2 January 2020

Setting the Cost of Equity in UK Price Controls, by Professor Alan Gregory

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1. My CV

1.1. My name is Alan Gregory. I am a Professor Emeritus in Corporate Finance at the University of Exeter and a director of AGRF Ltd. My research interests are in the general area of market-based empirical research, including the empirical estimation of cost of capital.

1.2. From September 2001 to September 2009 I was a Reporting Panel Member of the UK Competition Commission (CC) where I was involved in a number of inquiries, including the merger investigation of two potential European takeover bids for the London Stock Exchange, and the groceries or "supermarkets" market investigation.

1.3. I was a member of the CC's cost of capital panel from 2009 to 2017 and continue to provide advice to the Competition and Markets Authority (CMA).

1.4. AGRF Ltd's consulting interests include profitability analysis and cost of capital, particularly for regulatory purposes, together with investment portfolio analysis. Past clients include fund managers, stockbrokers, law firms, large accounting firms, the Victoria (Australia) gas distribution companies, HM Treasury, Ofcom, The Treasury Solicitor's Department and the CC.

1.5. I have undertaken expert witness work both in the UK and Australia. In addition to more than thirty papers in peer-reviewed academic journals, I have contributed to an OECD

Roundtable publication on Excessive Prices and I am the author of the Financial Times book 'Strategic Valuation of Companies'.

2. Overview

2.1. In AGRF Ltd's capacity as a sub-contractor of KPMG LLP, I have been commissioned by Northumbrian Water Limited, Wessex Water Services Limited and Anglian Water Services Limited to provide a report on the approach to setting the allowed cost of equity (CoE) in UK charge controls. The contents of this report are intended to assist the CMA in its redetermination of the price control for NATS (En Route) Plc (NERL).

2.2. This report sets out:

a) my views on the overarching approach to setting the regulatory CoE; and

b) my estimates for market wide parameters in the CoE, being the total market return (TMR) and risk free rate (RFR).

2.3. My report focuses on these two areas because they have read-across beyond the NERL appeal to other regulated sectors, including water.

3. Structure of the rest of this report

3.1. First, I explain where the CoE feeds into the charge control and the model used to estimate the CoE.

3.2. Second, I summarise the regulatory precedent that is of relevance, when setting the CoE.

3.3. Third, I set out my views on the framework for setting the CoE, and introduce some key terminology.

3.4. Fourth, I set out my views on the correct methodological approach to setting the TMR, RFR and beta in the regulatory CoE and provide estimates and supporting analyses for the RFR and TMR. I do not provide an estimate of beta, as the precise figure is sector specific, so I comment on the methodology only.

3.5. Fifth, I summarise my concerns with recent regulatory approaches to setting the CoE adopted by UK sector regulators.

3.6. Sixth, I explain the implications of setting the CoE too low.

4. Where CoE feeds into charge controls and the use of the CAPM

The purpose of the CoE allowance

4.1. Equity investors are exposed to risk (variation around the mean expected return on investment) when they provide capital to firms. Investors are risk averse. In order to provide capital, investors therefore expect a return to compensate them for the risks taken. In particular, the type of risk investors expect compensation for is risk that cannot be diversified away. This form of risk is known as 'systematic' or 'market' risk.

4.2. Equity investors will provide equity (or retain existing equity holdings) only if the mean expected return on their investment is in line with the return on investment they expect. This is because if the mean expected return is below the return investors expect, investors are exposed to an opportunity cost – being the missed opportunity of earning returns commensurate with the risks taken from alternative investments.

4.3. It follows that, in order to attract and retain equity finance, firms must expect to earn sufficient profits to pay investors a market-based return on equity. This is a cost to all firms that rely on equity finance; the cost of equity.

4.4. In UK regulated firms, there is an allowance in the charge control for the CoE, which reflects the opportunity cost faced by the equity investors in a 'notional' firm in the sector.[1] The CoE allowance is estimated in real terms because the regulatory asset base (RAB, or regulatory capital value, RCV) is indexed to inflation. A CoE in both real RPI and real CPI terms is now required, as regulators transition from a RAB indexed to RPI to a RAB indexed to CPI (or CPIH).

4.5. Importantly, the CoE is not a guaranteed return to equity investors. As with non-regulated firms, if the regulated company underperforms against its cost allowances or performance incentives, equity investors will receive a lower return than the CoE and vice versa if the regulated company outperforms.

The CAPM

4.6. The CoE in regulatory charge controls is set using the capital asset pricing model (CAPM), which is described by the following equation:

$$CoE = RFR + \beta(TMR - RFR)$$

Where:

a) RFR is the risk-free rate, i.e. the return expected from investing in riskless assets.

b) TMR is the total market return, which is the returns expected by investors from a suitably diversified portfolio of equities.[2]

c) β is the equity beta, which is a measure of the systematic riskiness of equity assets of the sector in question, relative to markets as a whole.[3]

4.7. As can be seen from the CAPM equation, the resultant CoE captures the return investors can expect on the market portfolio, given the risks taken (beta). It therefore directly estimates the opportunity cost to investors because it estimates what return investors can expect to achieve on the market portfolio, if they take risks commensurate with those in the regulated firm/(s).

[1] The CoE is estimated for a notional firm, because the CoE can be influenced by a given firm's approach to financing. For example, if a firm has high gearing, the CoE is higher. It is therefore standard regulatory practice to describe a notional firm and estimate the CoE for that firm. The concept of a notional firm is not directly relevant to this paper, which largely focuses on market wide parameters.

[2] More accurately, the returns to investing in the market portfolio.

[3] More specifically, beta is estimated by computing the covariance of returns of a portfolio of comparable stocks with returns to the market portfolio, and normalising by the variance of returns to the market portfolio. Beta therefore captures systematic risk only, or risk that affects the market as a whole, as opposed to unsystematic risk or specific risks.

TMR estimation approaches

4.8. TMR is the return expected by investors from investing in equity markets; more specifically a portfolio of equities that reflects the market, i.e. the market portfolio. TMR is inherently an unknown parameter, as it is a forward looking estimate of investors' expectations.

4.9. There are three available approaches to estimating TMR:

a) *Historical ex post returns:* this approach assumes that returns achieved by equity investors in the long-run past are a good proxy for forward looking expectations of returns. An estimate of the forward looking TMR is therefore derived by calculating average returns (dividends and share price appreciation) achieved over the very long-run, being 1900 to the present day.[4]

b) *Forward looking dividend discount models:* this approach estimates TMR based on the implied return from current share prices and dividend forecasts. The idea being that investors in listed firms value the shares based on discounting future cashflows, in the form of dividends, to their present value. The discount rate adopted across the market portfolio is the expected return for holding equities, or the TMR. It follows that if the combined value of the market portfolio and dividend forecasts are known, the TMR can be estimated.

c) *Historical ex ante returns:* this approach applies forward looking dividend discount models over the long-run past. This involves estimating the forward looking TMR from past share price and dividend forecast data and averaging the results.

4.10. Where historical returns are used to estimate TMR, i.e. both the historical ex post and historical ex ante approaches, there are two main adjustments that must be applied to the underlying data.

a) *Deflating observed nominal returns:* As explained at paragraph 4.4, for regulatory charge controls the CoE needs to be estimated in real terms. The ex post returns over the long-run are observed in nominal terms. The nominal returns therefore have to be deflated using an inflation index over the same time period to derive a real TMR.[5]

b) *Averaging:* The historical returns are calculated annually. Algebraically, the mean can be calculated as an arithmetic or geometric average (the arithmetic average is a simple average of the annual returns[6], whereas the geometric average[7] is the annualised compound rate of return achieved over the entire period of the dataset (119 years)). The arithmetic average is the best estimate of TMR over a 1 year holding period, whereas the geometric average is the best estimate of returns if one held a portfolio of equities over the full 119 year period. This is because the

[4] The start date of 1900 is chosen simply for convenience, as it is the longest run of data that is comprehensively available across markets.

[5] As the RCV is indexed to inflation, so a real return is applied to the inflated RCV, to avoid double counting the allowance for inflation.

[6] $Arithmetic\ mean = \frac{1}{n}\sum_{i=1}^{n} a_n = (a_1 + a_2 + \cdots + a_n)/n$

[7] $Geometric\ average = \sqrt[n]{(a_1 a_2 \ldots a_n)}$

arithmetic average compensates investors for volatility in annual returns. If an investor holds equities for one year only, then they may therefore use the arithmetic average when pricing assets. If on the other hand, an investor was holding equities for the full 119 year period, they would not require compensation for annual volatility and may therefore use the geometric average when pricing assets. One therefore has to take a view on the investment horizon and therefore the appropriate averaging approach.

RFR estimation approaches

4.11. RFR is the rate of return expected by investors for holding an asset with a future payoff with zero risk (i.e. having no uncertain variation around the mean expected return).

4.12. The RFR is usually estimated by selecting an instrument or instruments, which are considered to have negligible risk and measuring the expected return from investing in this instrument/(s) over the relevant investment horizon.

Beta estimation

4.13. Beta measures the exposure to systematic risk of the firm or sector in question. Systematic risk is risk that impacts the market as a whole. Beta is therefore estimated as follows:

$$\beta = \frac{Covariance(AssetReturn, MarketReturn^{8})}{Variance(MarketReturn)}$$

4.14. Where the firm/(s) are listed, one can select the shares of the firm itself to measure the asset return. However, where the firm/(s) are not listed, listed comparators have to be selected, that have comparable systematic risk exposure.

4.15. The FTSE All-Share index is ordinarily used to estimate the market return, as a suitably broad basket of home-currency equities that is sufficiently representative of the market portfolio.

4.16. The estimation methodology relies on suitable choices of a time horizon and frequency of returns for the chosen index and listed comparators.

The time horizon

4.17. The CoE is time varying over short time horizons. This is because both the RFR observed from market instruments and betas estimated using short time horizons can produce different estimates over time. [9]

4.18. It is therefore important to consider and specify the appropriate time horizon over which the CoE is being estimated, which corresponds to the time horizon considered by investors, as discussed further in Section 6 below.

[8] *MarketReturn* is the return on a well-diversified portfolio of assets that represents the market portfolio.
[9] In theory, the TMR also changes for different time horizons, as the time period for averaging annual returns differs for different time horizons.

Aiming up

4.19. When estimating the CoE there is ordinarily a range of figures from which a point estimate for each parameter and therefore the allowed CoE in the charge control is determined. When selecting point estimates for the allowed CoE, there is an argument that ‘aiming up’ is required, i.e. selecting a point estimate above the mid-point of the range.

