PwC Economics

Estimating the cost of capital for H7 and RP3 - Response to stakeholder views on total market return and debt beta

A report prepared for the Civil Aviation Authority (CAA)

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Summary

In February 2019 the Civil Aviation Authority (CAA) published its draft proposals for the RP3 price control for NATS (EN Route) plc. As part of that consultation, the CAA published "H7 Initial WACC response document by PwC". In that report we set out our responses to the issues raised by stakeholders on the cost of capital for the 'as-is' case and updated the market data for the period to the end of October 2018.

The CAA consultation period has now closed and the CAA has received responses from stakeholders.

In this document we set out our responses to the issues raised by stakeholders on the cost of capital for the 'as-is' case. Specifically, this report focuses on responding to new evidence provided by stakeholders on total market return (TMR) and debt betas given the relevance of these components to the CAA's decision on the NERL price control for RP3. We have also provided some additional analysis where relevant on these topics.

The topics covered in this report were identified in conjunction with the CAA. We respond to four reports that have been produced since we published our initial response to stakeholder views in February 2019[1]. These include:

- Cost of Equity for HAL at H7, NERA, April 2019.
- Groupe ADP business plan, April 2019.
- Estimation of the debt beta of the bond issued by NATS (En-Route) plc, by Professor Ania Zalewska on behalf of NERA, April 2019.
- Heathrow's response to CAP1758 and CAP1762, April 2019.

We note that other cost of capital components, such as the cost of debt and gearing, are out of scope for this report. Our latest views on these issues are presented in our February 2019 report.

Reponses on total market return (Section 2)

Topic 2a – Evidence underpinning a lower TMR estimate relative to Q6

- NERA argue that there is no evidence underpinning the lower estimate of TMR relative to the Q6/RP2 price review. Specifically, they find that realised returns, forward-looking survey evidence, US regulatory precedent and forward-looking DGM evidence do not support a lower TMR estimate.
- Having reviewed the new evidence provided by NERA, we do not consider it justifies an increase to the TMR range proposed in our previous reports. Data on realised equity returns does not show an upward trend for the UK equity market, and when considering average equity returns using a ten-year trailing average (instead of the thirty-year average used by NERA), we find that there has been a noticeable decline in returns over recent decades.
- The Fernandez survey, which provides a useful cross-check on the TMR assumption, shows a slight increase in the average TMR estimate for 2019. However, when deflated by RPI, the estimate (5.3%) remains comfortably within our estimated TMR range for H7 of 5.1% to 5.6% (RPI-deflated terms).
- In our view, the evidence from US regulatory precedent has limited relevance for the UK given that it is drawn from a substantially different regulated market. Moreover, when the full set of historical data for US regulatory allowed returns market are considered, they show that US treasury yields and the approved return on equity have both declined over time, albeit yields have fallen at a faster rate.

[1] PwC (2019), 'Estimating the cost of capital for H7 - Response to stakeholder views'

- Having analysed this new evidence, we have not changed our view that the CAA should set a TMR in the range of 5.1 to 5.6% (RPI-deflated).

Topic 2b – Inflation measure used to estimate CPI returns

- The 2018 UKRN[2] report on the role of the cost of capital in the regulation of UK utilities finds that the Bank of England's back-projected measure of the CPI should be used in constructing and analysing historic real returns. In their April 2019 consultation response and previous responses, NERA argue that this measure was not reliable and should not be used as a basis of estimating historical real TMR.

- In our February 2019 report, we undertook additional review of the Bank of England CPI inflation series. Like UKRN, Ofgem[3] and Ofcom[4] we concluded that the deflation of nominal returns by the Bank of England CPI series provides the most consistent and credible historical inflation data to interpret the history of market returns and set appropriate real allowances for the cost of capital.

- In their April 2019 response, NERA suggest that instead of using the BoE CPI series, the CAA should estimate historical returns using the historical RPI index and then adjust the output for the estimate of the historical RPI-CPI wedge. NERA propose using two different estimates of the historical wedge to make the adjustment.

