Review of RIIO-2 finance issues

The estimation of beta and gearing

Prepared for
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Final

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Executive summary

In preparation for the RIIO-2 electricity and gas transmission and distribution price controls, the Energy Networks Association (ENA) has commissioned Oxera to provide advice on the estimation of equity beta and how this is influenced by gearing.

Scope

This report investigates the following areas where Ofgem's methodologies and assumptions may be leading to the incorrect estimation of the cost of equity:

1. the methodology for estimating beta from market data;
2. the impact of gearing on the equity beta, including Ofgem's use of an 'adjusted' gearing ratio;
3. the estimation of debt beta

While the report focuses on the beta and issues of gearing, it is to be read in conjunction with Oxera's other reports on the allowed returns for networks in RIIO-2. Oxera is submitting additional evidence on a number of issues in relation to the estimation of allowed equity returns, including evidence on total market returns and an assessment of the asset risk premium.

Response to Ofgem's sector specific methodology consultation

The mechanics that underpin Ofgem's raw (i.e. before adjusting for differences between market and notional gearing) equity beta range of 0.6-0.7 are not specifically stated. Instead, Ofgem suggests that its range is conservatively anchored on Indepen's range (i.e. a broad range of 0.55 to 0.7, and narrow

range of 0.57 to 0.65, with 0.6 as a central estimate).[1] We therefore respond to methodological points made by Ofgem, as summarised in the table below.

Table 1 Response to Ofgem, including advice from Indepen

Ofgem's summary of advice from Indepen (para 3.103) Ofgem's arguments (para 3.106, 3.108)	Oxera response
(Finance Annex, para 3.103, bullet 1 and 2; also, para 3.106, bullet 1, 2 and 5) Equity betas should be analysed over at least five years, and probably the last ten years. Analysis of betas should commence with an evaluation of structural breaks. All of the UK networks showed structural breaks in 2008-09. However, given the time-varying and mean reverting nature of observed betas, as long a time period as possible is recommended. Data from 2011 to 2014 may also be valuable to understand how investors perceive risk during periods of economic uncertainty.	We agree that an evaluation of structural breaks is helpful. We provide evidence that the full sample of available data contains structural breaks attributable to market events. Therefore, while the use of longer term data up to ten years may be appropriate to assess the extent to which betas exhibit mean-reversion, e.g. over the economic and regulatory cycles, there may be other factors driving shifts in the betas over time, such as changing business risk and leverage. This suggests that any move away from the regulatory precedent in relation to a focal time period, of two to five years should be made with caution and good justification. Also, we note by examination of UK networks betas over the full time period for which data is available, that once leverage is controlled for, there appears to be no basis for the earlier Ofgem statement that 'network companies are a lot less risky as investments than previously assumed.'[2] See section 2.2.
(Finance Annex, para 3.103, bullet 3; also, para 3.106, bullet 3 and 4) In choosing a frequency of data observations, there is a trade-off between noise and signal. There is a heteroscedasticity problem for all networks when using daily or weekly data observations. Low frequency data could reduce this problem but introduce others such as potentially reduced estimator precision. Ofgem proposes to consider both high and low frequency observations, and disagrees that relying on low frequency data may result in less precise beta estimates.	There is no explanation of why changes in volatility (heteroscedasticity) might lead to biased beta estimates, and therefore why there should be a higher weight on low-frequency data in the context of a regulatory price control. From a statistical point of view, it is generally the case that the more data points in the analysis, the more robust the results.[3] We agree that both high and low frequency observations can be examined (e.g. daily and weekly), but we do not use quarterly data. Moving from daily data to quarterly data entails discarding a significant amount of important information on the systematic risk of the comparator companies, especially if pre-crisis data is not used due to an identified structural break. Moreover, the CMA (2015) decided against the use of quarterly data. See section 2.3.
(Finance Annex, para 3.103, bullet 4 and 5; also, para 3.106, bullet 7 and para 3.108, bullet 2 and 3) The choice of the estimation approach depends on the characteristics of the data. The weaknesses of the standard ordinary least squares (OLS) model should be considered. OLS and generalised autoregressive conditional heteroscedasticity	OLS models should produce an unbiased and consistent estimate of the beta coefficient. In theory, GARCH models are used to improve standard errors, not to correct for potential biases in the point estimate of the beta. As regards the selection of a GARCH model (or other) for analysis of each particular sample of data, this may not be practical in introducing a degree of regulatory unpredictability as regards model

[1] Ofgem (2018), 'RIIO-2 Sector Specific Methodology Annex: Finance', Consultation, 18 December, p. 39.
[2] Ofgem (2018), 'RIIO-2 Framework Consultation', para. 7.46.
[3] Recognising that there may be differences in levels of liquidity and data constraints, for different segments of the UK capital market. For example, if there is a higher degree of trading in listed equity, rather than the secondary trading that is observed in debt markets, then it may be appropriate to use daily data for equity capital markets analysis and monthly data for bond market analysis.

(GARCH) can provide similar estimations of equity beta, particularly when using a long period of outturn data. GARCH models come in many forms and any one specification may not be suitable for all companies.	selection for each price control, potentially even differentiated by company. See section 2.
(Finance Annex, para 3.103, bullet 6) Accounting information did not appear to provide a useful cross-check to the share price data.	Oxera has not assessed accounting information as a cross-check for raw equity betas derived from capital market data.
(Finance Annex, para 3.103, bullet 7; also, para 3.106, bullet 8 and para 3.108, bullet 1) International comparators may have limited value for estimating UK equity betas, due to differences in country-specific risk, tax and business environment, financial structure and tax regime, and potential differences in structural breaks within the time frame. There could also be differences in exchange rates and how regulatory frameworks differ over time. However, the sample set should be wider than the two pure-play water networks (Severn Trent and United Utilities).	Given the paucity of data on betas for UK energy networks (i.e. only National Grid and SSE are listed), it is appropriate to widen the sample. Notwithstanding differences in the jurisdictions and regulatory regimes, other listed European energy networks should be no less relevant as comparators than UK water companies. To test this, we find that the equity betas of comparator European energy networks track closely the equity beta of National Grid. This is market evidence that is consistent with investors' viewing these businesses as having similar movements in systematic risk, especially since 2015. Water company asset betas are on average than energy network betas. See section 2.1.
(Finance Annex, para 3.103, bullet 8; also, para 3.108, bullet 4) Regulators should be willing to exercise judgement in comparing the effects of de-gearing and re-gearing. There may not be a linear relationship between asset betas, equity betas and debt betas. Debt betas could be in the range of 0.05 to 0.22. Gearing ratios, in the exercise of de-gearing and re-gearing betas, may be appropriately adjusted for differences in enterprise value (EV) and regulatory asset value (RAV).	We do not agree with Ofgem's exercise of judgement in deriving an 'adjusted' gearing ratio to de-gear equity betas based on an assumption of an EV / RAV of 1.1x. For internal consistency, equity betas estimated using market data should be de-geared in line with the market-based estimate of the capital structure that underpins the observed share price movements. Ofgem's adjusted gearing approach produces a hybrid asset beta that reflects an assumed level of financial risk combined with the actual level of market risk—the resultant asset beta and re-geared equity beta are therefore unreliable and will be under-estimated given the 1.1x assumed multiple. We also provide current market evidence to demonstrate that our debt beta assumption of 0.05 is appropriate in setting allowed network returns for RIIO-2. See section 3 and 4.
(Finance Annex, para 3.103, bullet 9) It may be important to decompose beta estimates to reflect that listed stocks may include non-regulated businesses.	We agree that beta estimates would ideally comprise a sample of pure-play comparators. However, the disaggregation of betas is likely to involve a number of assumptions, and it is beyond the scope of this report to decompose beta estimates to exclude the effect of non-regulated businesses.
(Finance Annex, para 3.106, bullet 6 and Para 3.108, bullet 5) **Raw beta estimations are more reflective of actual investor costs and avoid the potential for the effects of gearing to be misunderstood.** De-gearing and re-gearing should be applied, but raw beta values should also be employed as a cross-check.	This report provides evidence consistent with the principle that higher financial risk is associated with higher expected returns, such that the use of raw betas is not reliable, for determining or cross-checking betas, as part of the allowed returns for RIIO-2. We note that CMA (2015) precedent also advocated controlling for differences in financial gearing between companies or over time to facilitate direct comparison between equity betas. See section 3.

Source: Oxera analysis and Ofgem (2018), 'RIIO-2 Sector Specific Methodology Annex: Finance', Consultation, 18 December.

Conclusions

As an overarching consideration, we observe that Ofgem is considering several changes to its previous estimation methodologies and assumptions in relation to beta and gearing. As acknowledged by Ofgem: 'we are also mindful of the benefit to investors and consumers of predictability and stability in regulatory policy and judgements'.[4] We consider that care should be taken when introducing new methodologies, which provide different results from the existing ones, unless their superiority over the existing methodologies is clear. Even then, companies invest in assets with lives greater than 25 years; as a result, changes in methodology that produce lower returns to investors should be introduced only gradually over several price controls.

In line with the summary table above, this report concludes the following.

1. The case for moving away from OLS models to potentially deploying case-by-case specifications of GARCH models is not robust.
2. Analysis of European network betas provides additional relevant data to a limited sample of UK utilities and indicates a higher beta for energy networks relative to water companies.
3. Use of post-crisis data is more relevant than a pre-crisis sample, in estimating betas. A time period of analysis of two to five years is in line with regulatory precedents, and any move away from this precedent should be made with caution and with good justification.
4. The use of low frequency (quarterly) data has not been substantiated in the context of regulatory price control settings.
5. Raw (i.e. before adjusting for differences between market and notional gearing) betas are not reliable in setting or cross-checking allowed returns for RIIO-2.
6. Ofgem's 'adjusted' gearing ratio is not reliable as it is inconsistent with the market-based gearing implicit in the equity betas; the resultant asset beta and re-geared equity beta are therefore unreliable and will be under-estimated given the 1.1x assumed multiple.
7. Current evidence supports a debt beta estimate of 0.05, which is considerably lower than the current 0.1 to 0.15 range assumed by Ofgem.

[4] Ofgem (2018), 'RIIO-2 Sector Specific Methodology Annex: Finance', Consultation, 18 December, paragraph 3.80.

Contents

Figures and tables

1 Introduction

In preparation for the RIIO-2 electricity and gas transmission and distribution price controls, the Energy Networks Association (ENA) has commissioned Oxera to provide advice on issues relating to the estimation of equity beta and how it is influenced by gearing.

This report investigates some of the areas where the methodologies and assumptions used by Ofgem may be leading to the incorrect estimation of allowed returns for energy networks in RIIO-2, i.e.

1. the methodology for estimating beta from market data;
2. the impact of gearing on the equity beta, including Ofgem's use of an 'adjusted' gearing ratio;
3. the estimation of debt beta.

The report is structured as follows:

- section 2 discusses the methodology for estimating beta from market data;
- section 3 reviews the impact of gearing on the equity beta;
- section 4 provides evidence on the debt beta estimate;
- section 5 concludes.

2 Econometric approach to beta estimation

In its RIIO-2 Framework Consultation in March 2018, Ofgem referred to estimates of the allowed equity beta for energy networks in the range of 0.3 to 0.5 as 'econometrically defensible'. This conclusion was based on a subset of earlier analysis undertaken for the UKRN (hereafter the 'MPW analysis'). According to Ofgem:

> equity betas, in the range 0.3 to 0.5, would be 'econometrically defensible' ie equity beta could be less than half the value (c 0.9) assumed for RIIO-1. The implication is that network companies are a lot less risky as investments than previously assumed.[5]

We note that the MPW analysis was presented as very preliminary, with a number of points for further investigation.