4.20. The argument for aiming up, simply put, is that there is an asymmetric risk of over versus under-estimating the cost of capital. If the cost of capital is set too high, customers pay more for their bills.[10] However, if the cost of capital is set too low, there would be under investment in the sector. Given that most regulated services are essential goods and customers have no choice but to purchase the service from the provider being regulated, the welfare loss from under investment is large. The asymmetric risk therefore lies in the knock-on consequences of setting the cost of capital too low being worse than if the cost of capital is set too high.

4.21. Due to this asymmetric risk, point estimates for the allowed CoE are sometimes selected above the mid-point derived from applying the CAPM to market data.

5. Regulatory precedent and pertinent publications

5.1. In my view, there are two main pieces of regulatory precedent of relevance to the CMA’s redetermination of the CoE:

a) the CC’s final determination (FD) on Northern Ireland Electricity (NIE);[11] and

b) the CMA’s FD on Bristol Water.[12]

5.2. This is because the NIE and Bristol Water cases are the last occasions on which the CC/CMA did a full re-evaluation of the CoE as part of a regulatory appeal.

5.3. In addition, a recent report by Wright et al (2018), commissioned by the UK Regulator’s Network (UKRN)[13] is the most recent academic study into the regulatory CoE. I refer to this report as ‘Wright et al (2018)’ in the rest of this report.

The CC’s NIE Determination in 2014

5.4. In April 2014, the CC published its final determination on the NIE case. As part of its redetermination, the CC did a complete reassessment of the CoE using the CAPM.

5.5. The CC undertook an in depth analysis of the TMR, using evidence of both historical ex post and historical ex ante returns.[14]

[10] Ofwat has nearly halved RAR-CoE in real terms and customers are expected to save £50 per annum. https://www.ofwat.gov.uk/pn-16-19-2019-price-review-ofwat-unveils-programme-of-huge-investment-service-improvements-and-lower-bills-for-water-customers/
[11] Competition Commission (2014), ‘Northern Ireland Electricity Limited price determination’, referred to as the NIE FD in future footnotes.
[12] CMA (2015), ‘Bristol Water plc, A reference under section 12(3)(a) of the Water Industry Act 1991’, referred to as the Bristol Water FD in future footnotes.
[13] Wright et al (2018), ‘Estimating the cost of capital for implementation of price controls by UK Regulators’, referred to as Wright et al (2018) in future footnotes.
[14] NIE FD, paragraph 13.146

5.6. In deriving estimates from the historical ex post approaches, the CMA calculated the average return over a range of investment horizons (or "holding periods") using four different approaches to deriving the average return over these holding periods; simple, overlapping, and estimators based on the analyses in Blume (1974) and Jacquier, Kane and Marcus (2005) (JMK). I provide an explanation of each of these averaging approaches in Technical Annex 1.

5.7. The CC did not consider the preferred averaging approach, for historical ex ante returns.

5.8. The CC derived a range for the TMR of 5.0-6.5% (real, RPI) and selected a point estimate of 6.5% (real, RPI) based on the following:

a) The weight of evidence tended to support numbers at the upper end of the range.[15]

b) In the context of setting a cost of capital for an efficient licence holder, they were less concerned with a lower limit.[16]

5.9. To estimate the RFR, the CC examined the yields on UK government bonds. To derive an estimate of the real RFR it considered three benchmarks:

a) Yields on index-linked gilts.[17] These are bonds issued by the UK government where the coupon and principal are indexed to a pre-defined measure of inflation.

b) Yields on nominal gilts.

c) Long-run realised returns on gilts and treasury bills in the UK.

5.10. The CC derived a range of +1.0% to +1.5% (real, RPI) from the aforementioned data, despite rates on index-linked gilts being approximately zero at the time.[18] The CC noted that in adopting a range for the RFR of +1.0% to +1.5%, which was considerably above rates on long-duration index-linked gilts, they were adequately allowing for the possibility that rates might rise during the remainder of NIE's charge control.[19]

5.11. As with the TMR, the CC relied upon the upper end of its RFR range of +1.5% (real, RPI) when selecting a point estimate.

5.12. Whilst beta is specific to the sector in question, the CC's consideration of the beta methodology remains relevant. The CC's views on the two main methodological judgments when estimating beta (see paragraph 4.16) were as follows:

a) *Time horizon:* the CC considered that betas using a relatively long run of data were most appropriate.[20]

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[15] NIE FD, paragraph 13.187
[16] NIE FD, paragraph 13.147
[17] NIE FD, Figure 13.3 and 13.4
[18] NIE FD, paragraph 13.128
[19] NIE FD, paragraph 13.128
[20] NIE FD, paragraph 13.183

b) *Sampling frequency:* the CC used daily data, rather than weekly or monthly observations.[21]

5.13. However, in the light of subsequent empirical evidence from Gilbert et al (2014) and Gregory et al (2018),[22] in the CMA's Energy Market investigation, the CMA's preferred approach switched to long run betas estimated on the basis of low frequency (monthly and quarterly) data.[23]

5.14. With regards to the relevant time horizon, the CC stated that it was aiming to estimate the cost of capital over the length of the charge control.[24] The CC noted that long-run averages were only relevant to the extent that they affect the cost of capital in that period.[25]

5.15. Finally, with regards to aiming up, the CC selected a point estimate for the CoE at the top of the range derived from applying the CAPM to market data.[26] They refer to the point estimate as the 'allowed rate of return' and/or WACC (weighted average cost of capital) interchangeably.[27]

The CMA's Bristol Water Determination in 2015

5.16. In October 2015, the CMA published its final determination on the Bristol Water case. As part of its redetermination, the CMA had to set the allowed CoE.

5.17. The final determination does not include detailed analysis and discussion on TMR, as the CMA adopted the 6.5% (real, RPI) estimate used in NIE. This was because:

a) NIE had been published within the last 18 months and was therefore relatively up to date;

b) each of the methods for estimating TMR had a large degree of uncertainty associated with them; and

c) there was limited disagreement amongst the parties.[28]

5.18. With regards to the RFR, the CMA followed a similar approach to the NIE FD and examined the evidence on both index-linked and nominal gilts.[29] The CMA found that gilt yields remained "very low" at around 0% (real, RPI).[30] However, the CMA concluded that in light of the NIE precedent, a range of +1.0% to +1.5% was appropriate and used a point estimate of +1.25% (real, RPI).[31]

[21] NIE FD, Appendix 13.3, paragraph 1
[22] Note that an earlier working paper version is cited by the CMA as Gregory et al (2016).
[23] See Appendix 9.12 to the CMA's energy market inquiry, paragraph 48. Footnote 33 also explains that betas have been estimated for the full period of data this is available.
[24] NIE FD, paragraph 13.6
[25] NIE FD, paragraph 13.6
[26] NIE FD, paragraphs 13.147 and 13.189
[27] See for example, NIE FD Section 13 hearing 'Allowed rate of return' and paragraph 13.193
[28] Bristol FD, paragraphs 10.184 and 10.185
[29] Bristol FD, paragraph 10.170
[30] Bristol FD, paragraph 10.171
[31] Bristol FD, paragraph 10.173

5.19. To estimate beta, the CMA considered a wider range of sampling frequencies (including daily, weekly and monthly) and horizons (from latest day, to five-year averages).[32] A point estimate was then selected based on the range of evidence from these different sampling approaches.[33]

5.20. With regards to the time period in Bristol Water, the CMA did not set out an explicit time period. However, it noted the following in its section entitled 'Overall approach to the cost of capital':

"An important part of this analysis is the application of a consistent approach to setting the assumptions which form the basis of the calculation of the cost of capital. Both debt and equity investors make long-term financing decisions, including debt financing of up to 30 years' maturity. This reflects investors' expectations not just in respect of the immediate regulatory period, but of a consistent approach over the longer term…the financing environment is influenced by the stable approach to the estimation of the cost of capital, applied by both sector regulators and also in previous CC/CMA decisions.[34]

5.21. Finally, with regards to aiming up considerations, the CMA stated that it was aware of the customer welfare arguments for using an estimate above the mid-point of any range.[35] The CMA then concluded as follows with regards to how it had factored in this argument:

5.22. *"Although we generally used the midpoint of our ranges, there were a number of areas in which we made prudent upward adjustments for Bristol Water relative to observable market evidence…This gave us some assurance that even accounting for the inherent potential errors in market observations, this was a reasonable WACC for Bristol Water."*[36]

Decisions by sector regulators between the NIE FD and 2019

5.23. Decisions on TMR taken by sector regulators for the four years following the CC's NIE FD closely followed the CC's precedent in that case, with TMR estimates in the range of 6.10% to 6.75% (real, RPI).[37] RFR estimates were set between +0.50% and +1.50% (real, RPI) up until 2018 when Ofcom reduced the RFR to 0.00% (real, RPI).

5.24. However, in 2019 there was a material reduction in both TMR and RFR, with sector regulators selecting substantially negative RFR estimates (-2.4 to -1.3%, real RPI) and TMR estimates below 6.0% (5.4-5.8%, real RPI).[38] In large part this change was based on a study by Wright et al (2018), which I explain at paragraphs 5.28 and 5.29.