- In our view, using these two historical wedges calculated using data for different time periods is not a robust or accurate way to obtain CPI-deflated estimates of TMR. This approach does not accurately capture the differences between RPI and CPI back to 1899 when the DMS dataset, which is used to calculate TMR, begins.

- In our February 2019 report, we undertook additional analysis on the Bank of England CPI inflation series. We found that while the two CPI measures[5] have tracked each other closely, a significant divergence between measured RPI and CPI inflation measures opened up from around the 1970s. This divergence explains much of the observed differences between CPI and RPI over the 1899-2013 period. More recent estimates of the wedge between CPI and RPI are therefore much higher

- As regulators are interested in estimating investors (unobservable) real return expectations from historical data, there is no definitive measure of inflation to use. Ofcom considered this issue in its 2018 BCMR consultation[6]. It concluded:

  "The ONS has recently established that RPI is a flawed and upwardly biased measure of inflation. Hence, assuming investors target real returns, it seems plausible that expected returns would be shaped by an expectation that nominal returns would compensate investors for CPI (currently the headline measure of inflation) rather than RPI inflation. As such, using historical evidence on real returns as a guide for forward-looking real (CPI-deflated) returns is reasonable in our view."

- This is consistent with the observation that RPI differences opened up from the 1970s, and the Bank of England inflation CPI measure provides a long-term estimate of to guide investor inflation expectations and real returns.

- Therefore, consistent with UKRN, Ofgem and Ofcom, we continue to consider the deflation of nominal returns by the Bank of England CPI series provides a suitable estimate of ex-post real returns as the basis for calibrating forward-looking real returns for use with CPI inflation.

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[2] UKRN (2018), 'Estimating the cost of capital for implementation of price controls by UK Regulators'
[3] Ofgem (2018) 'Consultation - RIIO-2 Sector Specific Methodology Annex: Finance'
[4] Ofcom, "Business connectivity market review, publication updated on 19 December 2018", Annexes 1-22, Page 213
[5] We analysed the CPI preferred and CPI original measures produced by the Bank of England.
[6] Ofcom, 'Business connectivity market review, publication updated on 19 December 2018', Annexes 1-22

Topic 2c – Evidence of predictability at long horizons

- When estimating TMR it is important to consider the degree to which returns are "predictable[7]" in equity markets. As we noted in our February 2019 report, if market returns are independent of all previous periods they follow a 'random walk'. We observe that while there is an element of 'random walk' in markets, numerous academic studies[8] find evidence of negative serial correlation, i.e. periods of good return performance are followed by periods of weak return performance and vice-versa. We also find evidence of negative serial correlation in UK equity returns data.

- Consistent with previous consultation responses, NERA continue to dispute the existence of return predictability at long horizons. They comment that, "predictability of returns at long horizons is a contentious issue and there is no consensus in financial literature which provides clear-cut evidence to support the notion of predictability".

- In our February 2019 report, we undertake economic analysis to examine whether the different length holding periods impacted returns. We find that as the investment holding period increases, the predictability of returns also increases. This suggests equity return variance decreases as holding period increases, even when we control for autocorrelation. Our findings are consistent with Mason, Miles and Wright (2003)[9] and Robertson and Wright (2002)[10], who also find evidence of the predictability of returns at longer horizons.

- NERA continue to view that a holding period assumption of one to five years remains appropriate for estimating historical TMR. However, we refer back to our February 2019 paper which suggested that many market investors typically have longer-term investment horizons, and are therefore unlikely to make significant changes to their equity holdings on an annual basis. Even short-term investors, such as traders, are basing their investment decisions on the valuation of investments made by long-term investors, and any arbitrage opportunity this may create. This means that the typical investment holding period for an asset cannot be used to infer the investment horizon used to value assets and set expected returns.

- In addition, given that infrastructure investment is for long investment horizons and regulation is set for repeated five year time periods, we recommend that the CAA use a longer-term investment horizon when estimating TMR. This is consistent with the UKRN recommendation that a longer-term perspective is taken to cost of capital estimation.