Subsequently, as part of its RIIO-2 Sector Specific Methodology, Ofgem and its consultants Indepen, provided further analysis of betas for RIIO-2. The mechanics that underpin Ofgem's raw equity beta range of 0.6–0.7 are not specifically stated. Instead, Ofgem suggests that its range is conservatively anchored on Indepen's range (i.e. a broad range of 0.55 to 0.7, and narrow range of 0.57 to 0.65, with 0.6 as a central estimate).[6]

In this section, we respond to a number of issues in relation to the econometric approach to beta estimation by MPW in the first instance, and by Indepen / Ofgem in the Sector Specific Methodology—where this builds on or departs from the approach taken by MPW.

Specifically, this section examines:

- the model for beta estimation;
- the comparator sample;
- the time series for the analysis; and
- relevant data frequencies, ranging from daily to quarterly data.

The common methodology used by UK regulators, including Ofgem, for estimating the cost of equity is the capital asset pricing model (CAPM). Appendix A1 provides more background on the CAPM, its limitations, and the reasons why it remains the common reference point for UK regulators, including Ofgem. The analysis that follows is therefore set within the context of the traditional CAPM framework for asset pricing.[7]

The standard econometric procedure for estimating betas is to run an ordinary least squares (OLS) regression of the actual excess return on the stock against the actual excess return on a broad market index. In the context of estimating the return for the whole UK equity market, the market index typically used is the FTSE All-share index. The slope of the regression corresponds to the equity beta, and measures the systematic or market-related relative risk of the stock (see Appendix A2). The generalised form of an OLS regression equation with a single explanatory variable is:

$$y_i = \alpha + \beta(x_i) + \varepsilon_i$$

[5] Ofgem (2018), 'RIIO-2 Framework Consultation', para. 7.46.
[6] Ofgem (2018), 'RIIO-2 Sector Specific Methodology Annex: Finance', Consultation, 18 December, p. 39.
[7] For further discussion on alternative asset pricing models, see Oxera (2018), 'The cost of equity for RIIO-2 – a review of evidence', Appendix 1.

where a linear relationship is modelled between the dependent variable (y) and the independent or explanatory variable (x). ε refers to an error term in the equation (i.e. the unexplained variation in the value of y). In OLS estimation, a common assumption is that the residual, i.e. the error term, will have constant variance.

Following from this, there are econometric challenges with estimating equity betas via the standard OLS procedure in a CAPM framework. Specifically, the error terms in a regression involving financial variables tend to be heteroscedastic (i.e. any variance is not constant) and autocorrelated (i.e. variance from one period to another is related over time).

Alternative techniques have been proposed to correct for potential biases in beta estimation.

First, to correct for any statistical bias due to measurement error, Vasicek (1973) proposed what is now referred to as the 'Vasicek adjustment'. The approach is to compute the beta estimate as a weighted average of the OLS estimate and a prior (or 'null') expectation. The magnitude of the shift (towards the 'null' expectation) is greater when the standard error of the OLS estimate is higher. Were the Vasicek adjustment to be used, its effect would be to bring the estimated beta coefficient closer to the prior expectation (e.g. if the prior expectation is estimated to be 1, a raw beta coefficient over unity would be reduced due to the Vasicek adjustment, and a raw beta coefficient under unity, as in the case of most utilities, would be increased). The Vasicek adjustment is rarely used by regulators, with a preference for using 'raw' (i.e. unadjusted) beta coefficients from OLS models.

Second, MPW and Indepen have advised Ofgem to consider the use of alternative models, including generalised autoregressive conditional heteroscedasticity (GARCH) models. We note that:

- UK regulatory precedents, including CMA decisions, have tended to use OLS models rather than GARCH models for beta estimation.
- GARCH models are commonly used to forecast and estimate asset volatility for a wide range of purposes, rather than to model expected asset returns.
- GARCH models tend to respond more quickly to structural changes in a data series, and are more useful for forecasting a few periods ahead with noisy and high-frequency data. Such models are useful when aiming to capture short-term dynamics (e.g. intra-day variation). As such, they would not appear immediately relevant in the context of a price control where the task is to estimate an equity beta over a five-year price control period.
- GARCH models are used, in theory at least, to improve standard errors, not to correct for potential biases in the point estimate of the beta. The use of GARCH instead of OLS models is not a key driver of differing beta estimates; rather, these models are ways to model variation over time in the residuals of equity beta regressions. In other words, heteroscedasticity would tend to affect the measurement of the error term and does not cause OLS beta estimates themselves to be biased:

  > What happens if the errors are heteroscedastic…? In this case, OLS estimators will still give unbiased (and also consistent) coefficient estimates…The reason is that the error variance, σ_2, plays no part in the proof that the OLS estimator is consistent and unbiased.[8]

[8] Brooks, C. (2014), *Introductory Econometrics for Finance*, 3rd Edition, Cambridge University Press, p. 183.

Moreover, as acknowledged by Ofgem's advisers:

> 'Various GARCH specifications exist and a process is needed to find the one that best characterises a given company's data. This leads us to company specific solutions.'[9]

If using alternative models, the regulator will need to be cautious to avoid model over-fitting or over-identification problems. Ofgem will also want to ensure that it can clearly communicate its analysis to external stakeholders. Introducing company-specific models for beta estimation, which may then change over time, will lead to a degree of regulatory subjectivity and unpredictability. Care should be taken when introducing new methodologies, which provide different results from the existing ones, and where company-specific solutions would introduce a degree of regulatory subjectivity in model selection, unless their superiority over the existing methodologies is clear.

2.1 Comparator sample

The MPW analysis of equity betas was based on only two water companies. To produce robust beta estimates of relevance to energy networks, the empirical analysis requires a larger sample that includes energy networks. Ofgem acknowledged that a wider sample should be considered.[10] Indepen's analysis comprised National Grid, Pennon, SSE, Severn Trent, United Utilities and BT.[11]

It is straightforward to conduct the beta estimation for companies publicly listed on a stock exchange, as all the required data is available in the public domain. For companies that are not listed, listed companies need to be identified as comparators. The observable equity betas for these comparator companies would then need to be adjusted for the level of leverage for the company in question in order to be comparable. As we set out in our February 2018 report, to enable a robust estimation of the beta, it is important to ensure the availability of data and sufficient liquidity of stocks. Furthermore, when estimating the beta for a particular economic activity, the main challenge is finding publicly listed companies that are largely involved in the specific activity of interest. Beta estimates would ideally comprise a sample of pure-play regulated comparators.[12]

In the UK there is a paucity of equity market data on energy companies, with only National Grid and SSE as publicly listed UK networks. The remaining listed UK networks are water companies (i.e. Pennon Group, Severn Trent and United Utilities). We note that the CMA (2015) used a sample of UK utilities for beta analysis.[13] However, while this may have been appropriate in determining allowed returns for Bristol Water with reference to three UK water companies, the sample would be even smaller with only two listed UK energy networks, especially if SSE is excluded from the analysis.

A priori, it is reasonable to assume a difference in the systematic risk exposure of energy and water companies, e.g. due to structural changes over time and

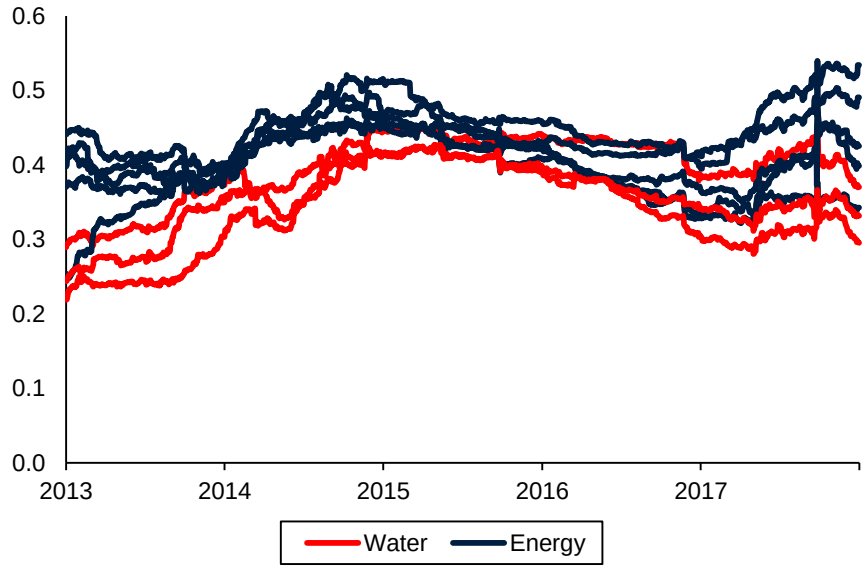
[9] Indepen (2018), 'Ofgem Beta Study — RIIO-2 Main Report', December, p. vii.
[10] Ofgem (2018), 'RIIO-2 Sector Specific Methodology Annex: Finance', Consultation, 18 December, paragraph 3.108.
[11] Indepen (2018), 'Ofgem Beta Study — RIIO-2 Main Report', December, p. 7.
[12] Or be 'disaggregated' to reflect the risk of the relevant regulated business within the observed group beta; however, the disaggregation of betas is likely to involve a number of assumptions, and it is beyond the scope of this report to decompose beta estimates to exclude the effect of non-regulated businesses.
[13] Competition and Markets Authority (2015), 'Bristol Water plc, A reference under section 12(3)(a) of the Water Industry Act 1991', Appendices 5.1 – 11.1 and glossary, A10(1)-20, para. 86.

different regulatory regimes. We note Ofgem's concern that there would also be differences in UK energy networks relative to European energy networks, including jurisdictional differences. Nonetheless, given the paucity of available data on listed energy networks, we have increased the sample of comparators beyond listed UK utilities. Other listed European energy networks should be no less relevant as comparators, in informing a range of reasonable asset beta estimates, than UK water companies. To test this, we have analysed data that shows how the equity betas of European energy networks closely track the equity beta of National Grid (particularly since 2015, see figures below).[14] This is consistent with investors viewing these European businesses as having broadly similar movements in systematic risk.

Specifically, as we showed in our February 2018 report, in the past couple of years the asset betas for the energy networks in the European comparator group have converged, and are more stable than they used to be. This close relationship may be due to the fact that the macroeconomic situations of the European countries in question have stabilised relative to the euro crisis period and become more comparable to the UK.

Figure 2.1 provides an update of the two-yearly rolling daily asset betas for UK energy networks and water companies as well as other listed European energy networks. This shows that water company asset betas have on average been lower than energy network asset betas.

Figure 2.1 Two-year rolling asset betas for UK and European utility companies



Note: Asset betas were estimated relative to the FTSE All-share index for the UK companies and the Europe Total Market Index for the other European companies. We have assumed a debt beta of 0.05. The water companies are: United Utilities Group, Severn Trent and Pennon Group, while the energy companies are: National Grid, Enagas, SNAM, Red Eléctrica and Terna. SSE has been omitted from the comparator sample due to a high proportion of non-regulated activities. The cut-off date for the analysis presented in this report is 1 October 2018.