5.25. Beta estimates have tended to rely primarily on a 2-year rolling window of daily data, i.e. a short time horizon, with daily sampling frequency.[39]

[32] Bristol FD, Appendix 10.1, paragraphs 87 to 96
[33] Bristol FD, Appendix 10.1, paragraphs 87 to 96
[34] Bristol FD, paragraphs 10.6 to 10.7
[35] Bristol FD, paragraph 10.191
[36] Bristol FD, paragraph 10.192
[37] UKRN 2018 and 2019 annual reports on the cost of capital
[38] UKRN 2018 and 2019 annual reports on the cost of capital and Ofwat's Final Determination (referred to as Ofwat's FD in future footnotes), Allowed return on capital technical appendix, page 4
[39] UKRN 2019 annual report on the cost of capital, page 22

5.26. I am not aware of the regulators specifically making an allowance for aiming up in recent decisions when selecting a CoE estimate for the allowed return. I also note that:

a) The CAA's business plan guidance for NERL set out that NERL should assume a cost of capital that is *"no more than the efficient level necessary to compensate NERL for the business and regulatory risks it faces."*[40]

b) Ofwat makes several references to its allowed return being in the middle of ranges by various stakeholders.[41]

5.27. Both approaches suggest that the regulators did not consider that aiming up was required.

The UKRN academic paper by Wright et al (2018)

5.28. The shift in market-wide estimates in 2019 may, in part, be due to an academic paper commissioned by the UKRN into setting the regulatory cost of capital by Wright et al (2018). The key recommendations in respect of the CoE by Wright et al (2018) were as follows:

a) A fairly long horizon (for example, ten years) should be used to estimate the cost of capital. More importantly, all components of the cost of capital should be estimated using a methodology which is consistent with the chosen horizon;[42]

b) A measure of inflation consistent with that chosen by HM Treasury and the Bank of England should be used;[43]

c) Regulators should use the (zero coupon) yield on inflation-indexed gilts at their chosen horizon to derive an estimate of the RFR at that horizon. This was recognised by the authors as a 'nontrivial change' from previous regulatory practice;[44] and

d) The expected market return (also known as TMR) should continue to be based on long-run historic averages and should be 6-7%, real **CPI**.[45] The use of CPI, as opposed to RPI, by the authors is important, as I explain further at paragraph 5.29(b) and Section 7 below.

e) The term WACC should be restricted to the expected market return estimated through applying the CAPM to market data and should not be confused with the allowed return in the charge control. They propose use of the term CAPM-WACC for an estimate of the expected market return and use of the term RAR (regulatory allowed return) for the allowance for the cost of capital in the charge control. Additionally, they introduce the acronym RER for regulatory expected return. This refers to the return on investment expected by firms after taking into account

[40] UK RP3 CAA Decision Document (referred to as the CAA's FD in future footnotes), Appendix E, paragraph E8 and Guidance for NERL in preparing its business plan for Reference Period 3 (January 2018)
[41] Ofwat FD Allowed return on capital technical appendix, page 6
[42] Wright et al (2018), Recommendation 2
[43] Wright et al (2018), Recommendation 3
[44] Wright et al (2018), Recommendation 4
[45] Wright et al (2018), Recommendation 5

expected outperformance on other components of the charge control, such as costs and performance incentives. The idea being that if the cost allowance is higher than it needs to be and/or the performance commitments are easy to 'beat', firms expect to get an additional return for their investors by outperforming the settlement.[46]

5.29. In my view, the recommendations at 'b', 'c' and 'd' are likely to have caused the material reductions in RFR and TMR adopted by the sector regulators. This is because:

a) Regulators had in the past followed the CC's NIE precedent when setting the RFR, to not lock-in current negative market rates, due to the possibility that rates might rise during the charge control period. However, Wright et al (2018) suggested that regulators should use the actual yield on zero coupon inflation-linked gilts directly in the CoE.

b) Whilst optically the 6-7% real TMR estimate appears in line with the CC's NIE precedent and indeed is purported to be based on historical averages, the range is actually 50 to 150 basis points lower than the CC's estimate of 6.5% TMR in real RPI terms. This is because Wright et al (2018) present the TMR in real, CPI terms and the forward looking RPI, CPI wedge used by regulators is approximately 100 basis points. [47] Thus, if a regulator adopts a 6.5% TMR in real CPI terms, this translates to a TMR of approximately 5.5% in real RPI terms. The reduction is driven largely by Wright et al's (2018) choice of inflation indices and (less so) by the size of their uplift from the geometric average. I discuss my approach to inflation and averaging in Section 7 below.

6. Framework for setting the CoE

Use of the CAPM

6.1. I consider that the CAPM remains the most appropriate model for setting the CoE in price controls. This is because it is accepted regulatory practice to use CAPM and the model has been used to set the CoE since privatisation. The model is therefore understandable by firms and regulators. Further, there is disagreement on the validity of alternative asset pricing models.

The relevant time horizon

6.2. As explained at paragraph 4.17 above, the CoE is time varying over short time horizons. This is because both the RFR observed from market instruments and rolling, short-term betas can change over time.[48] The specified time horizon can therefore be key for the outturn CoE estimate.

6.3. In my view, the correct time horizon for estimating the forward looking CoE in regulatory charge controls is the long-run, i.e. more than 10 years.[49] This is because, as

[46] Wright et al (2018), Recommendation 10
[47] See for example, CAA FD, Appendix E, paragraph E16
[48] In theory, the TMR also changes for different time horizons, as the time period for averaging annual returns differs for different time horizons.
[49] Consistent with the Wright el al (2018) recommendations, on the relevant forward looking time horizon, page 7.

recognised by the CMA in Bristol Water (see paragraph 5.20 above), investors in regulated utilities often invest over long time horizons of 10 years or more. In order to attract investment, a forward looking CoE over that same long-run horizon is therefore required. Further, as Wright et al (2018) note, regulatory assets tend to be long-lived. The choice of a time horizon of more than 10 years or more does not appear to be controversial.[50]

6.4. The chosen time horizon should be specified clearly and estimation of each parameter in the CoE should be done through the lens of the chosen time horizon, as otherwise the CoE estimate is not a true expected return over the chosen time horizon. In this regard, I am in agreement with each of the authors[51] of the Wright et al (2018) paper, where they stated:

*"However, we are in agreement on a key caveat: that, whichever horizon is chosen, the components of the cost of capital should, as far as practically possible, be estimated in a way that is **consistent** with the chosen horizon, since without this consistency we cannot view our CAPM-WACC estimate as a true expected return. We shall argue that this has not always been the case for the choices made by UK regulators."*[52]

CAPM-CoE and A-CoE

6.5. I refer to the CoE based on a best estimate from market data, using the CAPM, over a specified time horizon as the CAPM-CoE.[53]

6.6. Having established a best estimate of the CAPM-CoE over the specified time horizon, there should be explicit consideration as to whether adjustments to the CAPM-CoE are required for policy reasons. The two main policy considerations are:

a) Are investors unduly exposed to market movements, given that the CoE is a fixed allowance in the price control?

b) Where there is a range of outturn CoE estimates, should one select an estimate above the mid-point of the range, recognising the asymmetric risk on either side of the trade-off between incentivising investment versus keeping bills low?

6.7. I refer to the CoE that takes account of the aforementioned regulatory policy considerations as the allowed CoE or 'A-CoE'. It is the A-CoE that is used to set regulatory price controls. Estimating the CAPM-CoE from market data is therefore an intermediate, calculation stage, when setting the A-CoE.[54]

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[50] See for example Wright et al Recommendation 2 and Ofwat's chosen investment horizon of 15 years – FD, Allowed return on capital technical appendix, page 38.
[51] I say 'each of the authors' as they don't agree on all of their recommendations.
[52] Wright et al (2018) page 29
[53] Consistent with Wright et al 2018, who note that the estimate of the WACC using the CAPM (CAPM-WACC), the regulatory allowed return (RAR) and the regulatory expected return (RER) were distinct concepts.
[54] Consistent with the Wright el al (2018) recommendations, page 6.

7. TMR

My view on the available estimation approaches for TMR

7.1. I explain the available approaches for estimating TMR at paragraph 4.9 above. In my view, the weight of evidence supports use of ex post returns data over long run time horizons, consistent with the Wright et al (2018) recommendation[55] and regulatory precedent prior to 2019.[56]

7.2. It is evident that the long-run ex post returns are a proxy for future expected returns because the achieved returns can be split into an expected return and unexpected return using the following equation:

$$\boldsymbol{Realised\ return = Expected\ return\ \pm\ "surprise"}$$

7.3. The rationale for assuming that long-run ex post returns are a good proxy for a forward looking TMR is that over the long-run, the surprises cancel out, such that the realised return is equivalent to the expected return.

7.4. The long-run ex post approach is the only method available for estimating TMR that is based on hard evidence and not affected by assumptions and forecasts.

7.5. Forward looking dividend growth approaches are unstable over time and reliant on dividend forecasts, which are inherently uncertain. For example, the implied TMR can change by just over 1:1 with changes in dividend growth assumptions made by the practitioner.[57] This point about instability and the problems it raises for regulatory implementation are discussed at length in Wright et al (2018), Chapter 4.

7.6. In my view, forward looking approaches are therefore unsuitable for estimating TMR over my specified long-run time horizon.

7.7. The instability over time of dividend growth approaches is alleviated when applying long-run ex ante approaches. However, long run ex ante approaches still suffer from the inherent uncertainty in dividend forecasts. Nevertheless, I agree with the CC's position in its NIE FD that empirical studies of long-run ex ante returns provide a useful cross check on the results of the long-run ex post data. I therefore summarise the evidence from empirical studies on long run ex ante TMR below and use this as a cross-check on my long-run ex post TMR.

7.8. Given my position that long run ex post data provides the most robust evidence on forward looking TMR, over my specified time horizon, I present empirical analysis of the TMR derived from this approach. In the context of such returns, I note that the potentially contentious issues appear to be the adjustment needed to move between CPI and RPI based real returns and the balance given to geometric vs arithmetic means. This is

[55] Wright et al (2018) recommendation 5
[56] As explained in Section 5, in NIE, the CC found that the weight of the evidence supported the 6.5% TMR, real RPI terms. This estimate was predominantly based on ex post returns averaged over various holding periods. Until 2019, sector regulators closely followed the precedent from NIE.
[57] Since the TMR is derived from the constant growth dividend discount model, which at market level implies Market Capitalisation= (Market Dividends x (1+g)) / (TMR – g). Some versions of the model use specific forecasts for N years ahead, meaning that the model is highly sensitive to short run and long run growth estimates.

perhaps not surprising as to the two main adjustments that are required to the underlying data are i) deflating the nominal returns and ii) averaging the returns for the specified investment horizon (as I explain at paragraph 4.10).

My approach to deflating ex post returns

7.9. My source for historical TMR data is the Dimson Marsh and Staunton (DMS) Global Investment Returns Yearbook. DMS is widely accepted as the most reliable source of UK and international stock market data. Referring to the February 2019 publication, Table 75, the long run (1900-2018) average real returns for UK equities are 5.44% on a geometric basis and 7.25% on an arithmetic basis. The returns in the 2019 DMS publication, are not derived on the basis of a consistent inflation series, but a combination of CPI from 1988, an ONS back estimate of CPI from 1949 to 1987, and before that a compound retail price index.[58]

7.10. For the UK, no consistent inflation series back to 1900 exists, hence an important consideration, when estimating real TMR for regulatory purposes, is the approach to calculating real returns in both CPI and RPI terms.