- We have not changed our view that the CAA should take a longer-term approach to assessing cost of capital inputs and it is important to account for the predictability of returns at long horizons when estimating an appropriate TMR.

Topic 2d – DDM assumptions used in PwC's analysis

- Consistent with previous responses, NERA argue that PwC's dividend discount model (DDM) assumptions are flawed. In particular, they argue that analyst forecasts should be used to proxy short-term dividend growth and use of UK GDP growth to proxy FTSE dividend growth is incorrect.

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[7] i.e. exhibit serial correlation, so the returns in one period are influenced by the returns in prior periods. There may be other factors which can also predict returns.
[8] The evidence on negative serial correlation is widely cited, including analysis conducted by Fama and French (1988). While one year serial correlation is low, they find that five year correlations are strongly negative across all size classes. Fama, E.F. and K.R. French, 1992, The Cross-Section of Expected Returns, Journal of Finance, Vol 47, 427-466.
[9] Mason, R. Miles, D. Wright, S. (2003), 'A Study into Certain Aspects of the Cost of Capital for Regulated Utilities in the U.K.'
[10] Robertson D. and S, Wright. (2002), 'The Good News and the Bad News about Long-Run Stock Returns'

- NERA undertake a literature review to assess the evidence of historical optimism bias. They observe that much of the literature on optimism bias focused on US companies prior to institutional reform in 2003. NERA find that following the reforms to change analyst pay structures and place more weight on external analyst input, the issue of biased forecasting has been addressed.

- However, as we outline in our February 2019 report, there is also evidence that the use of analyst forecasts is not appropriate for regulatory purposes as they have been found to be both biased and inefficient[11]. While NERA provide evidence that suggests this problem has reduced following regulatory changes, there remains a sizeable body of literature that finds evidence of biased and event-driven analyst forecasts[12]. In addition, while there have been substantial changes to how the financial services industry is regulated following the 2008/9 crisis, it will take time to understand the impact that more recent legislation, such as MiFID II, has had on equity research.

- Furthermore, regulators do not require a model which picks up high frequency variations in analyst return expectations, as they are typically concerned with setting longer-term parameters that are suitable for an entire price control. Chart 3 in the Bank of England's latest DDM research note[13] highlights why analysts forecasts are unsuitable for use in DDM models being used for regulatory purposes. The chart shows that there is significant variability in twelve-month ahead dividend growth forecasts, which suggests that analyst forecasts can be strongly impacted by specific market events and market sentiment. The future dividend growth forecasts for the FTSE All-Share range from -15% in 2009 to +17% in 2011, while the variation of dividend growth forecasts for Euro Stoxx and the S&P 500 is wider still.

- We continue to consider that UK regulators require cost of capital assumptions which are sufficient to enable UK regulated companies to finance their activities. This typically requires use of UK input parameters to derive cost of capital estimates. Global assumptions could be used, on a consistent basis, but then adjustments would be required convert them back into a UK cost of capital (for example, for differential real yields or forecast inflation). Our preference is therefore to use UK based parameters, and proxies, wherever possible as it avoids the need for further adjustments.

- Having considered this evidence, we consider that the CAA should continue to use UK input parameters to cost of capital estimates and, more specifically, UK GDP growth assumptions to proxy dividend growth.

Topic 2e –TMR and overall WACC estimate proposed in ADP's business plan

- In April 2019, Groupe ADP (ADP) published its business plan for the 2021 to 2025 Economic Regulation Agreement. The proposal contained ADP's estimate of the weighted average cost of capital for the period, which is estimated using available market financial data and parameters considered for companies engaged in comparable activities.

- In the proposal, ADP's estimates a WACC of 5.6% in nominal terms, which is towards the lower end of our estimated range for HAL of 5.5% to 6.4% in nominal terms (RPI-deflated real returns of 2.5% to 3.4% inflated using an RPI assumption of 3%). This provides reassurance that the cost of capital estimates for both airports are broadly aligned.

