification—for example, when the scale variable is replaced in models OWW7–12, the models tend to estimate a negative and/or statistically insignificant coefficient on the density variable (population over length, or Ofwat's weighted density measure).[18]

[17] As well as requiring an extra degree of freedom and resulting in possible over-fitting.
[18] This is not necessarily surprising, as Ofwat has included a density measure only where mains length is used as a scale measure (which could be capturing sparsity effects to some extent). In such cases, the density measure estimates incremental cost for operating in a congested region (i.e. density effects). When length of mains is replaced with a water volume measure, the density variable estimates sparsity effects for the average company in the industry rather than density (as with the original mains length measure).

4 Conclusion

In this note, we reviewed and highlighted concerns with using water volume measures in econometric cost analysis from a public policy perspective as well as from an operational and statistical perspective. In doing so, we have considered observations from both Ofwat and the CMA, and the implications of government's targets regarding water efficiency.[19]

We have also shown that controlling for water volume has a material impact on the estimation of SRN's costs. Depending on the approach used, the impact is quantified to be approximately between 7% and 14% of modelled BOTEX.

While a cost claim for DI has not been made, there might be a need for one should Ofwat consider models that control for DI or volume measures in its final suite of models. In such a case, the materiality of the cost adjustment claim should be assessed relative to SRN's business plan TOTEX and consider an efficiency adjustment as noted in Ofwat's cost claim guidance. The quantification will also require updating once business plan information and additional data/modelling refinements are considered.

[19] Department for Environment Food & Rural Affairs (2017), 'The government's strategic priorities and objectives for Ofwat', September.