7.11. As I explain at paragraph 5.28(d), Wright et al (2018) set out a real TMR from historical data of 6-7% in real **CPI** terms. Previous CC precedent on TMR was 6.5% in real **RPI** terms. Since 1989, when CPI became an official statistic, there has been a positive wedge between RPI and CPI, being that RPI is 72 basis points[59] higher than CPI. This wedge is sometimes referred to as the “Formula Effect”. On a forward looking basis, the Formula Effect[60] is estimated to result in a wedge of 100 basis points. [61]

7.12. The TMR range estimated by Wright et al (2018) therefore represented a material reduction in TMR compared to the CC’s 6.5% real RPI estimate. This is because the equivalent forward looking RPI return for the UKRNs 6-7% real CPI estimate would amount to approximately 5-6% in real RPI terms (6-7% in CPI terms, reduced for the 100 basis point difference between RPI and CPI).

7.13. The reason for this reduction, becomes apparent when one examines Wright et al’s choice of CPI series. The authors used a CPI series constructed by the Bank of England (BoE), using various different sources for CPI. Table 1 below summarises the CPI sources used by the BoE, and compares it to the BoEs RPI data series.

[58] 2019 DMS Publication, page 212

[59] The wedge varies over time, this is an average. The wedge from 1989-end 2018 is calculated as the difference between the two ONS data series. Precisely, the difference between the arithmetic means is 0.724% and the difference between geometric means is 0.721%.

[60] Although this is a commonly used shorthand, strictly speaking the difference is the result of the calculation method combined with differences in the index composition.

[61] See for example, the CAA’s FD, Appendix E, paragraph E16

Table 1: The BoE CPI inflation series used by UKRN and the implied RPI-CPI wedge

Period	BoE RPI source	BoE CPI source	RPI-CPI wedge (bps)
1989-2016	Official ONS RPI	Official ONS CPI	72
1950-1988	Official ONS RPI	ONS modelled back series CPI	28
1915-1949	Implied deflator for consumers' expenditure (O'Donoghue et. Al., 2004)	Implied deflator for consumers' expenditure (O'Donoghue et. Al., 2004)	0
1900-1914	Implied deflator for consumers' expenditure (O'Donoghue et.al., 2004)	Cost of living index (Feinstein, 1991)	-30

Source: Table 1 of NERA Economic Consulting's Review of UKRN recommendations on the appropriate inflation index for estimating historical TMR and https://www.bankofengland.co.uk/statistics/research-datasets

7.14. Table 1 above shows that Wright et al's (2018) chosen series, which is based on back-casting by the BoE assumes a negative Formula Effect in the early part of the period and assumes no RPI-CPI wedge for a 34 year period, as the same data source is used for CPI and RPI.

7.15. It seems unlikely that the Formula Effect in the early part of the time period would in fact be negative, as suggested by the Wright et al (2018) analysis, given that the ONS official data reveals an actual Formula Effect of 72 basis points from 1989-2017, and an estimated Formula Effect of 28 basis points from 1949-1988. Further, a key driver of the RPI-CPI wedge is that CPI is based on geometric averages and RPI primarily uses arithmetic averages.[62] As with the empirical findings of the long-run returns data reported in DMS (see paragraph 4.10(b) and 7.9), arithmetic averages are higher than geometric averages. A negative Formula Effect therefore seems unlikely. Use of the BoE constructed CPI series is therefore likely to result in a somewhat artificial reduction in the real TMR.[63]

7.16. What is clear, though, is that no reliable estimate of CPI is available before 1949. In my view, some uplift to the pre-1949 data for the Formula Effect may be desirable if a CPI deflated return series is sought. However, given the absence of data pre 1949 it is not clear what the precise figure should be.

7.17. My view is that the best starting point is to take the nominal equity returns series from the DMS 2019 publication, and separately deflate a "CPI" adjusted series and an RPI adjusted series, using the back data published by ONS for the period that it is available. In effect, I therefore assume that the Formula Effect is zero pre 1949 (which likely

[62]https://www.ons.gov.uk/economy/inflationandpriceindices/methodologies/consumerpriceinflationincludesall3indicescpihcpiandrpiqmi

[63] Both in real CPI terms and also in real RPI terms, if the TMR is estimated in CPI terms first and then reduced for a forward looking RPI-CPI wedge to derive the TMR in real RPI terms.

understates the Formula Effect for the reasons given at paragraph 7.15) and then use the wedge derived from ONS data from 1949 onwards.

7.18. My approach is summarised in Table 2 below.

Table 2: My RPI and CPI inflation series and the implied RPI-CPI wedge

Period	My RPI source[64]	My CPI source[65]	RPI-CPI wedge (bps)[66]
1989-2018	Official ONS RPI	Official ONS CPI	72
1950-1988	Official ONS RPI	ONS modelled back series CPI	28
1915-1949	Retail price index (RPI)	Retail price index (RPI)	0
1900-1914	Retail price index (RPI)	Retail price index (RPI)	0

Source: DMS 2018 and 2019 publications and my analysis

7.19. My approach to inflation therefore relies on the CPI and RPI data from the ONS for the period that the data is available and a conservative assumption that the Formula Effect is zero pre 1949. I term this a “quasi-CPI” series to emphasise that I am probably over-stating the true (but unobservable) CPI pre 1949, and hence under-stating the associated real CPI-based returns.

My approach to averaging ex post returns

7.20. The next question is what weight to place on geometric and arithmetic averages, an issue that was considered at length in the NIE case.[67] As I explain at paragraph 4.10(b) and Technical Appendix 1, this depends on the time horizon selected.

7.21. My view is that if a long-run time horizon of more than 10 years is chosen, consistency demands the same horizon is used in deriving an average TMR from the historical data. I therefore estimate the average returns for holding periods of 10 and 20 years. These estimates lie between the arithmetic average i.e. the 1 year expected return and the geometric average i.e. the return expected if equities were held for the 119 year period of the dataset.

7.22. I take several approaches to estimating average returns over 10 and 20 years, which closely follows previous CC practice in the NIE FD.

[64] To derive my RPI series, I use the 2018 DMS publication. The 2018 publication used the index of retail prices to 1949, Official ONS RPI to 1988 and then Official ONS CPI from 1988. I therefore use the DMS data to 1988 and then use ONS RPI data from 1989 to end of 2018.
[65] To derive my CPI series, I use the 2019 DMS publication. The 2019 publication uses the retail price index (RPI) to 1949, ONS modelled CPI to 1988 and then Official ONS CPI from 1988.
[66] The wedge from 1989-end 2018 is calculated as the difference between the two ONS data series. Precisely, the difference between the arithmetic means is 0.724% and the difference between geometric means is 0.721%.
[67] NIE FD, Table 13.7 pages 13-27

a) First, I use averaging estimators suggested by Blume (1974) and Jacquier, Kane and Marcus (2005; JKM)). These produce unbiased or efficient[68] estimates of expected returns over multiple years using annual data.

b) Second, I estimate simple rolling and non-overlapping averages for 10 and 20 year periods. These estimate expected returns directly using *actual* observed 10 and 20 year returns.

7.23. My view is that weight should be placed on each of the averaging approaches. This is consistent with the CC's position in NIE, where it does not favour any one of these approaches (see paragraph 5.6). A detailed explanation of each approach and my rationale for placing weight on each approach is set out in Technical Appendix 1.

My TMR results from the historical ex post data

7.24. My estimates, derived from the historical DMS data, using a quasi-CPI and RPI adjusted series and different averaging approaches are set out below.

Table 3: Real TMR from DMS Data

Basis	**Quasi-CPI adjusted basis**	**RPI adjusted basis**
Arithmetic average	7.25%	6.98%
Blume (1974) adjusted, 10 year returns	7.11%	6.85%
Blume (1974) adjusted, 20 year returns	6.95%	6.69%
JKM (2005) unbiased estimator, 10 year returns	7.17%	6.91%
JKM (2005) unbiased estimator, 20 year returns	7.01%	6.75%
JKM (2005) MSE efficient estimator, 10 year returns	6.85%	6.59%
JKM (2005) MSE efficient estimator, 20 year returns	6.37%	6.11%
UK 10-year non-overlapping returns 1918-2018	7.47%	7.18%
UK 20-year non-overlapping returns 1938-2018	7.84%	7.45%
UK 10-year rolling average returns	7.00%	6.73%
UK 20-year rolling average returns	7.08%	6.78%

Source: My analysis of returns data in the DMS 2019 publication

7.25. The first point I note from the above analysis is that the values in Table 3 bear a strong resemblance to those shown in Table 13.7 and Figure 1, Appendix 13.2 of the CC's NIE FD. At that point, the DMS data used by the CC was RPI-based, and so the appropriate comparator is found in the RPI column. At most, the difference is 10 basis points and the JKM MSE estimator has near identical values. Indeed the non-overlapping returns are actually higher in the current case.[69]

Cross check using long run ex ante data

7.26. As I explain at paragraph 7.7, I consider that long run ex ante estimates, provide a useful cross check on the ex post figures. I draw on three pieces of long-run ex ante evidence to cross check my ex post figures.

7.27. First, I use the analysis of Fama and French's dividend discount model (2002) found in Vivian (2007) and Gregory (2011), and use the estimates of dividend growth and "Bias

[68] Efficiency should be interpreted in the 'mean squared error' sense.
[69] Note that by construction, our non-overlapping periods will not be comparable with those in NIE, due to the different starting points. See Technical Annex 2.

Adjustment" found in those papers. Both of those papers use the former Barclays' Equity-Gilt Study data, which was RPI deflated.

7.28. The so-called "Bias Adjustment" refers to the inherent geometric averaging in dividend discount models. Volatility in returns can be decomposed into volatility in dividend growth and volatility in equity price growth. When using dividend discount models, the mean returns that are derived take account only of the volatility in dividend yield, through the dividend growth input assumption.[70] However, investors expect volatility in both dividend yield and share price (see paragraph 4.9(a)). Dividend discount approaches therefore, understate expected returns by failing to recognise that the volatility of price growth has historically been far greater than the volatility of dividend growth.

7.29. The bias adjustment effectively converts the geometric average implied by the use of a dividend growth model to an arithmetic average. Vivian (2007) finds UK dividend growth to be around 1%, whilst Gregory (2011) reports a growth of 1.21%. The latter paper estimates the size of the Fama-French (2002) bias-adjustment to be 1.3%. Assuming these historical growth numbers are predictive of future dividend growth would give an equivalent arithmetic average return of between 6.4% and 6.6%, real RPI given a current dividend yield of 4.1%.[71]

7.30. My second, ex ante cross check, is the historical decomposition approach found in the DMS publications. This decomposes the geometric mean real risk premium, i.e. the wedge above the risk-free rate[72], received by a US investor into the geometric mean dividend yield, the growth rate of real dividends, the expansion in the price/dividend ratio (i.e. a valuation increase) and a change in the real exchange rate relative to US dollars. The argument behind this approach is that in equilibrium the expected valuation change and changes in the foreign exchange rate would not be expected to continue, but if (based on rational expectations) equity prices reflect the present value of future dividends, then the expected return should reflect the mean dividend yield on equities plus the historical rate of dividend growth. For the UK, based on DMS (2019, Table 10) the numbers are a geometric mean yield of 4.58% plus growth of 0.83%, giving an expected return of 5.41%.