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[11] Analysis by the Bank of England in the past found that IBES aggregate forecasts of earnings and dividend growth in both the United Kingdom and the United States for the first, second and third year (fixed-event forecasts) are biased (non-zero average error) and inefficient (errors correlated with past information). In particular, analyst based forecasts are excessively optimistic during economic downturns and too pessimistic in recoveries. Harris (1999) found also that analysts' long-run earnings forecasts for US companies are biased and inefficient.

[12] Eames and Glover (2017) find that more unpredictable earnings are associated with earnings forecast pessimism. Their evidence is particularly prevalent for sample periods including years after 1996, i.e., years subject to the Public Securities Litigation Reform Act of 1995 and then to Regulation FD after 2000. Recent evidence finds that analysts piggyback their recommendations (Altınkılıç & Hansen 2009; Loh & Stulz 2011) and earnings forecasts (Altınkılıç, Balashov & Hansen 2013) on recent news and events.

[13] Bank of England (2017), 'An improved model for understanding equity prices'

- Notably, ADP assume a real TMR estimate of 5.0% (RPI-deflated terms) which is lower than the TMR range proposed in our Feb 2019 report of 5.1% to 5.6%. This provides the CAA with reassurance that the TMR estimates are broadly consistent.
- The comparator based approach used by ADP to estimate its equity beta could warrant further investigation given that ADP beta estimates inform the HAL beta estimate. However, there is no information in the ADP business plan on which entities are used to estimate the equity beta.

Responses on debt beta (Section 3)

Topic 3a – Estimation of debt betas for NATS and HAL using regression analysis

- In our February 2019 paper, we revisited our initial debt beta estimate of 0.05. Based on empirical analysis of debt betas using iBoxx indices as well as HAL's bond data, we found an upward trend in debt betas over the past 18 months, suggesting that a higher debt beta is warranted for H7. Checking this empirical estimate against recent regulatory determinations, which generally support a debt beta in the region of 0.1, we revised our debt beta estimate upwards from 0.05 to 0.1.
- To further assess the debt beta assumptions proposed for H7 and RP3, Professor Ania Zalewska[14], on behalf of HAL and NERA, undertook additional analysis of the beta of the bond issued by NATS (En-Route) plc using a range of econometric estimation approaches.
- Zalewska finds that the NATS-bond's beta is statistically significantly negative for most of the period investigated, and statistically insignificantly different from zero in the last few years. These results are robust across various specifications and methods of estimation.
- We replicate Zalewska's analysis and produce very similar results across the various specifications. However, we also conduct further analysis using different time periods and frequencies of data. We find a persistent difference between debt beta estimates for HAL and NATS, as HAL's debt has a higher correlation with the 'market portfolio' across the different econometric specifications used.
- Our analysis using five-year regressions with monthly data supports the debt beta estimate of 0.10 for HAL's bonds presented in our February 2019 report[15]. However, this approach produces lower debt beta estimates for NATS. In our view, this could be because NATS is a critical national asset with regulatory protections and government support. It also has significantly lower gearing[16], which reduces the probability of distress. These factors are reflected in the credit rating of the NATS bond, which at AA is higher than the rating of the HAL's bonds considered in our analysis.
- In summary, our econometric analysis indicates that empirical estimates of debt betas are highly sensitive to the time period and frequency of data used, and slightly sensitive to the choice of the equity index used to proxy the market portfolio. We examine the impact of data frequency on the estimation of debt betas in Appendix B and find that the problems with daily data, especially around non-trading and slow response of the security to the market movements are likely to be more severe for the bond market than the equity market. Though bond indices are heavily traded, this might not be true for individual bonds, which are typically much less liquid than the corresponding company equity. Consequently, in our view, more weight should be attached to the five-year monthly approach for debt beta estimation.
- In preparing for H7/RP3, we recommend that the CAA considers existing regulatory precedent and takes a balanced view across a range of estimation approaches, including five-year monthly and two-year daily

[14] Zalewksa A (2019), 'Estimation of the debt beta of the bond issued by Nats (En-Route) plc'
[15] PwC (2019), 'Estimating the cost of capital for H7 - Response to stakeholder views'
[16] HAL's actual gearing level is generally within the 75% to 80% range (see our December 17 report), whereas NATS' actual gearing has been closer to 30% in recent years.

econometric regressions, as well as the decomposition approach used by Europe Economics (EE)[17]. The CAA should also align the debt beta estimation period with the equity/asset beta estimation period for consistency.