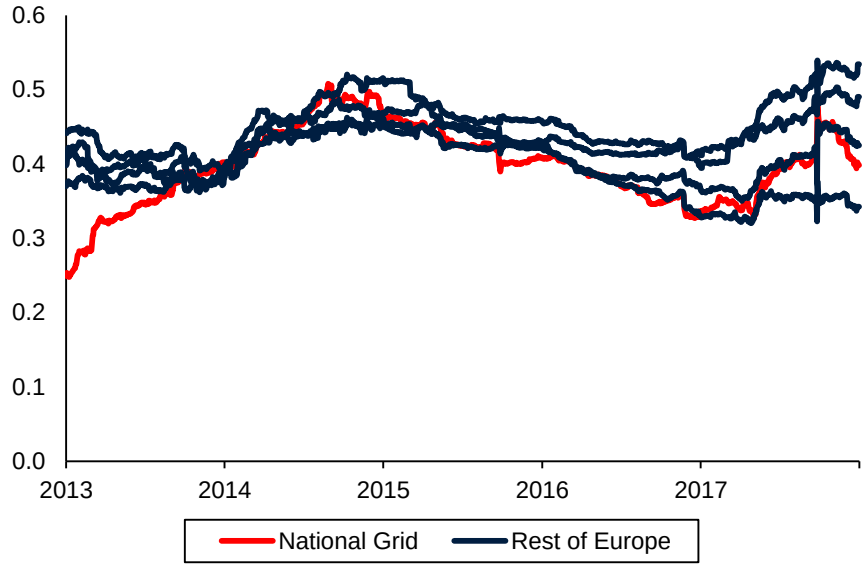
Source: Oxera analysis based on Bloomberg data.

Figure 2.2 provides an update of the two-yearly rolling daily asset betas for National Grid as well as European energy networks. We find that the asset betas of comparator European energy networks track the asset beta of

[14] The comparator energy networks are: Enagas, SNAM, Red Eléctrica and Terna.

National Grid closely in recent years. This is consistent with investors' viewing these businesses as having similar movements in systematic risk.

Figure 2.2 Two-year rolling asset betas for National Grid and European energy networks



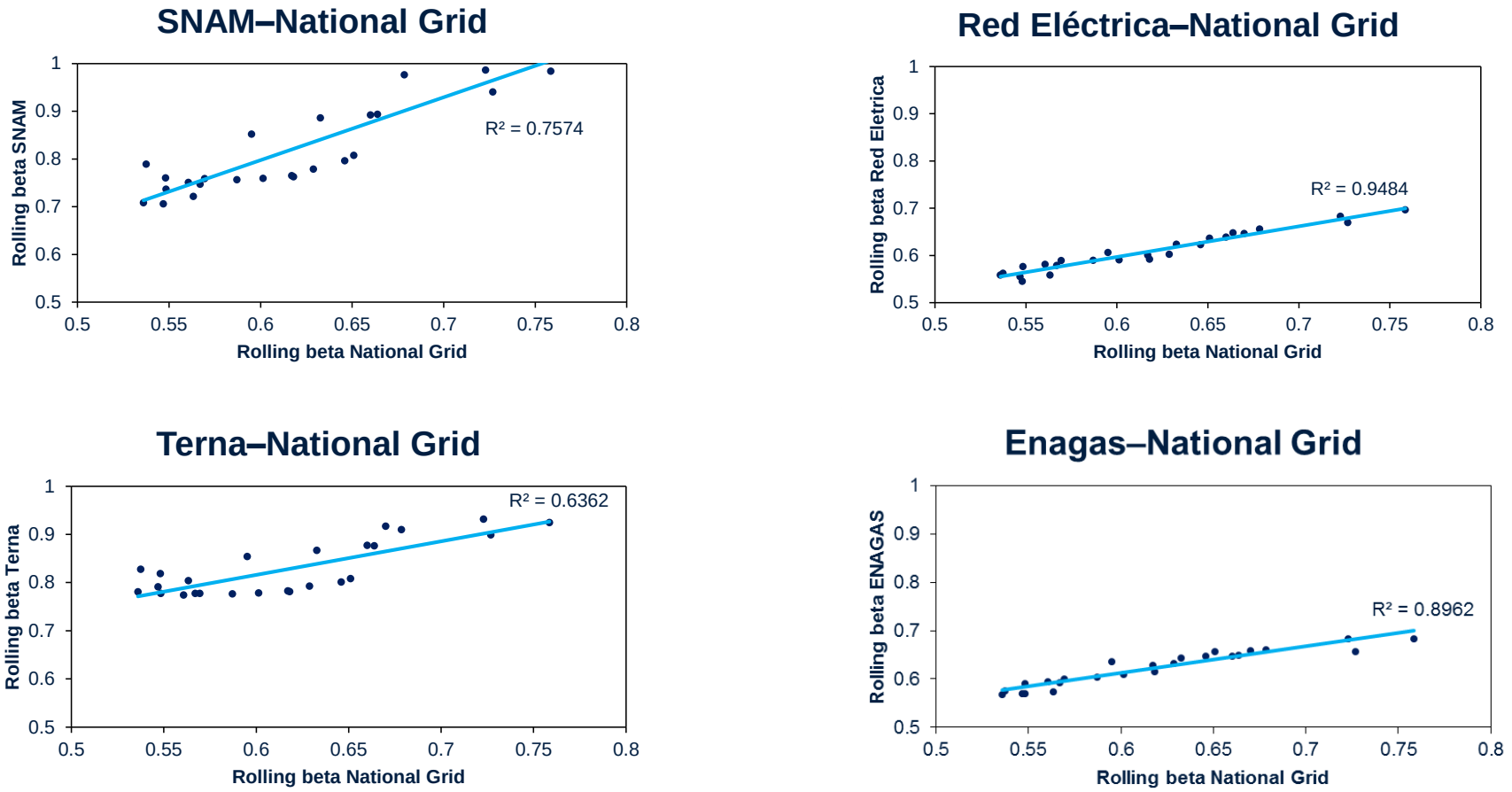
Note: Asset betas were estimated relative to the FTSE All-share index for the UK companies and the Europe Total Market Index for the other European companies. We have assumed a debt beta of 0.05. The European companies are Enagas, SNAM, Red Eléctrica and Terna. SSE has been omitted from the comparator sample due to a high proportion of non-regulated activities. The cut-off date for the analysis presented in this report is 1 October 2018.

Source: Oxera analysis based on Bloomberg data.

There is a high degree of correlation between the asset betas of National Grid and other European energy networks. Figure 2.3 below shows that the relationship between changes in the equity betas of each of the European comparators and National Grid has been approximately linear over the last two years and that a high proportion of the changes in the comparator betas can be explained by changed in the National Grid beta (the R-squared metrics are high).

This evidence supports our previous analysis based on a broader set of comparators, including European energy companies, to expand the sample size for the estimation of equity betas for RIIO-2.

Figure 2.3 The relationship between UK and European energy utilities over the last two years



Note: The charts plot National Grid's rolling equity beta against the rolling equity beta of four European utility companies, using daily data and a rolling window of two years between 1 October 2016 and 1 October 2018.

Source: Oxera analysis based on Bloomberg data.

2.2 Period of analysis

The selection of the time period for analysis is a relevant consideration. In theory, a longer time period increases the number of observations in the regression, which should reduce the standard error of the beta estimates and make them more reliable.

MPW recommends using the full sample of available data unless there is clear statistical evidence of structural shifts.[15] We have analysed the full time series of available data and provide evidence of structural breaks in the time series. We note that Ofgem's advisers (Indepen) concur that there is a significant break in the time series for UK utilities in September/October 2008.[16] We are therefore more cautious than MPW about using the full time series of available data to forecast betas for UK networks.

As cited by Ofgem, Indepen recommends the use of as long a time series as possible, in analysing betas:

> All of the UK network companies showed structural breaks at some point in the period of the Global Financial Crisis of 2008-09. Indepen recommends that it is appropriate to use relatively more recent periods that are free from structural breaks. However, given the time varying (and mean reverting) nature of observed betas, and the need for the regulator to make longer-term forecasts, as long a time period as possible is recommended when estimating betas.[17]

If systematic risk is changing over time, using a longer time period might be less relevant for assessing a company's forward-looking exposure to market risk. Furthermore, the beta risk of a company also changes over time for a variety of reasons, including changes in the business mix through acquisitions and disposals, and changes in demand for, and market perceptions of, certain business activities. On the other hand, the use of longer term data may be appropriate to assess the extent to which betas exhibit mean-reversion, e.g. over the economic and regulatory cycles.

We have analysed the full sample of available data for a wider group of comparators, including energy networks. We provide evidence of structural breaks in the time series. Moreover, we show that, over time, the leverage of these companies has changed. Once leverage is controlled for by estimating asset betas, there appears to be no basis for the statement that 'network companies are a lot less risky as investments than previously assumed.'[18]

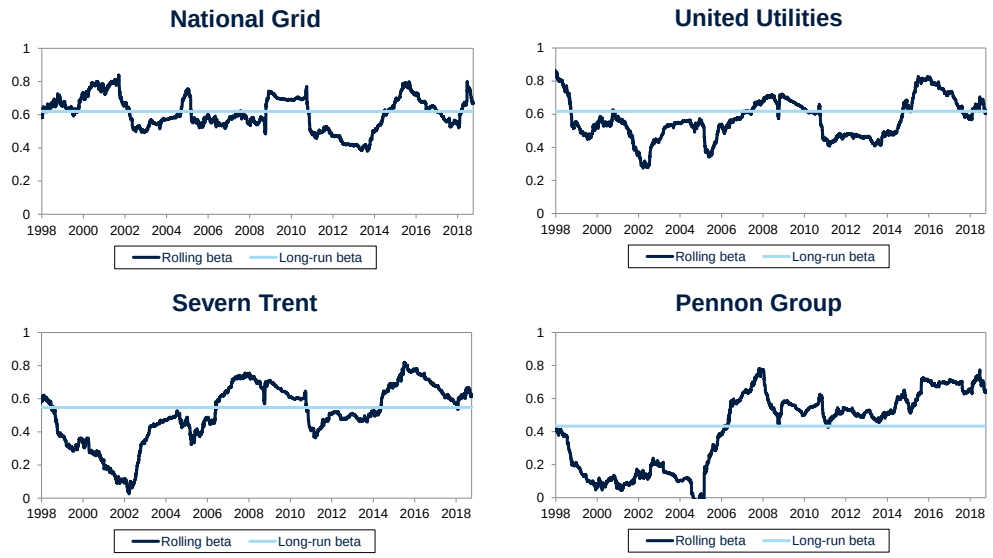
First we have estimated the equity beta using all available data for:

- National Grid (1995–2018);
- United Utilities Group (1990–2018);
- Severn Trent (1991–2018);
- Pennon Group (1990–2018).

Figure 2.4 plots the equity beta estimates using the full sample of data for each company against its beta estimated with a two-year rolling window.

[15] See Wright, S., Burns, P., Mason, R. and Pickford, D. (2018), 'Estimating the cost of capital for implementation of price controls by UK Regulators: An Update on Mason, Miles and Wright (2003)', 6 March, p. 152.
[16] Indepen (2018), 'Ofgem Beta Study – RIIO-2, Main Report, Final', December, p. 6.
[17] Ofgem (2018), 'RIIO-2 Sector Specific Methodology Annex: Finance', Consultation, 18 December, paragraph 3.103.
[18] Ofgem (2018), op. cit. para 7.46.