7.31. As with the dividend discount models employed by Fama and French, Vivian and Gregory, the DMS decomposition approach results in an expected return that is, by construction, an estimate of the *geometric* return. To convert these figures to a regulatory/discounting rate, DMS (2019, p.37) recommend an uplift of 1.5%, which suggests a forward estimate of 6.9% real for the UK.[73,74]

7.32. Finally, I consider qualitatively the changes in dividend yields since the CC's NIE FD. Ideally, I would be able to update the historical ex ante data referred to in the NIE FD

[70] Assuming an arithmetic average of dividend/earnings growth data has been used for the dividend growth input assumption.
[71] Note that this is a crude approximation, since Fama and French (2002), Vivian (2007) and Gregory (2011) express the dividend/price ratio as Dt/Pt-1, i.e. dividend over *opening* prices not current prices.
[72] Which is estimated based on treasury bills.
[73] As with the other DMS (2019) UK data, these are compound CPI/RPI estimates, and unfortunately no dividend indices are published, so I cannot adjust these numbers to consistent RPI and CPI bases, as I have done for the ex post returns. But the geometric mean return for the UK (which is the subject of the decomposition analysis) is 5.44% on a CPI basis and 5.15% on an RPI basis, a difference of 26 basis points. Applying this difference suggests a forward looking RPI based estimate of 6.64%
[74] I note that references to survey data are also inherently geometric averages and should be adjusted upwards by the 1.5% estimate referred to in DMS (2019) explained above.

(paragraphs 13.142 to 13.144), but unfortunately the Barclays Equity Gilt data referred to are no longer produced. However, at the time of the NIE FD, the dividend yield was 3.6%, which was materially below the historical average yield of 4.5%.[75] At the time, the CC interpreted this as evidence that ex ante return expectations may have fallen by 1%.[76] However, the current dividend yield in the UK is 4.1%.[77] The corollary is that, *ceteris paribus*, expected returns are 0.5% higher than they were at the time of the NIE FD.[78]

Conclusion on TMR

7.33. I agree with Wright et al (2018) that the weight of evidence supports use of historical ex post returns data over long run time horizons to estimate TMR. When using ex post returns data, the approach to deflating nominal returns and averaging the annual figures are the two main judgments.

7.34. The reduction in real TMR by sector regulators following the Wright et al (2018) publication is somewhat artificial, as it is largely driven by a constructed CPI series that has a negative Formula Effect for a significant portion of the time series. My approach to inflation on the other hand, relies on the CPI and RPI data from the ONS for the period that the data is available and a conservative assumption that the Formula Effect is zero pre 1949.

7.35. In order to average the annual returns, I apply four different averaging techniques to derive returns for 10 and 20 year holding periods, consistent with my chosen forward looking time horizon.

7.36. Taken as a whole, I note that the results of my analysis continue to support the CC's rate of 6.5% real, RPI used in the NIE FD and Bristol Water FD.

7.37. I cross check the TMR derived from historical ex post returns with historical ex ante approaches and find that the historical ex ante results corroborate the 6.5%, real RPI estimate.

7.38. For the purposes of deriving a real TMR in CPI terms, my view is that the TMR in real RPI terms should be adjusted for the forward looking wedge between RPI and CPI. This is because no reliable CPI series exists over the same time period as the historical returns data. My TMR estimate in real CPI terms is therefore 7.6% (if a 100 basis point forward looking RPI-CPI wedge is used) or 7.3% (if a 72 basis point forward looking RPI-CPI wedge is used).[79]

[75] NIE FD, paragraph 13.144.
[76] NIE FD, paragraph 13.144. This is because a lower implied discount rate arises when the expected dividend yield is lower.
[77] This figure is from the value-weighted market index in the December 2019 London Business School Risk Measurement Service publication.
[78] This is because the implied TMR increases by approximately 1:1 with increases in the dividend yield.
[79] This is towards the upper end of the range derived from my quasi-CPI series in Table 3. This is consistent with my quasi-CPI series being based on a conservative assumption that the Formula Effect is zero pre 1949, which is likely to overstate the inflation portion of returns and therefore understate the real TMR in CPI terms.

8. RFR

8.1. As set out in section 4, the RFR is usually estimated by selecting an instrument or instruments, which are considered to have negligible risk and measuring the expected return from investing in this instrument/(s).

8.2. Available instruments in the UK with negligible risk include:

a) *Nominal gilts:* a guarantee by the Government to pay the holder of the gilt a fixed cash payment (coupon) every six months until the maturity date, at which point the holder receives the final coupon payment and the principal;

b) *Index-linked gilts:* similar to Nominal gilts above, but where coupon and principal payments are indexed to an appropriate inflation index; and

c) *Interbank loan:* an interbank loan is a (non-tradeable) loan from a bank to another financial institution. The borrower receives an agreed amount of money for a given period of time, at an agreed interest rate. The interest rate is the rate at which banks are willing to lend cash to other financial institutions.

8.3. The yields on the aforementioned UK instruments are shown in Table 4 below. A detailed explanation of the underlying instruments and the derivation of these rates is set out in Technical Appendix 2.

Table 4: The implied RFR over a 5 and 15 year time horizon, using UK gilts and interbank market rates[80]

5 year time horizon	**Average implied 5 year forward yield**			
-	**Nominal**	**Real, CPI**	**Real, RPI**	**Difference to RPI-linked gilt yield (bps)**
Nominal gilts	0.50%	-1.47%	-2.43%	+30
RPI-linked gilts	0.19%	-1.78%	-2.73%	0
Commercial bank liabilities (LIBOR)	0.76%	-1.21%	-2.17%	+56
Commercial bank liabilities (OIS)	0.54%	-1.43%	-2.39%	+34

15 year time horizon	**Average implied 15 year forward yield**			
-	**Nominal**	**Real, CPI**	**Rea, RPI**	**Difference to RPI-linked gilt yield (bps)**
Nominal gilts	1.05%	-0.93%	-1.89%	+43
RPI-linked gilts	0.61%	-1.36%	-2.32%	0
Commercial bank liabilities (LIBOR)	0.88%	-1.10%	-2.06%	+26
Commercial bank liabilities (OIS)	0.65%	-1.32%	-2.28%	+4

Source: Bank of England and my analysis in Technical Appendix 2

8.4. As Table 4 shows, yields on UK instruments that are ordinarily suitable proxies for the RFR are substantially negative.

[80] The forward rates have been computed using averaged spot yields that were observed during the month of October 2019, and assume a period start date of 1 July 2022, which is the midpoint of the RP3 charge control period. See Technical

8.5. I note that, in 2019, sector regulators have used the negative yields on market instruments – namely RPI-linked gilts - as the RFR when setting a fixed CoE in a price control.[81] The choice of a negative rate, based on current market yields by regulators appears to rest on the arguments put forward in Wright et al (2018). Those authors argue, in essence, that the "market price is what it is" (see paragraphs 5.28(c) and 5.29(a)).

8.6. While this reasoning may not be unreasonable as a basis on which to derive an estimate of the CAPM-CoE using **current** market data, this is not the ultimate aim (albeit deriving the CAPM-CoE can be a useful intermediate step). The aim, instead, is to estimate a RFR over the specified time horizon for use in the A-CoE. The subtle difference is that A-CoE is a fixed allowance in the charge control, and under the CAA's (and Ofwat's) regime I am not aware of an indexation mechanism should interest rates increase above current levels. In setting the RFR based on the yields implied by current gilt markets, regulators are (implicitly) assuming that they can be confident that these negative yields will prevail over the specified investment horizon (which, as set out in paragraph 6.3, I consider should be more than 10 years).

8.7. However, there are three main reasons why I do not consider that regulators can be confident in this assumption.

8.8. The first is that notwithstanding the arguments in Wright et al (2018), it has hitherto been unusual to find any arguments to support the rationalisation of a negative RFR. The normal assumption is that time preference for consumption now rather than consumption in the future would ensure a positive real interest rate. The "neo-classical" assumption is that this rate would be close to the long run steady-state GDP growth rate (e.g. Taylor 1993). In this regard, long run historical data may have a role to play in providing insights to the likely long run interest rate equilibrium.

8.9. Whilst I acknowledge the difficulties of looking at long run bond data, including, *inter alia*, problems with historically and internationally consistent inflation adjustments, the DMS 2019 Publication shows a world average real bond return of +1.9% and +2.5% on geometric and arithmetic average bases respectively. The UK numbers are +1.8% and +2.7% respectively.[82]

8.10. The second argument is that what should matter for long run interest rate expectations is that in open economies, *real* interest rates should be the same across countries, something known as the "International Fisher Effect". This is a standard theory of economics, and suggests we should be concerned with real interest rates in other countries. Indeed, in earlier work, Wright et al (2003, pp40-43) emphasised the importance of looking at international data. In this context I also note that the "price of tomatoes" argument, cited by Wright et al (2018), can be used to comprehensively reject the idea of a negative UK real interest rate being sustainable. If "tomatoes" (or in this case safe risk free and inflation free assets) are readily available and instantly

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Appendix 2 for further details. I use 5 and 15 year horizons here, because to the extent that the evidence in my report is used in any potential water appeals, the water charge control is a 5 year period and Ofwat's investment horizon is 15 years.

[81] Ofgem is the exception as they plan on indexing the RFR. See for example Consultation on RIIO-2 Sector Specific Methodology December 2018, Annex: Finance, paragraph 3.14.

[82] Table 4 of the 2019 DMS publication. Note that these are calculated using CPI estimates 1949 onwards, and before that a retail price index based measure for the UK (CPI for the World Index).

transportable, then the international price of such assets should, in theory, be identical. This is otherwise known as purchasing power parity (PPP). Whilst at present PPP theory has not translated into equivalent rates in the US and the UK, I consider this theory to be another reason why regulators cannot be confident that the current, substantially negative, market rates in the UK will prevail over the long run.

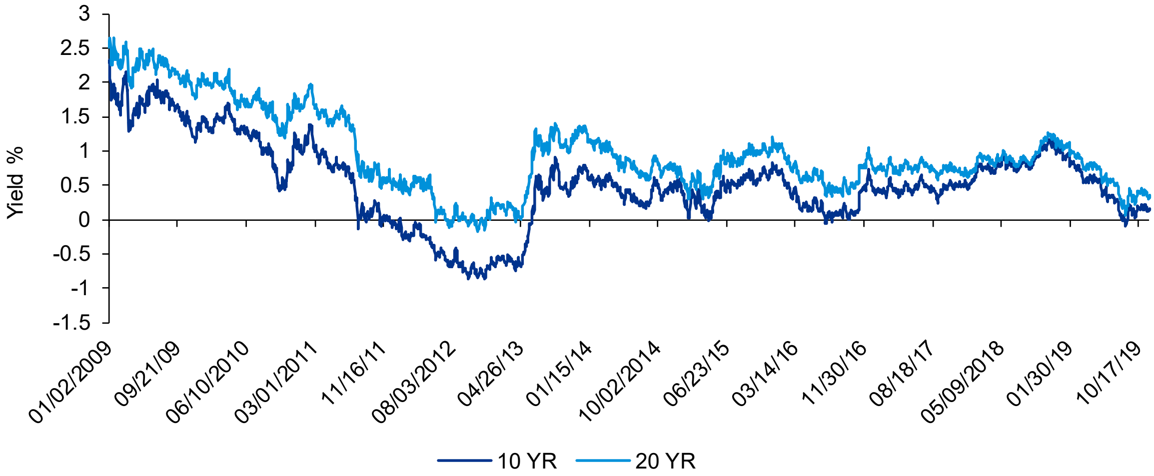
8.11. Third, by any standard, the UK is in a volatile and unusual situation at the moment. I particularly note Mark Carney's recent statements about the UK's reliance on 'the kindness of strangers' and his potential scenarios for the future of UK interest rates.[83]

8.12. In my view, the current distortions in UK bond markets described above mean that regulators cannot be confident that the RFR estimates derived from market instruments will prevail over the relevant time horizon. If one locks in a distorted RFR into the A-CoE and rates rise, the A-CoE could, all else being equal, be lower than the CAPM-CoE and the notional firm may not be able to raise or retain equity finance. On this basis and given the importance of retaining and attracting investment (described in further detail in Section 11), I do not consider that the correct policy decision when setting the A-CoE is to lock in current rates. This assumption of distortion has regulatory precedent, as set out at paragraph 5.10.[84]

8.13. In the absence of 'distortion-free' UK data, the obvious international market benchmark for spot real long run interest rates is the US Treasury Inflation-Protected Securities (TIPS). These are CPI (not RPI) linked securities where yields are set at issue through competitive auction. They are issued with 5-, 10- and 30-year maturities and the US Treasury publishes implied yields to maturity at varying horizons. These derived real yields to maturity on 12 December 2019[85] are +0.18% at 10 years, +0.37% at 20 years, and +0.53% at 30 years. Figure 1 further illustrates that US TIPS are currently positive and have been so for most of the last ten years.

[83] See for example https://www.ft.com/content/33d6e16a-bf81-11e9-b350-db00d509634e
[84] This issue is particularly significant when setting the RFR in the RAR-CoE, where the equity beta is less than 1. This is because beta is multiplied by the difference between TMR and RFR, referred to as the equity risk premium (ERP) (see Section 4). Where a substantially negative RFR is used the ERP component, to which the beta is applied is larger. It follows that the outturn CoE is lower.
[85] https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=realyield

Figure 1: Real yields for maturities of 10 and 20 years on US TIPs, daily data from 2009 to December 2019



Source: https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=realyieldAll, data extracted on 12 December 2019

8.14. Additionally, in its Inflation Report of August 2018 Box 6, p.37-43, the BoE provided an analysis of the long run real interest rate equilibrium rate. Its central conclusion is that although this will be below long run historical levels, it is nonetheless a positive at +0.5% (real, CPI). I also note from Table 1 of Box 6 that this estimate is at the low end of both the UK and World estimates made by other authors.

8.15. My conclusion is therefore that an equilibrium RFR estimate should be used in the A-CoE, taking into account the international evidence from the US, long-run data from DMS and BoE estimates. In my view, this evidence points to a reasonable central estimate of the long run RFR in real CPI terms, for use in the A-CoE, of around 0.0% to +0.2%. On an RPI basis, this translates into an RPI based RFR of -1.0% to -0.8% if a forecast 100 basis point difference between RPI and CPI is assumed (or -0.72% to -0.52% if the historical average (1987-2018) difference of 72 basis points is used).

9. Beta

9.1. The regulatory problem is to estimate beta over the chosen time horizon. As I explained at paragraph 6.3, it is relatively uncontentious that the time horizon is 10 years or more.

9.2. When estimating a beta over 10 years or more, one should estimate an unconditional beta. That is a beta that is not unduly reliant on recent volatility in data. In my view, the most appropriate technique for doing this is to obtain returns data for the full period of time over which the comparable stock has been listed and undertake a linear regression analysis (using ordinary lest squares, OLS) on this data. I refer to this as full sample OLS.

9.3. There are two main reasons why I prefer full sample OLS, rather than beta estimates based on a short time windows.

9.4. First, use of time-varying short-term betas inherently assumes that there has been a change in the systematic risk of the sector or a ‘structural break’. However, where short-term betas have been relied upon, there is often little attempt to justify whether the estimated break points are attributable to any obvious causal factor. One can envisage that breaks could occur because of a change in the circumstances of individual utilities, used as comparators (e.g. mergers; de-mergers/carve outs, and changes in gearing (which would impact the equity beta but not the asset beta)). However, the idea that structural breaks happen sufficiently frequently for the unconditional beta to change over short time frames, appears unlikely.

9.5. Second, in using short-run conditional beta estimates, e.g. based on 2-years' worth of data, one is assuming that this short-run conditional beta is the best estimate of the beta for the forecast time horizon. Short-run, conditional betas may be of use if the objective was 'hedge fund-like' or short run portfolio management, but that is not the regulatory objective.[86] Instead, the regulatory objective is to estimate a beta over the forward looking time horizon, which in my view is the long run, i.e. more than 10 years. As I explain at paragraphs 4.18 and 6.4, the underlying parameters must all be estimated in a way that is consistent with this chosen time horizon.

9.6. I note that my recommended approach to using long run data to estimate a long run beta is entirely consistent with the majority recommendation in UKRN who note that

"Crucially, there is strong historical evidence that short-term shifts in volatility and correlations do not persist indefinitely. As a result, Robertson and Wright conclude that the most recent rolling beta estimates are very likely to prove temporary."[87]

9.7. Wright and Robertson, in Appendix G of the Wright et al (2018) paper, also argue that data should be extended as far back as possible in estimating beta in order to avoid spurious inferences from observed time variation in volatility. This is consistent with my position that changes in the beta used for regulatory purposes must be accompanied by an assessment of the structural break that the variation in the short-run beta over time can be attributed to.

9.8. Turning to the choice of sampling frequency, in theory, providing stock returns exhibit no auto-correlation, the frequency of observations used to estimate beta should be irrelevant. One might therefore consider high frequency data to be preferable because there would be many more observations available, so that although the beta should be identical, the standard error of the beta estimate would be lower with high frequency data.

9.9. However, the empirical evidence shows that the sampling frequency does have an impact on the outturn beta.

9.10. Recent research (acknowledged by Wright et al (2018) and cited by the CMA in recent cases) shows that the use of daily (high frequency) data may lead to biased estimates of the true beta. These papers (Gilbert et al, 2014 for the US, and Gregory, Hua and Tharyan 2018 for the UK) show that the difference between high frequency and low frequency estimates can be explained by factors including opacity, liquidity and industry

[86] It may be possible to use short-run betas to derive a forward looking long-run beta but to do so one would need correctly specified model in order to do this – one that takes into account time variation in conditional beta and not simply an OLS between returns on the stock and the market portfolio.
[87] Wright et al, page 52

membership. This leads the authors of both papers to conclude that low frequency data may give more reliable estimates of beta than those from high frequency data.

9.11. That said, it is clear that the problem is of more importance in smaller and less liquid companies. Table 9 of Gregory et al (2018) shows little difference between monthly and daily betas for the largest quintile of companies. Additionally, Table 6 reveals that Utilities is the only industry for which the dummy variable in their regressions is not significant. Given this evidence, the expectation is that one would not expect high frequency beta estimates to be particularly problematic in the case of large utility companies.

9.12. To conclude, I consider that betas should be estimated using the longest time horizon, since the last major change in the company's business structure. Where large, liquid stocks are used as comparators, the beta should be estimated at various sampling frequencies and weight placed on the results from across the different frequencies.

10. Recent regulatory approaches to setting the A-CoE

10.1. As I explain in Section 5, there has been a material change in TMR and RFR estimates used by sector regulators. Further, regulators continue to use 2 year, daily betas, i.e. short-run beta estimates.

10.2. I summarise my concerns with recent regulatory approaches to setting the A-CoE in this section.

The evidence does not support a reduction in TMR

10.3. In 2019, regulators reduced TMR materially. For example, the CAA estimated TMR of 5.4%,[88] real RPI and Ofwat used 5.47%.[89] This compared to the CAA's estimate in RP2 (the previous NERL charge control in 2014) of 6.25% and Ofwat's TMR at PR14 (the previous water charge control in 2013) of 6.75%, real RPI, in 2014 and 2013. [90]

10.4. As I explain above, this is primarily driven by:

a) reliance on a constructed CPI inflation series, which assumes a negative (rather than positive) wedge between RPI and CPI, which serves to understate the real TMR derived from nominal historical data; and

b) insufficient adjustment for the uplift from a geometric average, which assumes a time horizon of 119 years when using the DMS historical data and an indefinite time horizon when using long run ex ante approaches.

10.5. I estimate TMR using the data available on RPI and CPI inflation back to 1949 and assume a zero wedge before that date. I then estimate an appropriate average return, consistent with my time horizon. My empirical analysis shows that there is limited basis upon which regulators can conclude that TMR has decreased significantly since 2014, let

[88] CAA FD, Appendix E, paragraph E88
[89] Ofwat FD, Allowed return on capital technical appendix, page 53
[90] UKRN annual cost of capital report 2017, page 9. CAA TMR = 0.75% RFR+5.5%ERP = 6.25% and Ofwat's TMR = 1.25% RFR+ 5.5% ERP = 6.75%.

alone by circa 100 basis points. Indeed, my analysis supports the precedent set by the CC that a TMR of 6.5% in real RPI terms remains appropriate.