Figure 2.4 Full sample rolling equity betas



Note: Equity beta of UK utility companies with the FTSE All-share as the market index. The rolling beta has been estimated using a two-year window of daily observations, while the long-run beta refers to the OLS parameter estimation using all data available. The cut-off date for the analysis presented in this report is 1 October 2018.

Source: Oxera analysis based on Bloomberg data.

Table 2.1 Full sample estimates of equity beta

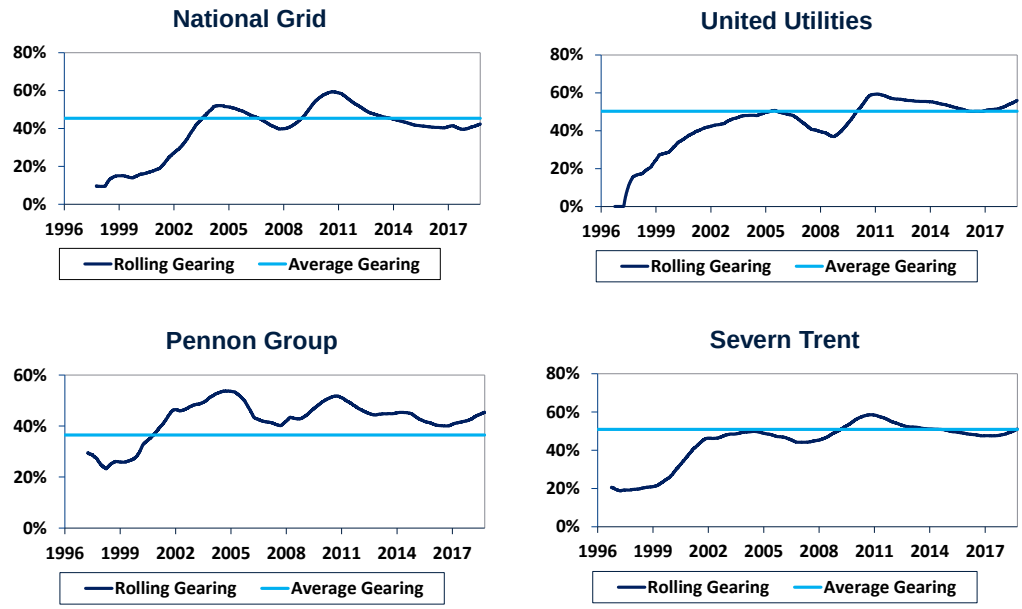
Sample period	National Grid	United Utilities	Severn Trent	Pennon Group
Last two years	0.653	0.606	0.626	0.636
Last five years	0.649	0.692	0.691	0.679
Last ten years	0.656	0.622	0.617	0.608
All data	0.603	0.656	0.591	0.448

Source: Oxera analysis based on Bloomberg data.

Table 2.1 sets out the overall results, which indicate that using all available data leads to slightly lower equity betas than the current point in time (two-year rolling beta) estimates for National Grid, Severn Trent and Pennon Group, and a slightly higher equity beta for United Utilities Group.

One of the reasons why we are more cautious about using all available data is that the leverage of these companies has changed. Therefore, any analysis of the risk of the companies over the full sample period needs to focus on a comparison of asset betas, not equity betas. Figure 2.5 shows how the market leverage of the companies has increased over time.

Figure 2.5 Full sample gearing ratios



Note: The cut-off date for the analysis presented in this report is 1 October 2018.

Source: Oxera analysis based on Bloomberg data.

For illustration we have compared the estimates for equity and asset betas using the full time series and the last two-year rolling window. For National Grid, the equity beta estimated over the last two years of data is slightly higher than the average of the full time series. However, after controlling for leverage, the asset beta is broadly similar. The asset betas for the other companies are either higher based on all available data than the current point in time (two-year rolling beta) for United Utilities, or lower for Severn Trent and Pennon Group.

Accordingly, once leverage is controlled for, there appears to be no basis for the statement that 'network companies are a lot less risky as investments than previously assumed.'

Table 2.2 Full sample estimates of asset beta

Sample period	National Grid	United Utilities	Severn Trent	Pennon Group
Last two years	0.399	0.296	0.331	0.370
Last five years	0.401	0.352	0.374	0.409
Last ten years	0.374	0.308	0.322	0.355
All data	0.393	0.363	0.314	0.262

Notes: To compute these asset betas, a debt beta of five basis points (bp) is assumed. The cut-off date for the analysis presented in this report is 1 October 2018.

Source: Oxera analysis based on Bloomberg data.

We performed statistical (Chow) tests for structural breaks in the data series around three events:

- the dotcom crisis—11/03/2000;
- the global financial crisis—15/09/2008;
- the UK referendum on membership of the EU—23/06/2016.

Table 2.3 presents the results of the analysis we have undertaken to test for the presence of structural breaks. Specifically, we undertake Chow tests[19] to identify structural breaks in the rolling equity betas of National Grid, United Utilities, Severn Trent and Pennon Group.[20] We find some evidence to suggest market-wide structural breaks in the series around the dotcom bubble, the global financial crisis and the EU referendum. As shown in the table, given that for all companies in the sample, there is a structural break at the time of the dotcom crisis and the financial crisis, this suggests that using data since 2008 would be preferable to using the whole sample of data (i.e. since the 1990s). There is still a question about how to deal with the EU referendum in this analysis. Notwithstanding that the data supports a structural break in equity betas coinciding with the EU referendum, discarding the most recent data may not be feasible in undertaking analysis for setting allowed returns in RIIO-2. This is because the most recent data contains the most up-to-date information about the perceived risk of the businesses, given their current operations, leverage, and regulatory regime expectations.

A conclusion from this analysis of structural breaks would be not to use pre-2008 data when examining market evidence on asset betas for listed UK utilities. Consistent with this, we observe that Ofgem's advisers, Indepen, have de-emphasised the use of data over the period 2000 to 2018 because:

> it has limited value given at least one major structural break in the relationships [September/October 2008].[21]

Table 2.3 Results of Chow tests for structural breaks on rolling equity betas

Companies	Dotcom crisis	Financial crisis	EU referendum
National Grid	✓	✓	✓
United Utilities	✓	✓	✓
Severn Trent	✓	✓	✓
Pennon Group	✓	✓	✓

Note: ✓ = structural break identified; × = no structural break identified.

Source: Oxera analysis.

The question then remains whether the full period since 2008 is equally relevant in examination of market data on asset betas for listed UK utilities. The CMA addressed this question in its decision for Bristol Water (2015), concluding that using market data for a period of up to five years would achieve an appropriate trade-off between having a sufficiently large sample size and allowing for changes in the risk profile of utilities over time:

> 94. Looking at the observed asset beta estimates over time in Figures 6 and 7, it appeared to have displayed a certain variability over time. Since CAPM is a single-period model, using an unsuitably long time period would risk introducing inconsistencies into the analysis. For example, this analysis would have spanned multiple AMPs [regulatory price control periods] with different regulatory frameworks.
>
> 95. On the other hand, over-reliance on short-term beta may be distorted by specific events, for example, any uncertainty associated with the price review process itself.

[19] The Chow test is an econometric test of whether the coefficients in two linear regressions, on different data sets, are equal. This is typically used in time series analysis to test for the presence of a structural break.
[20] See Chow, G. (1960), 'Tests of equality between sets of coefficients in two linear regressions', *Econometrica*, **28**:3, pp. 591–605.
[21] Indepen (2018), op. cit., pp. xii and 6.

> 96. Therefore, we considered that an analysis which includes different timings up to five years remains the most appropriate periods of time to include in this analysis.[22]

In summary, this analysis provides evidence that the full sample of available data contains structural breaks attributable to market events, especially around the global financial crisis such that the use of post-crisis data is more appropriate than pre-crisis data. There may be other factors driving shifts in the betas over time, such as changing business risk and leverage. A time period of analysis of two to five years is in line with regulatory precedents, and any move away from this precedent should be made with caution and with good justification. In this context, we note by examination of UK networks betas over the full time period for which data is available, that once leverage is controlled for, there appears to be no basis for the statement that 'network companies are a lot less risky as investments than previously assumed.'

2.3 Data frequency

Another important issue concerns the frequency of data used in the regression.

MPW argues for the use of low frequency (i.e. quarterly) data. Using quarterly instead of daily data is a key driver of the low estimates obtained by MPW, driving a 0.24–0.27 reduction in its reported OLS betas for United Utilities and Severn Trent.[23] The MPW analysis justifies quarterly data by lower variance in volatility. However, there is no explanation of why changes in volatility (heteroscedasticity) might lead to biased beta estimates, and therefore no justification for putting weight on low-frequency data in the context of a regulatory price control.

In contrast to MPW, it is notable that Indepen has not explicitly endorsed the use of quarterly data—it presents only daily, weekly and monthly estimates.[24] From a statistical point of view, it is generally the case that the more data points in the analysis, the more robust the results. There is a limit to this due to some econometric challenges with very high frequency (intra-day) data, including that:

- trades occur at irregularly spaced random intervals, which presents challenges for standard econometric models. Observations are unlikely to be identically distributed as some are very closely spaced in time, while others may be separated by hours;
- transaction prices are always quoted in discrete units, based on the tick sizes of the asset;
- the presence of the bid–ask spread complicates statistical analysis. Instead of one price for each security, there are now three: the bid price, the ask price, and the transaction price. As random buys and sells arrive, the market prices can bounce back and forth between the ask and the bid prices. This creates spurious volatility and serial correlation in returns, even if the economic value of the security is unchanged. This phenomenon is often referred to as the *bid–ask bounce* and is a common challenge for analysis with intra-day data.

In practice, daily (end of day) data does not pose the same challenges as intra-day data.

[22] Competition and Markets Authority (2015), op. cit.
[23] Wright et al. (2018), p. G-148.
[24] Indepen (2018), 'Ofgem Beta Study – RIIO-2, Main Report, Final', December, Table 2.3.

Choosing lower-frequency data comes at the cost of losing some information in the process. As mentioned earlier, the use of quarterly instead of daily data is a key driver of the low estimates obtained by MPW, driving a 0.24–0.27 reduction in its reported OLS betas for United Utilities and Severn Trent.[25] Moving from daily data to quarterly data entails discarding a significant amount of important information on the systematic risk of the comparator companies.[26] This is particularly the case if there are structural breaks, as acknowledged by Indepen, such that the use of pre-2008 data would not be appropriate.

In considering the question of data frequency for beta estimation, the CMA (2015) explicitly decided against the use of quarterly data:

> 'We did not use quarterly betas in this review as a result of the evidence that betas have not been stable over the period, which casts doubt on the reliability of this data.'[27]

There is also an argument, within the UKRN report itself, against the MPW position of using quarterly data, on the grounds that this is highly unusual with reference to academic studies and commercial providers of beta estimates. Specifically, Phil Burns responded to MPW within the UKRN report that:[28]

> MPW's results based on higher frequency data are recognisably similar to the existing regulatory estimates over the relevant time-frames, but MPW also adopt the highly unusual practice of estimating the CAPM on quarterly data, which is the key factor that drives the lower estimates of beta. **It should be noted that using quarterly frequency data is unusual in academic studies and is not used by any commercial provider**. As it stands it does not satisfy the criteria used in this report. [emphasis added]

We have also noted Ofgem's distillation of a recommendation from Indepen that the choice of estimation approach (including which of various specifications of GARCH is preferred), depends on the characteristics of the data, and may vary by company.[29] We consider that this may not be practical in a regulatory price control setting, if it introduces a degree of regulatory unpredictability as regards model selection for each price control, potentially even differentiated by company.