RFR should not lock in current distorted rates

10.6. In 2019, regulators have used the yields implied from market data on index-linked gilts to set the RFR in the A-CoE. As I explain in Section 8, whilst I recognise that the yield on market instruments is currently negative, I do not consider that it is the correct policy decision to lock in a significantly negative RFR in the A-CoE. Such an approach could have significant implications on incentives to invest, especially in light of the current economic uncertainty.

10.7. I therefore consider that a RFR that reflects equilibrium values should be used in the A-CoE.

10.8. One can envisage a theoretical alternative to my preferred RFR approach, which involves locking in the RFR on UK market instruments and then indexing the A-CoE over time. However, in my view, such an approach could have perverse incentives for investment, in so far as it introduces a fresh element of uncertainty into the allowed rate of return.

Application of the specified time horizon

10.9. More generally, I consider that recent approaches adopted by regulators demonstrate inconsistency in the application of the specified time horizon. As I explain at paragraphs 4.18 and 6.4, the underlying parameters must all be estimated in a way that is consistent with the chosen horizon, as otherwise the CoE estimate is not a true expected return over the chosen time horizon.

10.10. There are two main examples of where regulators adopt inconsistent time horizons when estimating the underlying parameters in the CoE:

a) First, with respect of beta, as explained in Section 9, 2-year rolling betas may be appropriate for estimating CoE over short time horizons. However, they do not provide a robust estimate of the forward looking beta over the regulatory horizon. Rather long-run, unconditional, betas provide the most robust estimate of the forward looking beta over the regulatory horizon.

b) Second, when estimating TMR, the approach to moving between geometric and arithmetic averages should be consistent with the specified time horizon. This has not been the case in recent decisions. For example, the CAA cross refers to Ofcom's evidence on the Fama French dividend discount approach and the DMS decomposition method, without due consideration of the necessary uplift from the geometric average to the appropriate average for their specified time horizon.[91]

11. Consequences of setting A-CoE too low

11.1. In Section 6, I explain that there are two considerations when setting the A-CoE from the CAPM-CoE:

[91] CAA's FD, Appendix E, paragraph E62

a) Are investors unduly exposed to market movements, given that the CoE is a fixed allowance in the price control?

b) Where there is a range of outturn CoE estimates, should one select an estimate above the mid-point of the range, recognising the asymmetric risk on either side of the trade-off between incentivising investment versus keeping bills low? This is often referred to as aiming up, as explained at paragraph 4.19.

11.2. My discussion and analysis in this paper has not so far addressed item ‘b’.

11.3. However, I address point ‘b’ here, not because I am necessarily suggesting an additional uplift to my 6.5% TMR (real, RPI) and -1% to -0.8% RFR (real, RPI) but rather to highlight the risks of setting the A-CoE too low.

11.4. The rest of this section, sets out the risks of setting the A-CoE too low. Then, for completeness I address the Wright et al (2018) position regarding aiming up and summarise my own views on whether aiming up is required.

The risks of setting the CoE too low

11.5. The arguments around setting the CoE too low are well rehearsed. However, I repeat them here, at a high-level, because such risks have been heightened in 2019 as regulators have materially lowered the A-CoE.

11.6. As explained in Section 4, the argument for aiming up, simply put, is that there is an asymmetric risk of over versus under-estimating the cost of capital. If the cost of capital is set too high, there is a welfare loss as customers pay more for their bills.[92] However, if the cost of capital is set too low, there is a welfare loss in terms of underinvestment, or in extremis non operation of the regulated firm.

11.7. Given that demand for most regulated services is inelastic, because these services are essential in nature, the welfare loss from under investment is large. The asymmetric risk therefore lies in the knock-on consequences of setting the cost of capital too low being worse than if the cost of capital is set too high.

11.8. In addition, I note that the implications of setting the A-CoE too low are inextricably linked to the cost of debt. This is because rating agencies evaluate key ratios, which are largely aimed at estimating the headroom above interest costs. All else being equal, the higher the A-CoE, the higher the headroom and the better the credit rating. Where the A-CoE is set too low, the ratios tighten and companies could face a credit downgrade.

11.9. If the A-CoE is set too low, firms may therefore be incentivised to defer expenditure to improve cashflows and/or potentially suffer rating downgrades, which increases the cost of debt.

[92] Ofwat has nearly halved RAR-CoE in real terms and customers are expected to save £50 per annum. https://www.ofwat.gov.uk/pn-16-19-2019-price-review-ofwat-unveils-programme-of-huge-investment-service-improvements-and-lower-bills-for-water-customers/

11.10. I observe that there is emerging evidence that recent regulatory decisions on A-CoE are having knock-on consequences on credit ratings and incentives to invest. This is highlighted by a recent Moody's report on the water sector:

"If final determinations or appeals do not result in significant improvement, the credit quality of many companies is likely to deteriorate. We expect that companies will try to reduce or defer spending…"[93]

The Wright et al (2018) position on aiming up

11.11. Wright et al (2018) are careful to distinguish between the CAPM-WACC and the RAR (see paragraph 5.28(e)). I agree that this is a useful distinction. However, before I set out my views on the Wright et al (2018) position regarding aiming up, I highlight an important difference between my A-CoE definition and the RAR used by Wright et al (2018), which is as follows:

a) My A-CoE takes into account both the fixed nature of the allowed CoE in the charge control *and* the considerations with respect to aiming up. I consider this to be an important judgment when determining the A-CoE, in particular when selecting a point estimate for the RFR, as the market data can be volatile over short time periods (See Section 8).

b) Wright et al (2018), on the other hand, do not address the considerations with regards to the fixed nature of the allowed return. This is curious given their recommendation to use current market rates on UK gilts when setting the RFR. The only adjustment from the Wright et al (2018) CAPM based cost of capital to the RAR is therefore for aiming up considerations.

11.12. The aiming up considerations when setting the allowed return are discussed at length in Wright et al (2018), with a formal analysis in Appendix I.

11.13. This Appendix shows that any aiming up or 'regulatory wedge' between the CAPM-WACC and the allowed return is a function of:

a) The amount of new investment as a proportion of the asset base. The idea being that it is only new investment where an incentive to invest, created by aiming up, is required;

b) The elasticity of demand for the product or service being consumed. The idea being that the more essential the service and the fewer alternatives that customers have, the greater the welfare loss arising from underinvestment.

11.14. The demand for most regulated services is inelastic. This is because of the essential nature of the service[94] and the limited/no alternatives that customers have.[95] It follows that the welfare loss from under investment is large, with the corollary that the degree of aiming up required on new investment is high, typically above the 90th percentile.[96]

[93] Moody's report, Regulated Water Utilities- UK, 10 December 2019
[94]Water, gas and electricity are particularly identified in this Appendix as examples of essentials.
[95] With the firms in question being regulated monopolies.
[96] Wright et al (2018), page 72

11.15. However, this argument by Wright et al (2018) applies only to new investment. For sunk investment, i.e. the existing RAB, Wright et al (2018) suggest that the allowed return should be equal to the CAPM-WACC.[97]

11.16. Whilst this argument seems reasonable at first sight, the problem is that this implicitly views the regulatory process as a one-round process. The reality is that within the context of a quadrennial or quinquennial review process, investment takes place on average half-way through the cycle. That, in turn, implies that the allowed return on new investment will only exceed the (unobservable) 'true' WACC for two (or two and a half) years on average. This is because under the Wright et al (2018) approach, an uplift to the WACC would be applied based on the portion of new investment. However, this higher WACC would only be applied to the investment when it is made, which on average is part way through the charge control.

11.17. This may be why the actual degree of aiming up pursued by regulators has been rather higher than the value suggested in Wright et al (2018), who review international practice as well as past UK practice. For example, in New Zealand this has been formalised as the 67th percentile (reduced from the 75th in 2014).

My position on aiming up

11.18. It is clear, and in this regard I agree with Wright et al (2018), that the A-CoE must always be greater than the CAPM-CoE if any new investment is to be made. This is also discussed in detail in the 2007 Competition Commission Report on airports cited by Wright et al (2018).[98] Real options theory would suggest that for new investment, the expected return needs to be strictly greater than the WACC (Dixit and Pindyck, 1994). This is because, in the presence of uncertainty, the investing firm has to receive sufficient incentive to give up its option to delay investment.

11.19. So, the concept of aiming up is agreed, the only question is by how much, which is largely a matter of judgment.

11.20. However, what **is** clear and which should not be contentious, is that the A-CoE should not be below the mid-point CAPM-CoE. In my view, and based on the empirical evidence in this report, recent regulatory trends to select TMR's of c.5.4% (real, RPI) and substantially negative RFRs in the A-CoE run the risk that the A-CoE is below the mid-point CAPM-CoE. There is therefore a risk of underinvestment with the subsequent negative implications for consumer welfare.

My position on the informational wedge

11.21. The above analysis focuses specifically on what Wright et al (2018) term the "regulatory wedge", W_R between their estimate of the CAPM-WACC and the allowed return. The authors (with a dissenting view by Burns) also argue for the inclusion of an "informational wedge", W_I, which reflects the fact that the regulated companies are likely to have an

[97] Wright et al (2018), page 72
[98] Wright et al (2018), page 71

informational advantage over the regulator. The total regulatory wedge would then be the sum of W_R plus W_I.

11.22. Whilst not directly relevant to NERL or any potential water appeals on cost of capital,[99] I address the informational wedge discussed by Wright et al (2018) for completeness.

11.23. My view is that the asymmetry in information is not something that can, or should, be addressed through the A-CoE. The essential idea here is that firms have an informational advantage over the regulator, such that they obtain cost allowances and performance commitments that they expect to be able to outperform. Given that revenues are set on the assumption that actual costs are equivalent to allowed costs and that performance commitments are met, any outperformance simply increases expected profits and therefore expected returns to equity investors.

11.24. The problem with this argument is that there is no sound theory to link 'out-performance', which is essentially a cash flow matter,[100] with the cost of capital. The appropriate way of addressing the issue of expected outperformance on costs and performance commitments is therefore by recalibrating the cost allowances and performance commitments. It is theoretically incorrect to adjust the allowed rate of return downwards to address this informational wedge.

11.25. Rejecting the argument for an 'informational wedge' in the A-CoE leaves us with the basic idea that the allowed return should be strictly above the mid-point CAPM-CoE, to ensure investment is incentivised (unless planned Capex over the regulatory period is zero or negative, which is unlikely).

12. Conclusion

12.1. When estimating the forward looking CoE for charge control purposes, a long run time horizon of more than 10 years is appropriate. All parameters should be estimated in accordance with this time horizon, otherwise, the estimated CoE will not reflect a true expected return for investors.