Accordingly, the arguments against the use of quarterly data for beta estimation are numerous. Beta analysis is sensitive to the chosen data frequency; using daily estimates, MPW would derive considerably higher beta estimates using both GARCH and OLS methods.[30]

[25] Wright et al. (2018), op. cit., p. G-148.
[26] As an example, assuming that an illustrative post-crisis period being examined is 1 January 2009 to 1 October 2018, there would be 2460 daily data points, but only 117 monthly data points and 39 quarterly data points.
[27] Competition and Markets Authority (2015), 'Bristol Water plc, A reference under section 12(3)(a) of the Water Industry Act 1991', Appendices 5.1 – 11.1 and glossary, A10(1)-22, para. 92.
[28] Wright et al. (2018), op. cit., p. 9.
[29] Ofgem (2018), op. cit, p. 36
[30] See for example, Wright et al. (2018), op. cit., Table 1, p. G-148.

3 Gearing

This section responds to other issues raised by MPW or as part of the Sector Specific Methodology, in relation to gearing.

- First, we provide evidence consistent with the principle that higher financial risk is associated with higher expected returns, such that the use of raw betas unadjusted for differences in gearing is not reliable, for determining or cross-checking betas, as part of the allowed returns for RIIO-2.
- Second, we observe, and do not agree, with Ofgem's use of an 'adjusted' gearing ratio to de-gear equity betas based on an assumption of an EV / RAV of 1.1x. This is not compatible with the assumptions of the CAPM and more specifically the equation for linking asset and equity betas. For internal consistency, equity betas estimated using market data should be de-geared in line with the market-based estimate of the capital structure that underpins the observed share price movements.

3.1 Raw equity betas are not reliable in setting or cross-checking allowed returns

The previously quoted statement that 'equity betas, in the range 0.3 to 0.5, would be "econometrically defensible"'[31] is based on gearing derived from market values of gearing, rather than the regulator's notional gearing assumption. Ofgem also states in the Finance Annex of the Sector Specific Methodology:

> we disagree with the argument that the consideration of raw equity betas (absent the effect of any gearing adjustments) has no merit. Raw beta estimations are more reflective of actual investor costs and avoid the potential for the effects of gearing to be misunderstood[32]

We disagree that raw equity betas are informative where there is a significant difference between the market value of gearing for comparators, and the notional gearing assumption that is relevant in the context of the price control. Finance theory predicts that the cost of equity increases with leverage.[33] Therefore, if Ofgem sets a price control based on a notional gearing assumption that differs from market gearing ratios for comparators, then the equity beta for each comparator should be de-levered using its own gearing ratio prior to being re-levered at the notional gearing ratio.

The value of a company is determined by its expected cash flows. When the company issues debt and equity securities, it undertakes to split up the cash flows into two streams: a relatively safe stream of cash flows that goes to the debt holders, and a more risky one that goes to the shareholders.

The 'capital structure irrelevance' proposition developed by Modigliani and Miller (1958)[34] (MM) proves that, under certain conditions, the total value of the company—that is, the value of all claims over the company's income—is independent of the financial structure.[35]

[31] Ofgem (2018), 'RIIO-2 Framework Consultation', para. 7.46.
[32] Ofgem (2018), 'RIIO-2 Sector Specific Methodology Annex: Finance', Consultation, 18 December, paragraph 3.106.
[33] According to the second proposition of Modigliani and Miller (MM II), as the share of the company financed by debt increases, the required return to equity increases due to higher financial risk.
[34] Modigliani, F. and Miller, M. (1958), 'The Cost of Capital, Corporation Finance and the Theory of Investment', *The American Economic Review*, **48**:3, pp. 261–97.
[35] These conditions include no taxes; no bankruptcy costs; no agency costs; and no costs of adjusting the capital structure.

Modigliani and Miller's first proposition (MM Proposition I) implies that the level of debt, the split of debt claims into debt claims with different levels of collateral and different seniorities in the case of bankruptcy, dividend payout, and many other characteristics or policies relative to the financial structure have no impact on total company value.[36]

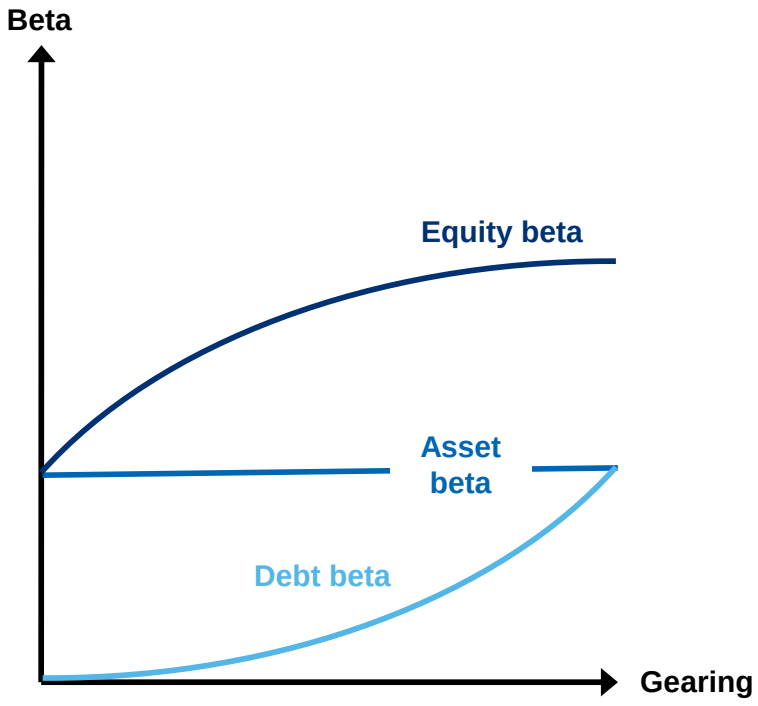
Modigliani and Miller's second proposition (MM Proposition II) establishes a positive relationship between leverage and equity returns that is ordinarily applied to compute the cost of equity for different levels of leverage.

As the share of the company financed with debt increases, both the equity and the debt become riskier and their cost rises. Yet, because more weight is put on the lower cost of debt, the weighted average cost of capital (WACC) remains constant.

Figure 3.1 below illustrates the effect of increasing the amount of gearing in a company's capital structure on its cost of equity, its cost of debt, and its overall WACC. With no debt, the WACC is equal to the unlevered cost of equity. As gearing increases:

- the cost of debt rises due to the increase in the risk of the company defaulting on its debt obligations;
- the cost of equity rises, as equity beta increases with higher financial risk.
- the WACC remains constant.

Figure 3.1 Relationship between gearing and cost of equity



Source: Oxera.

Subsequent to MM, many theories have been developed on the determinants of the capital structure of firms, including pecking order theory, free cash flow, trade-off theory and target capital structure. Some of these theories may be competing and others not. Moreover, they do not necessarily violate the

[36] See, for example, Tirole, J. (2010), *The Theory of Corporate Finance*, Princeton University Press.

relationship between gearing and the risk of equity (through beta and the CAPM). However, controlling for these possible theories to test the MM II relationship between gearing and the risk of equity is fraught with difficulty. It is not surprising that the empirical evidence does not give us clear answers.

Application to UK utilities

Ofgem has made it clear through its communications and the structure of the regulatory regime that the risks of gearing sit with shareholders. This is supported by a number of factors.

- A special administration regime is in place to manage the insolvency of energy companies. This reduces the likelihood of costs falling on customers or taxpayers in the event of distress.
- Company licences include a requirement to maintain an investment rating, where failure to do so would lead to lock-up and ultimately a breach of licence. There are also restrictions on the disposal of assets and the activities of the regulated business.
- There is a broader trend towards greater ring-fencing[37] of regulated assets. Credit rating agencies have recently pointed out that tighter contractual restrictions around the regulated business and stricter rules about the financial risk profile can amplify the subordination of holding company investors, especially where distribution triggers may prevent the free movement of cash within a group.[38]

In terms of relevant regulatory precedent, we note that CMA (2015) precedent has also advocated controlling for differences in financial gearing between companies or over time to facilitate direct comparison between equity betas.[39]

Concluding remarks

Finance theory, the design of the regulatory regime in the UK, and regulatory precedent are all supportive of an assumption that the cost of equity increases with leverage.

Therefore:

- we do not consider that raw equity betas are informative, where there is a significant difference between the market value of gearing for comparators, and the notional gearing assumption that is relevant in the context of the price control;
- equity betas presented at different levels of gearing should be re-levered to account for the impact of gearing on financial risk and the level of required equity returns.

3.2 Ofgem's adjusted gearing ratio

In its Sector Specific Methodology, Ofgem uses an 'adjusted' gearing ratio to de-gear equity betas, rather than a market value of gearing. The adjustment is anchored on an assumed differential in enterprise value (EV) and regulatory asset value (RAV), i.e. EV/RAV ratio of 1.1x. In support of this approach, Ofgem cites Indepen, as below:

[37] For a summary of the ring-fencing provisions, see UKRN (2018), 'UKRN Cost of Capital Annual Update Report', Table A2.
[38] Moody's (2018), 'Covenanted financing structures help mitigate growing risks', 9 October.
[39] Competition and Markets Authority (2015), op. cit.

> it is potentially inconsistent to de-gear raw betas using one definition of gearing (Net debt / Enterprise Value (EV)) and then re-gear equity betas using a different definition of gearing (Net debt / RAV). If the Enterprise Value is larger than RAV, then by de-gearing and regearing, the notional equity beta may be overestimated. For the relatively pure play UK utility companies, recent EV/ RAV ratios have been about 1.1x and these are reflective of average values since 2015…Therefore, it may be appropriate to adjust the observed EV gearing for the purpose of re-gearing betas to a notional RAV gearing level.[40]

The mechanics of Ofgem's adjusted gearing ratio calculation appear to be the following:[41]

- First, Ofgem assumes a raw equity beta range of 0.6 to 0.7;
- Second, Ofgem observes an average of the market value of gearing on October 19th for five networks—50.8%;
- Third, Ofgem multiplies the 50.8% estimate by an assumption of an EV / RAV ratio of 1.1x, to obtain an 'adjusted' gearing ratio of 56% which can be interpreted as net debt / RCV;[42]
- Fourth, Ofgem obtains an asset beta of 0.35 to 0.36 by de-gearing the equity beta range of 0.6–0.7 by 56% (assuming additionally that the debt beta range is 0.10–0.15);
- Fifth, the asset beta range is re-geared using a notional gearing assumption of 60%.

These calculations for de-gearing and re-gearing are prone to both mechanical and conceptual error.

Firstly, it is not appropriate to de-gear equity betas as a batch, by assuming an average gearing level. As we have shown in section 2.2, there is a spread in both the raw equity beta estimates, as well as the gearing ratios of UK utilities. Each company should be separately de-geared, using its own market gearing ratio that reflects the average of the gearing over the period.

Secondly, it is not appropriate to adjust the market gearing ratio by an 'adjusted' ratio which reflects an assumed differential between EV and RAV ratios of 1.1x. This is not compatible with the assumptions of the CAPM and more specifically the equation for linking asset and equity betas. Ofgem's adjusted gearing approach produces a hybrid asset beta that reflects an assumed level of financial risk combined with the actual level of market risk—the resultant asset beta and re-geared equity beta are therefore unreliable and will be under-estimated given the 1.1x assumed multiple.

There is also a potential interdependence between regulatory decisions and traded market-to-asset (or EV to RAV) ratios, such that assuming a normal relationship of 1.1x is not reliable. Ofgem has cited evidence from its own advisers that shows the volatility of traded EV to RAV ratios, and that the ratio can also be less than one.[43]

[40] Ofgem (2018), 'RIIO-2 Sector Specific Methodology Annex: Finance', Consultation, 18 December, paragraph 3.103.
[41] Ofgem (2018), 'RIIO-2 Sector Specific Methodology Annex: Finance', Consultation, 18 December, Table 12.
[42] I.e. assume ND/EV * EV/RCV = ND/RCV
[43] Ofgem (2018), 'RIIO-2 Sector Specific Methodology Annex: Finance', Consultation, 18 December, p. 43.

Thirdly, it is not reasonable to de-gear market observations of equity betas with anything other than market observations of the capital structure. The exercise of de-gearing is undertaken to control for differences in capital structure, or financial risk, between comparators to obtain a like-for-like comparison. While there may be an argument that the more relevant measure of gearing for debt investors is net debt to RAV, equity investors are exposed to deviations of market value from RAV. Internal consistency therefore requires that equity betas estimated using market data should be de-geared in line with the market-based estimate of the capital structure that actually underpins the observed share price movements.

In summary, we consider that Ofgem's de-gearing assumption is not appropriate. To obtain an asset beta range, each company should be separately de-geared using an average of its market value of gearing (i.e. net debt to RAV) over the period for which the beta estimation is being undertaken.

4 Debt beta

We observe that Ofgem is assuming a debt beta of 0.1–0.15 in its Sector Specific Methodology,[44] while we had an assumption of a 0.05 debt beta, in our February 2018 report for the ENA on the cost of equity for RIIO-2.[45] Accordingly, we examine further evidence on debt betas in this section.

The debt beta measures the sensitivity of the bond's return to the market return. If the debt is risk-free, the debt beta would be zero. In practice, even for very safe companies (e.g. with credit ratings of AA to AAA), the debt beta cannot really be zero. If a company's debt is traded, the debt beta can be estimated by regression. However, there are few published estimates of the value of debt betas, and more uncertainty around the estimates.

For this report, we have estimated the debt beta for bonds issued by publicly listed regulated companies. We have followed the approach used in Schaefer and Strebulaev (2008).[46] Our analysis has been undertaken in conjunction with Professor Schaefer, using up-to-date market evidence. To estimate the debt betas, we consider sterling-denominated bonds issued by UK regulated companies from 1998 to 2018. We have extended our analysis by combining the bonds of each company into a portfolio and examining the relationship between debt betas, maturity and issue date.

We have not supplemented the quantitative estimate of debt beta with a qualitative assessment of the potential impact on debt betas (if any) of changes in the proposed regulatory regime for RIIO-2. The net impact (if any) of return adjustment mechanisms or cash flow floor mechanisms on the systematic risk exposure of debt investors is not known at this stage, as the mechanisms are still being calibrated. For example, S&P has commented: [47]

> We recognize Ofgem's effort to balance the interests of consumers and investors by introducing new mechanisms such as the cash flow floor and return adjustment mechanisms. However, we see limited credit value in the proposed mechanisms, notably because of their complexity and because we expect that our investment-grade rated networks will maintain sufficiently solid liquidity profiles not to trigger them.

Many of the estimates of debt beta are not statistically significantly different from zero, and the average estimate across the full sample is 0.01. If the sample is censored by removing estimates that are not statistically significantly different from zero, then the average estimate increases to 0.03, and the estimate for National Grid is also 0.03.

There is some evidence that the debt beta of National Grid has increased over time based on the censored sample, although the uncensored sample suggests a decline.

The estimated coefficients are slightly higher when considering bonds with longer time to maturity. This is in line with the financial theory that longer bonds are more risky than shorter bonds as they are more exposed fluctuations in the value of the issuing firm's assets.

[44] Ofgem (2018), 'RIIO-2 Sector Specific Methodology Annex: Finance', Consultation, 18 December, Table 12.
[45] See Oxera (2018), 'The cost of equity for RIIO-2—a review of the evidence', prepared for the Energy Networks Association, 28 February.
[46] Schaefer, S., and Strebulaev, I. (2008), 'Structural models of credit risk are useful: Evidence from hedge ratios on corporate bonds', *Journal of Financial Economics,* **90:**1, pp. 1-19.
[47] S&P Global Ratings (2019), 'Ofgem's Proposed RIIO-2 Regulatory Framework Will Test U.K. Energy Networks', February 20, p. 1.

Overall, the results of our analysis are consistent with the 0.05 debt beta assumed in our February 2018 report for the ENA on the cost of equity for RIIO-2.[48]

4.1 Methodology

We have analysed the debt beta of the following UK regulated companies:

- National Grid;
- Severn Trent;
- United Utilities;
- Pennon Group.

For these companies, we collected data on the sterling-denominated bonds issued by the parent company and subsidiaries from 1998 onwards.

The analysis has been performed as follows:

- The bond data for each company was cleaned, removing index-linked, fungible, convertible, complex, perpetual, callable and floating bonds in order to prevent these characteristics from altering the analysis.
- We then obtained the relative debt beta for each bond, regressing the bond return against the company equity returns and the UK government bond index returns.
- We obtained the debt beta for each company taking the weighted average of the company's bond debt betas.[49]
- Finally, we analysed the relationship between debt betas and (i) the average observation date and (ii) average debt maturity. We extended our analysis by combining the bonds of each company into a portfolio.

4.2 Results

Fluctuations in the value of a firm's assets are the source of both credit risk in its debt and price risk in its equity. Since credit risk and equity risk have the same source of risk, the debt risk premium associated with credit risk is equal to the equity risk premium multiplied by the elasticity of the return on debt to the return on equity. However, as both corporate bond returns and equity returns are correlated with government bond returns we cannot estimate the elasticity of debt to equity simply by regressing corporate bond returns on the firm's equity (or on an equity index).

Schaefer and Strebulaev (2008) show that by including the return on government bonds as an explanatory variable along with the return on the issuing firm's equity, this problem is overcome and the coefficient on equity gives an unbiased estimate of the elasticity, i.e., the sensitivity of a bond's return to the company's equity return. To estimate the risk premium on the debt, we multiply the estimated elasticity by the risk premium on the equity. Using the CAPM, the beta on the debt that determines the debt risk premium is

[48] See Oxera (2018), 'The cost of equity for RIIO-2—a review of the evidence', prepared for the Energy Networks Association, 28 February.
[49] Weighted average with respect to the inverse of the squared standard error.

the elasticity (beta) from the regression multiplied by the company's equity beta.[50]

Excluding returns on government bonds will bias the estimate of the elasticity and the size and direction of the bias will depend on the correlation between government bonds and equity. For example, in the five years ending June 2018, the correlation between the FTSE and the Barclays 7-10 year UK government bond index was positive (around 0.25). Thus, over this period, riskless debt has a positive beta against the FTSE but this beta clearly has nothing to do with default risk. Since debt of National Grid and the listed water companies is fairly low risk, part of its sensitivity to equity will simply reflect the correlation between riskless debt and the equity market.

If (again for July 2013 – June 2018) we simply regress returns on a portfolio of National Grid debt against the FTSE we obtain a coefficient of 0.20 (t = 2.48) while a regression of returns on riskless debt (the Barclays 7-10 year gilt index) against the FTSE gives a coefficient of 0.13. Including the Barclays gilt index in the regression along with NG equity reduces the coefficient on NG equity to 0.08 (t=2.23) and it is this figure, multiplied by the equity beta of NG, that reflects the credit risk of NG rather than the estimate of 0.20 that we obtain by regressing simply on the FTSE.

The results are presented in the tables and figures below. Many of the estimates of debt beta are not statistically significantly different from zero, and the average estimate across the full sample is 0.01. If the sample is censored by removing estimates that are not statistically significantly different from zero, then the average estimate increases to 0.03, and the estimate for National Grid is also 0.03.

Table 4.1 Debt beta coefficients

	National Grid	Severn Trent	United Utilities	Pennon Group[1]
Debt beta	**0.01**	**0.01**	**0.01**	**0.02**
Average observation date in the last five years	0.00	0.02	0.02	0.02
Average observation date not in the last five years	0.02	0.01	0.00	-
Time to maturity[2] greater than 10 years	0.04	0.02	0.04	0.02
Time to maturity[2] less than 10 years	0.01	0.01	0.00	-

Note: The coefficients are calculated using the weighted average with respect to the inverse of the squared standard error of each bond. [1] Only one bond was analysed. [2] Calculated as the difference between the maturity date and the average observation date.

Source: Oxera analysis.

[50] The equity betas used are the following; National Grid (0.61), Severn Trent (0.52), United Utilities Group (0.58) and Pennon Group (0.43). The coefficients differ from previous sections to achieve consistency with the time period used to estimate sensitivity of bond returns to the company's equity return.

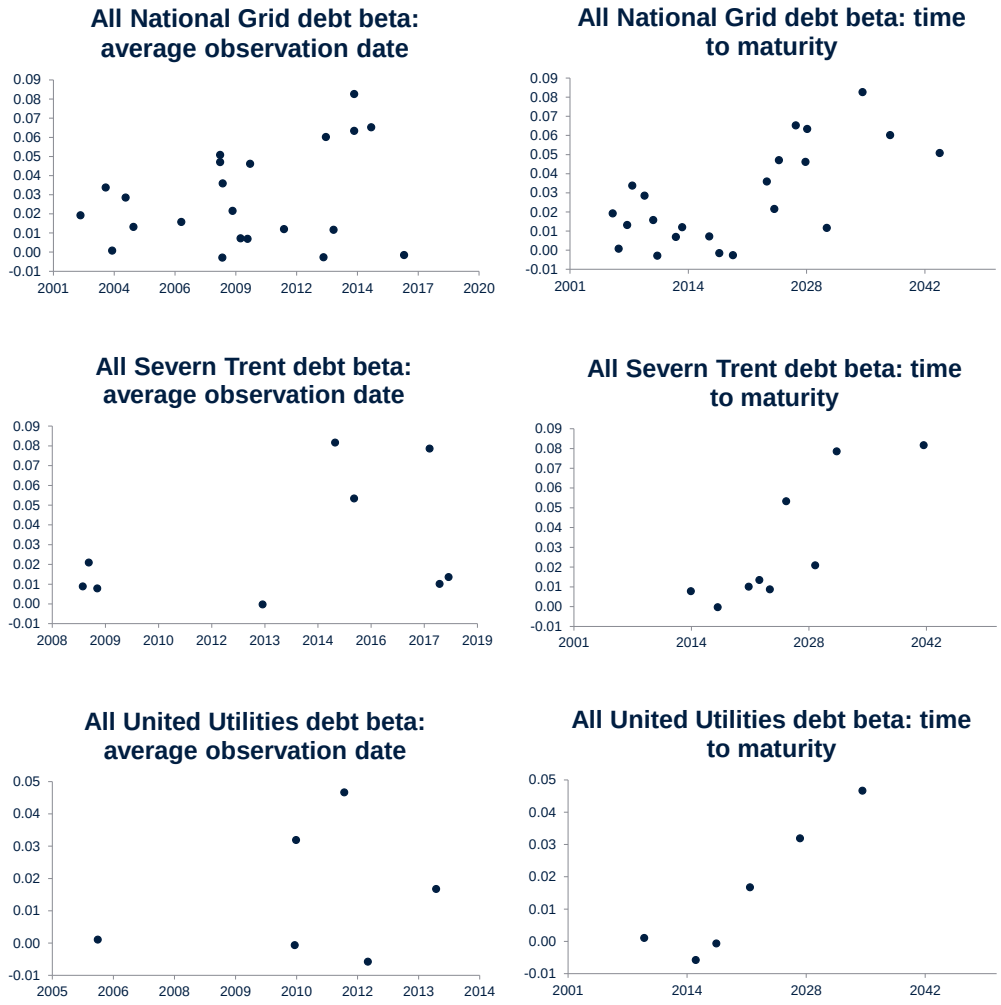
Table 4.2 Significant debt beta coefficients

	National Grid	Severn Trent	United Utilities	Pennon Group[1]
Debt beta	**0.03**	**0.02**	**0.04**	**-**
Average observation date in the last five years	0.07	0.02	-	-
Average observation date not in the last five years	0.03	0.02	0.04	-
Time to maturity[2] greater than 10 years	0.04	0.04	0.04	-
Time to maturity[2] less than 10 years	0.02	0.02	-	-

Note: The coefficients are calculated using the weighted average with respect to the inverse of the squared standard error of each bond and of the statistically significant estimations only.
[1] Only one bond was analysed. [2] Calculated as the difference between the maturity date and the average observation date.