12.2. CAPM-CoE and the A-CoE are two distinct concepts. The A-CoE takes into account the fixed nature of the CoE allowance in the charge control and the asymmetric risks on either side of the trade-off between incentivising investment versus keeping bills low.

12.3. In relation to TMR, the evidence has not changed materially since the CC did a thorough assessment during the NIE case in 2014. I have updated the CC's analysis for the last five years of data. I find that for investment horizons of 10 and 20 years, the data continues to support a TMR of 6.5% real, RPI.

12.4. In relation to RFR, whilst the market data may suggest a RFR for the CAPM-CoE that is materially negative, persistence of a negative RFR is not what would be predicted by economic theory or the international evidence. The RFR in the A-CoE is a fixed

[99] Albeit expected outperformance may be relevant for understanding historical market to asset ratios (MARs), should MARs be considered as part of any potential appeals.
[100] I.e. it relates to the firms operating and capital costs and rewards/penalties associated with performance commitments. Neither of these items are directly linked to the return on debt and equity that investors expect for providing capital (albeit the calibration of costs and performance commitments may impact the perceived risk of investing in the regulated firm).

allowance in the charge control. It follows that regulators must be confident that the substantially negative RFR implied by current market data will persist over the long-run. In light of the RFR implied from current market data being inconsistent with economic theory and the current volatility in UK market data, I do not consider that regulators can be confident that the materially negative rates will prevail. Instead, I consider that when setting the A-CoE, a rate that reflects an equilibrium RFR should be used. I estimate that an appropriate RFR is in the range 0.0% to +0.2%, real CPI (which translates to approximately -1.0% to -0.8%, real RPI, if a 100 basis point forward looking wedge between RPI and CPI is assumed).

12.5. Betas should be estimated using the longest run of data, absent structural breaks, consistent with the long-run forward looking time horizon that is appropriate for regulatory charge controls.

12.6. Recent regulatory decisions have significantly decreased the A-CoE, primarily as a result of reducing TMR to approximately 5.4%, real RPI and following current market evidence on index-linked gilts to set the RFR. I disagree that a TMR of 5.4% real RPI is supported by the evidence and consider that locking in substantially negative RFR figures is the wrong policy choice.

12.7. There are important consequences of setting the A-CoE too low. In particular, one risks deterring investment in important industries and potentially raising costs in the long-run. Whilst my estimates of TMR and RFR for use in the A-CoE are not predicated on aiming up, my view is that the A-CoE should be set above the mid-point CAPM-CoE, to retain incentives to invest.

12.8. Finally, I note that the A-CoE should be based on a robust, evidence based assessment of market data on the cost of capital. There is no sound theoretical basis for adjusting the A-CoE downwards, either explicitly or implicitly through selecting a point estimate at the lower end of the range, to take account of expected outperformance. The appropriate way of addressing the issue of expected outperformance (should one exist on a forward looking basis) is by recalibrating the cost allowances and performance commitments.

Technical Appendix 1: Averaging approaches applied to historical TMR data

A.1. In this technical appendix, I briefly review the motivations and methodologies behind the various averaging approaches that I have used in Section 7 to estimate the historical ex-post TMR parameter.

A.2. The estimation issue can be summarised as the following. Suppose one wishes to determine an estimate of the expected return on a portfolio of assets over a specified time horizon. It is commonly known that if one assumes that annual returns are approximately identically distributed independent normal random variables, then the expected return over the time horizon (e.g. 15 years) is given by compounding the expected population annual return.

A.3. However, the expected population annual return is unknown. Hence, it must be estimated. Simply compounding an arithmetic average of returns biases the estimate of expected returns upwards. Similarly, compounding the geometric average of returns biases estimates downwards. The estimators that attempt to correct for this bias and that I have used in my analysis in Section 7 are summarised in turn below.

Blume (1974) adjusted estimator

A.4. A variation on the unbiased estimator proposed by Blume (1974)[101] simply varies the weight between the arithmetic average return (*A*) and geometric average return (*G*), according to the time period for which observations are available (*T*) and the time horizon assumed (*H*). This estimator is approximately unbiased and is given by:

$$BlumeAdjustedEstimator = A\left(\frac{T-H}{T-1}\right) + G\left(\frac{H-1}{T-1}\right)$$

A.5. Thus in the extreme, for a one year time horizon, all weight is placed on the arithmetic average, whilst for a time horizon equal to the series length (i.e. 119 years for the DMS data), all weight would be placed on the geometric average.

JKM (2005) unbiased and MSE efficient estimators

A.6. Jacquier, Kane and Marcus (2005)[102] present two alternative estimators under slightly different assumptions. The general form for both estimators is given by:

$$JKM\ Estimator = e^{(u+0.5\sigma^2 k)}$$

A.7. Where *u* is the mean log return, *σ* is the standard deviation of returns, and *k* is a parameter that varies according to the estimator selected.

A.8. The first estimator, known as the 'unbiased' estimator, imposes a value for the weight *k* such that the estimator provides an unbiased estimate of the expected return over the specified time horizon. In this case, *k* is given by *k* = (1 - *H/T*).

[101] Blume, 'Unbiased estimators of long-run expected rates of return', 1974
[102] Jacquier, Kane and Marcus, 'Optimal estimation of the risk premium for the long run and asset allocation: A case of compounded estimation risk', 2005

A.9. The second estimator, known as the 'MSE efficient' estimator, imposes a value for the weight *k* such that the estimator minimises the mean squared error (MSE) in small samples. In this case, *k* is given by $k = (1 - 3H/T)$.

Rolling averages and non-overlapping returns

A.10. It should be noted that the estimators above all make some assumptions about the distribution of the returns. This is with the aim of incorporating all available annual observations in the data set. Returns are assumed to be independent and normally distributed in the case of the Blume estimator, and independent and log-normally distributed for both JKM estimators.

A.11. An alternative approach is to directly estimate the expected return for the specified time horizon empirically by observing the *actual* returns using the same time horizon. This estimate can be calculated using either non-overlapping or overlapping periods of data, both of which face the trade-off of robustness against sample size.

A.12. When using non-overlapping periods, I assume that the full 119 year period consists of a series of independent observations. However, the DMS data set contains only 119 annual observations. Therefore I have only 11 observations for a 10 year time horizon (and even less for a 20 year), which is a particularly small sample.[103]

A.13. The use of overlapping periods (or 'rolling averages') results in a data set containing 110 observations for a 10 year time horizon, for example. However, a consequence is that I no longer have independent observations. In this regard, the CC in the Bristol Water FD[104] notes that Blume's simulations suggest that an overlapping mean may be a less efficient estimator than the non-overlapping mean.

Serial correlation

A.14. To the extent that market returns are serially independent and follow a sub-martingale process, robust estimates of expected returns are likely to be close to the arithmetic average (Cooper, 1996).

A.15. However, there is some evidence (albeit contentious) of predictability of returns at longer horizons, which undermines this assumption. This is discussed in detail by the URKN's Wright et al. (2018).

A.16. This argument raises the subsequent issue of how serial correlation should be incorporated into estimates robustly in a regulatory context. This is also noted by Wright et al: *"it is much harder to point to an agreed quantitative methodology that could be employed to capture this feature in a methodology that is both implementable and defensible*". [105] Ultimately, this is a highly complex problem with no clear answers (see also Cooper 1996).

[103] It should be noted that I choose to drop the stub of the earliest annual returns, rather than the most recent, on account of reliability considerations.
[104] CC, 'A reference under section 12(3)(a) of the Water Industry Act 1991', 2010, appendix N, annex 5
[105] Wright et al, 'Estimating the cost of capital for implementation of price controls by UK Regulators', 2018, p.41

Technical Appendix 2: Approach and datasets used to derive market driven RFR estimates

A.17. In this technical appendix, I outline the approach and datasets that were used to derive the market-driven estimates for the RFR over 5 and 15 time horizons set out in Table 4.[106]

A.18. Throughout the analysis, I use data provided by the Bank of England (BoE). The BoE publishes estimates of four different yield curves, on a zero-coupon basis. [107] The yield curves are based on nominal gilts, index-linked gilts, LIBOR-based commercial bank liabilities and SONIA-based commercial bank liabilities. Estimates are provided for bonds that mature monthly up to 5 years, then annually up to 40 year maturities for nominal and index-linked gilts, 25 year maturities for LIBOR-based commercial bank liabilities, and 5 year maturities for SONIA-based commercial bank liabilities (OIS).

A.19. Zero-coupon varieties of instruments based on these yield curves are not actively traded for all the maturities listed. Therefore, they must be estimated. The BoE uses the following instruments in its estimation methodology: nominal and index-linked gilts; general collateral sale and repurchase agreements (gilt repo); interbank loans based on the British Bankers' Association's (BBA) London interbank offer rate (LIBOR); short sterling futures; forward-rate agreements and overnight index swaps (OIS).

A.20. In order to estimate maturities in excess of 5 years for the OIS yield curve, I reduce the yield of the LIBOR-based yield curve at the corresponding maturity, by the difference between the LIBOR-based yield curve and the OIS yield curve at the furthest common maturity (i.e. 5 years). If the OIS yield curve is to be viewed as the LIBOR-based curve without a component that compensates investors for creditworthiness considerations, then this approach effectively extrapolates this compensation at a constant level.

A.21. My estimates for the interest rates based on these four yield curves rely on daily data over the month of November 2019 from the BoE. The observations for each maturity of each yield curve are averaged to avoid placing all weight on data observed on a single trading day.

A.22. Market estimates of future yields can be inferred using the concept of forward interest rates. A forward rate for a time horizon *T*, starting on date *t*, is the interest rate that can be 'locked-in' today, for the period of time beginning on date *t,* and maturing *T* years hence. This is calculated according to the following:

$$ForwardRate_t(S, S+T) = \left(\frac{(1 + yield_t(S+T))^{S+T}}{(1 + yield_t(S))^{S}}\right)^{1/T} - 1$$

Where:

- *t* is the date of observation or 'locking-in';
- *S* is the start date of the period of time over which the rate is locked-in; and

[106] I use 5 and 15 year horizons here, because to the extent that the evidence in my report is used in any potential water appeals, the water charge control is a 5 year period and Ofwat's investment horizon is 15 years.
[107] Yields derived on this basis are commonly referred to as 'spot yields'.

- *T* is the duration of the period.

A.23. I calculate the forward rates for both 5 and 15 year time horizons (*T)*, that start at the midpoint of the charge control period (*S*), for each yield curve that has been averaged. This provides the market expectations as of November 2019 for the various interest rates at the midpoint of the charge control period, which are set out in Table 4.