Source: Oxera analysis.

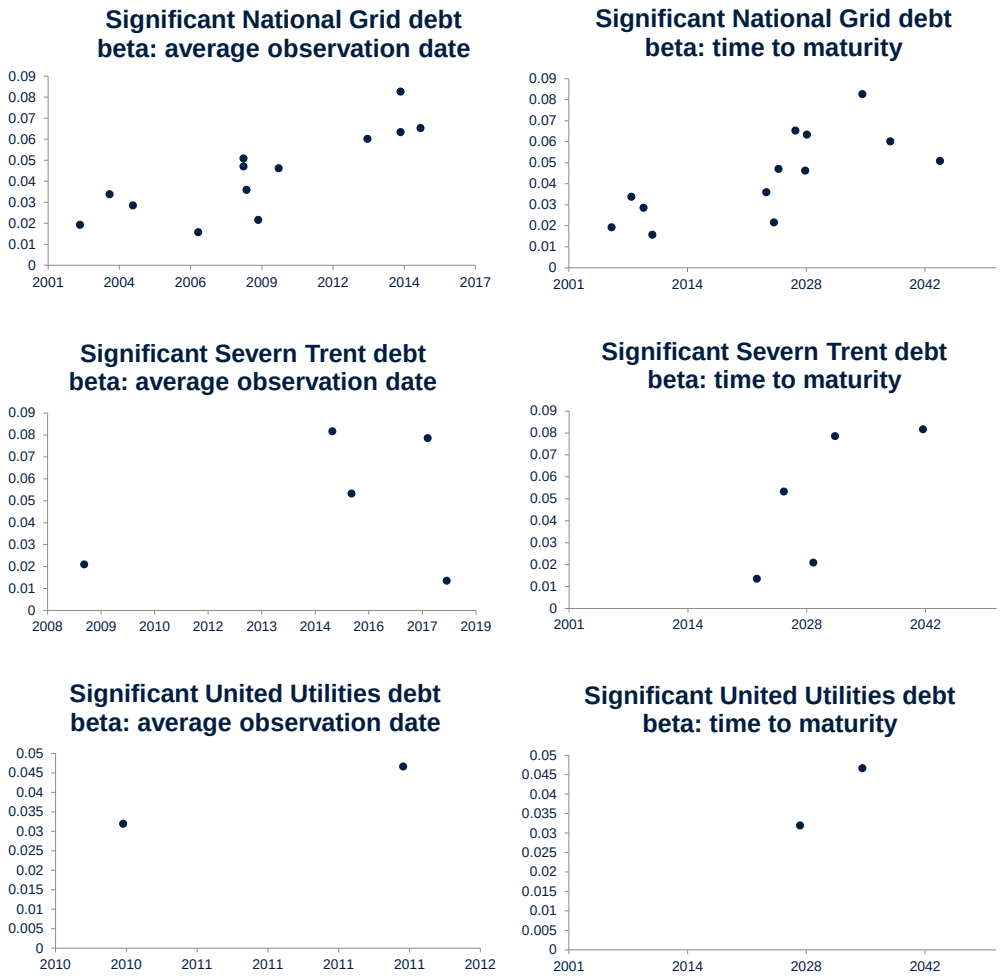
Figure 4.1 Relationship between debt beta and average observation date and maturity



Note: The plotted coefficients refer to the equity excess return independent variable.

Source: Oxera analysis.

Figure 4.2 Relationship between significant debt beta and average observation date and maturity



Note: The plotted coefficients refer to the equity excess return independent variable.

Source: Oxera analysis.

There is some evidence that the debt beta of National Grid has increased over time based on the censored sample, although the uncensored sample suggests a decline.

The results suggest a positive correlation between debt beta and maturity. For all companies, the debt beta rises as the time to maturity increases. This is in line with the financial theory that longer bonds are more risky than shorter bonds as they are more exposed fluctuations in the value of the issuing firm's assets.

Although the results suggest that the debt beta increases with maturity, we would need to undertake a statistical test to compare the debt betas of longer and shorter maturity bonds.[51] Due to the small sample size, we have not tested the difference in debt betas, and we consider that further research would be required before concluding that this particular result is robust.

[51] A common methodology for testing the statistical significance in the difference of means of two samples or populations is the t-test.

4.3 Conclusion

The results of our analysis are consistent with the 0.05 debt beta assumed in our February 2018 report for the ENA on the cost of equity for RIIO-2. An estimate of the debt beta of 0.05 using the methodology of Professor Schaefer with up-to-date market evidence, is considerably lower than the 0.1–0.15 range, currently assumed by Ofgem.

5 Conclusions

As an overarching consideration, we observe that Ofgem is considering several changes to its previous estimation methodologies and assumptions in relation to beta and gearing. As acknowledged by Ofgem: 'we are also mindful of the benefit to investors and consumers of predictability and stability in regulatory policy and judgements'.[52] We consider that care should be taken when introducing new methodologies, which provide different results from the existing ones, unless their superiority over the existing methodologies is clear. Even then, companies invest in assets with lives greater than 25 years; as a result, changes in methodology that produce lower returns to investors should be introduced only gradually over several price controls.

This report concludes the following.

1. **The case for moving away from OLS models is not robust.** Ofgem has not adequately supported a move away from ordinary least squares (OLS) estimation methods to generalised autoregressive conditional heteroscedasticity (GARCH) models for beta analysis in regulatory price controls. The use of OLS models should provide an unbiased and consistent beta coefficient.[53] Note also that UK precedent, including the decision by the Competition and Markets Authority (CMA) for Bristol Water (2015), supports the use of OLS estimation methods.[54]

2. **Analysis of European network betas provides additional relevant data.** Given the paucity of data on betas for UK utilities, and notwithstanding differences in the jurisdictions and regulatory regimes, it is appropriate to examine evidence on European energy networks. This is because the UK sample is very small and as such its estimated betas are less reliable. Moreover, we find that the equity betas of comparator European energy networks track closely the equity beta of National Grid. This is consistent with investors' viewing these businesses as having similar movement in systematic risk, especially since 2015. Water company asset betas are on average than energy network betas.

   We note that the CMA (2015) used a sample of UK utilities for beta analysis.[55] However, while this may have been appropriate in determining allowed returns for Bristol Water with reference to three UK water companies, the sample would be even smaller with only two listed UK energy networks, especially if SSE is excluded from the analysis.

3. **Use of post-crisis data is more relevant than a pre-crisis sample, in estimating betas.** Using pre-2008 data for beta analysis is unreliable due to structural breaks in returns for UK utilities during the global financial crisis. Note also that UK precedent, such as CMA (2015), supports the use of post-crisis data, for a period of up to five years.[56] We consider that a time period of analysis of two to five years is reasonable, and in line with

[52] Ofgem (2018), 'RIIO-2 Sector Specific Methodology Annex: Finance', Consultation, 18 December, paragraph 3.80.
[53] In theory, GARCH models are used to improve standard errors, not to correct for potential biases in the point estimate of the beta.
[54] Competition and Markets Authority (2015), 'Bristol Water plc, A reference under section 12(3)(a) of the Water Industry Act 1991', Appendices 5.1 – 11.1 and glossary, Glos-9.
[55] Competition and Markets Authority (2015), 'Bristol Water plc, A reference under section 12(3)(a) of the Water Industry Act 1991', Appendices 5.1 – 11.1 and glossary, A10(1)-20, para. 86.
[56] Competition and Markets Authority (2015), 'Bristol Water plc, A reference under section 12(3)(a) of the Water Industry Act 1991', Appendices 5.1 – 11.1 and glossary, A10(1)-23, para. 96.

regulatory precedents, and any move away from this precedent should be made with caution and with good justification.

4. **The case for estimating quarterly betas is not robust.** The use of low frequency (i.e. quarterly) data has not been substantiated in the context of regulatory price control settings. The use of quarterly instead of daily data is a key driver of the low estimates obtained by academics as part of a UKRN study.[57] The most recent UK precedent from the CMA (2015) explicitly disregards quarterly data for beta analysis.[58]

5. **Raw betas are not reliable in setting allowed returns for RIIO-2.** This report provides evidence consistent with the principle that higher financial risk is associated with higher expected returns, such that it is not reliable to use raw betas that do not adjust for differences between market and notional gearing, for the purpose of determining allowed betas as part of the allowed returns for RIIO-2. This directly contravenes the recommendation of Citizens Advice to rely on observed values of raw (i.e. unadjusted for differences in gearing) betas in setting allowed returns.[59] Accordingly, our analysis supports the principle followed in our February 2018 report for the ENA;[60] namely that equity betas presented at different levels of gearing should be re-levered to account for the impact of gearing on financial risk and the level of required equity returns. The CMA (2015) also supported controlling for differences in financial gearing to facilitate the direct comparison of equity betas.[61]

6. **Ofgem's 'adjusted' gearing ratio is not reliable.** We consider that the appropriate measure of gearing, to de-lever equity betas is the market value of gearing, rather than an 'adjusted' gearing ratio that adjusts for an assumed differential in enterprise value and regulatory asset values. We are not aware of any regulatory precedent for such an adjustment, and nor do we consider this adjustment to be theoretically sound. This is not compatible with the assumptions of the CAPM and more specifically the equation for linking asset and equity betas. For internal consistency, equity betas estimated using market data should be de-geared in line with the market-based estimate of the capital structure (i.e. the ratio of net debt to enterprise value), that underpins the observed share price movements. Ofgem's adjusted gearing approach produces a hybrid asset beta that reflects an assumed level of financial risk combined with the actual level of market risk—the resultant asset beta and re-geared equity beta are therefore unreliable and will be under-estimated given the 1.1x assumed multiple.

7. **Current evidence supports debt beta of 0.05 instead of Ofgem's range (0.1–0.15).** We have undertaken analysis that is responsive to Ofgem's observation that, 'Further research is required on estimating debt betas although there is regulatory precedent and academic support for debt betas in the range of 0.05 to 0.22'.[62] We have provided recent capital market evidence, prepared with Professor Schaefer, to substantiate that a debt beta assumption of 0.05 is appropriate in determining allowed returns for RIIO-2.

[57] Wright et al. (2018), op. cit., p. G-148.
[58] Competition and Markets Authority (2015), 'Bristol Water plc, A reference under section 12(3)(a) of the Water Industry Act 1991', Appendices 5.1 – 11.1 and glossary, A10(1)-22, para. 92.
[59] As cited by Ofgem; see Ofgem (2018), 'RIIO-2 Sector Specific Methodology Annex: Finance', Consultation, 18 December, p. 39.
[60] Oxera (2018), 'The cost of equity for RIIO-2—a review of the evidence', prepared for the Energy Networks Association, 28 February.
[61] Competition and Markets Authority (2015), 'Bristol Water plc, A reference under section 12(3)(a) of the Water Industry Act 1991', Appendices 5.1 – 11.1 and glossary, A10(1)-36, para. 148(a).
[62] Ofgem (2018), 'RIIO-2 Sector Specific Methodology Annex: Finance', Consultation, 18 December, p. 36.

This is considerably lower than the current 0.1 to 0.15 range assumed by Ofgem.[63]

[63] Ibid, Table 12.

A1 Capital asset pricing model

This section is taken from Oxera's February 2018 report.

The CAPM relates the cost of equity of a particular activity to its exposure to systematic or non-diversifiable equity market risk. In addition to the return on a risk-free investment, equity investors require a risk premium that reflects how correlated the returns on the investment in question are with the overall market. The risk that is captured in the correlation is the systematic risk. Non-systematic risk, on the other hand, does not require compensation through a risk premium in the CAPM because it can be diversified away by holding a portfolio of assets.

This exposure to systematic risk is measured by the equity beta. An investment with no systematic risk (i.e. with no correlation with returns on the market) would have an equity beta of zero. An investment in the equity of a company of average risk would have an equity beta of 1. In other words, the premium over the RFR that equity investors expect to earn on such an investment would be the same as the average for the overall market (equal to the ERP). The specification of the CAPM is shown in Box A1.1.

Box A1.1 The capital asset pricing model

$$R_i = RFR + \beta_e * ERP + \eta_i$$

$\boldsymbol{R_i}$**:** equity return;

$\boldsymbol{RFR}$**:** risk-free rate;

$\boldsymbol{ERP}$**:** equity risk premium;

$\boldsymbol{\beta_e}$: equity beta (sensitivity of equity returns to the returns of the market portfolio);

$\boldsymbol{\eta_i}$: idiosyncratic risk.

Source: Oxera analysis, based on Sharpe, W.F. (1964), 'Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk', *Journal of Finance*, **19**, pp. 425–442; Lintner, J. (1965), 'The Valuation of Risk Assets and the Selection of Risky Investments in Stock Portfolios and Capital Budgets', *Review of Economics and Statistics*, **47**, pp. 13–37.

Academic literature has challenged the CAPM's predictive ability, highlighting empirical and theoretical shortcomings. Alternative models have therefore been developed (e.g. the multi-factor models discussed in the next section), which have introduced new risk factors in order to improve precision. In addition, the results of the CAPM are sensitive to changes in specific data characteristics, which raises a question over their robustness.

There are, in general, three major conceptual challenges with the testing of CAPM.[64]

- The CAPM implies relationships concerning ex ante risk premiums and betas, which are not directly observable.
- Empirical tests use time-series data to calculate mean excess rates of returns and betas; however, it is unlikely that risk premiums and betas on individual stocks are stable over time. When time-series data are used to calculate betas and mean rates of returns on assets, it is implicitly assumed

[64] See Huang, C.-f. and Litezenberg, R.H. (1988), *Foundations for Financial Economics*, Prentice Hall, Chapter 10.

that the CAPM holds period by period, since the CAPM is a two-period model.

- Many assets are not marketable and tests of the CAPM are normally based on proxies for the market portfolio that exclude important classes of assets like human capital (the capitalised value of wage and salary income), private businesses, and private real estate.

Nevertheless, the CAPM's clear theoretical foundations and simplicity contribute to its popularity. As a result the CAPM is used as the primary approach for estimating the cost of equity by UK regulators.[65]

[65] UKRN (2017), 'Cost of Capital – Annual Update Report', 31 May, para. 2.6.

A2 The 'OLS approach' to beta estimation

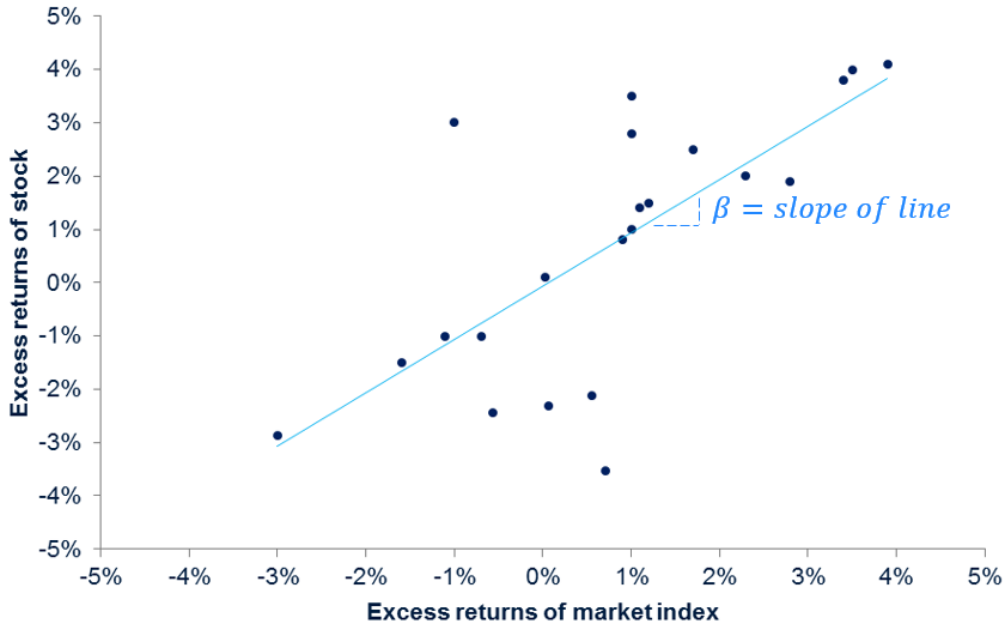
The standard procedure for estimating betas is to run a regression of the excess returns of an individual stock over and above the risk-free rate against returns on a market index.

The beta is typically estimated by an OLS regression of the actual excess return on the stock against the actual excess return on a broad market index. In the context of estimating the return for the whole UK equity market, the market index typically used is the FTSE All-share index.

The OLS estimator chooses the regression coefficient (i.e. the equity beta) so that the estimated regression line is as close as possible to the observed data, where closeness is measured as the sum of the squared mistakes in predicting the expected excess return of the stock given the excess return of the market.

More specifically, OLS identifies a 'line of best fit', which minimises the squared distance between the actual observed values and the values predicted by the regression.[66] The slope of the regression corresponds to the equity beta, and measures the riskiness of the stock.

Figure A2.1 OLS approach to beta estimation



Note: The excess return of stock is regressed against the excess return of market index using OLS. The slope of the regression line is known as beta and represents how sensitive the stock return is to changes in market returns.

Source: Oxera.

The dependent variable in the regression is usually the historical excess returns of the stock over a predetermined time horizon. This is regressed on the historical excess returns of the market, otherwise known as the equity risk premium (ERP), over the same time horizon. The specification of the OLS regression is as follows:

[66] See, for example, Greene, W. (2008), *Econometric Analysis*, sixth edition, Prentice Hall; and Wooldridge. J.M. (2006), *Introductory Econometrics: A Modern Approach*, third revised edition, South-Western, a division of Thomson Learning.

$$Excess\ returns\ of\ stock_t\ = \beta_e * ERP_t + \epsilon_t$$

The regression error (ϵ_t) consists of omitted factors. In general, these omitted factors are factors other than the ERP that influence the excess returns of the stock. The regression error also includes error in the measurement of the excess returns of the stock—for example, where an inaccurate measure of the risk-free rate is used.

A3 Debt beta estimation

The estimation of the relative debt beta ("debt beta" hereinafter) coefficient is the result of several steps, as explained below.

The reported coefficients represent the sensitivity of a bond's return to the company's equity return. To derive the sensitivity of the bond's return to the market return (i.e. the conventional debt beta) it is necessary to multiply the estimated coefficient by the company's equity beta as described in section 4.2.

A3.1 Data

For each company, we have collected returns from 1998 on all bonds issued from the parent company and subsidiaries.[67] Furthermore, we have collected returns data from 1988 on the FTSE All-share index, Barclays 7–10-year UK government bonds index, 3-month LIBOR and companies' equity returns.

Data cleaning

For all companies, we have analysed sterling-denominated bonds issued by the parent company and subsidiaries. To avoid bias in the analysis, we have excluded from our sample any bonds that are index-linked, convertible, callable, perpetual, floating-rate notes, fungible and complex.

Furthermore, we have excluded anomalous observations that show too high and/or too low returns using dummy variables. In particular, we have removed the October and December 2008 observations showing a -8.49% and 11.28% return on the Barclays 7–10-year government bonds index. In addition, we have removed observations on bonds outside the range of ±20%.

Sample

The data cleaning resulted in the following numbers of bonds for each company in our sample:

National Grid	22
Severn Trent	9
United Utilities Group	6
Pennon Group	1

A3.2 OLS regression

For each bond, we ran multiple regressions, considering different explanatory variables. The following regressions were run on weekly and monthly returns using all available data: [68]

- the excess return on the bond against the excess return on the FTSE All-share index;
- the excess return on the bond against the excess return on the FTSE All-share index and the Barclays 7–10-year UK government bonds index;

[67] Data collected from Datastream and double-checked with Bloomberg.
[68] For weekly regressions we considered Wednesday as data point, while for monthly regressions we considered the end of the month as data point.

- the excess return on the bond against the company's equity and the excess return on the Barclays 7–10-year UK government bonds index.

For each company, we then computed the simple and weighted average, with respect to the inverse of the standard error, using weekly and monthly observations. The results are reported in the tables below:

Table A3.1 Debt beta coefficients: weekly and monthly

	National Grid	Severn Trent	United Utilities	Pennon Group[1]
Weekly				
Simple average debt beta	0.00	-0.01	-0.02	-0.01
Weighted average debt beta	-0.01	-0.01	-0.02	-0.01
Monthly				
Simple average debt beta	0.05	0.06	0.03	0.05
Weighted average debt beta	0.02	0.03	0.01	0.05

Note: [1] Only one bond was analysed

Source: Oxera analysis.

For all companies, using weekly observations resulted in a slightly lower and most of the time statistically insignificant estimation. This is likely due to infrequent trading of their bonds. As a result we have used monthly observations, to ensure we are obtaining statistically significant estimates. The reported coefficients represent the sensitivity of a bond's return to the company's equity return. To derive the sensitivity of the bond's return to the market return (i.e. the conventional debt beta) it is necessary to multiply the estimated coefficient by the company's equity beta as described in section 4.2.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