Topic 3b – Estimation of debt betas using a decomposition approach

- In their December 2018 cost of capital paper for NERL, Europe Economics (EE) estimate a debt beta range of 0.1 – 0.19 for the NATS bond. The lower end is based on regulatory precedent while the top end is estimated using a decomposition approach, which uses the probability of default and percentage loss given default as inputs.
- EE use PwC's estimate of the risk-free rate (the mid-point from our December 2017 paper) in combination with their own estimate of NERL's cost of debt to obtain the debt premium (i.e. cost of debt minus risk-free rate minus 7bps for transaction costs). They base their estimates of probability of default and percentage loss given default on external sources (such as credit rating agencies' reports) and input this into a debt beta formula (see full Topic for more detail) to obtain an estimate of 0.19. Taking into account previous advice to the CAA on debt betas, EE propose a range of 0.1 - 0.19 for NERL's debt beta.
- One of the main benefits of the decomposition approach is that it can be less volatile than empirical approaches given that its inputs are less likely to experience daily changes. For instance, company and index returns typically change on a daily basis, whereas estimates for variables such as loss given default and probability of default are likely to be more stable over time. In contrast, empirical approaches as evidenced by our debt beta analysis can be volatile over time and approach used. In addition, there is regulatory precedent for using decomposition approaches. The Competition Commission[18] used a disaggregation of debt premium approach to obtain a debt beta for BAA.
- However, a limitation of the decomposition approach is that it requires more assumptions than the empirical approach to obtain a debt beta estimate. It requires estimates of the probability of default and the percentage loss given default, which are subject to uncertainty and require judgement.
- In preparing for H7/RP3, we recommend that the CAA takes a balanced view across a range of estimation approaches (empirical and decomposition) and aligns the time period used for debt beta estimation with that used for asset/equity beta estimation.

[17] Europe Economics (2018), 'Components of the Cost of Capital for NERL'
[18] Competition Commission (2007), 'A report on the economic regulation of the London airports companies (Heathrow Airport Ltd and Gatwick Airport Ltd)'

1. Introduction

1.1 In February 2019 the Civil Aviation Authority (CAA) published its draft proposals for for the RP3 price control for NATS (EN Route) plc. As part of that consultation, the CAA published "H7 Initial WACC response document by PwC". In that report we set out our responses to the issues raised by stakeholders on the cost of capital for the 'as-is' case and update the market data for the period to the end of October 2018.

1.2 The CAA consultation period has now closed and the CAA has received responses from stakeholders.

1.3 In this document we set out our responses to the issues raised by stakeholders on the cost of capital for the 'as-is' case. Specifically, this report focuses on responding to new evidence provided by stakeholders on total market return (TMR) and debt betas given the relevance of these components to the CAA's decision on the NERL price control for RP3. We have also provided some additional analysis where relevant on these topics.

Update to December 2017 initial WACC estimate

1.4 In Table 1 below, we provide a recap of the changes made when we updated the WACC analysis for the 'as is' case in February 2019 (using October 2018 as the cut off point for market data). An important point to note is that the H7 price control has been delayed by two years and will now start in 2022. The changes to the WACC range include:

- The risk-free rate in the 'low' case was reduced from **-1.4% to -1.5%**, reflecting the lower yield on gilts.
- Reflecting the revised (later) H7 control period dates and because the amount of embedded debt outstanding falls over the course of H7, the cost of embedded debt in both the 'low' and 'high' case reduced from **1.8% to 1.2%**.
- Based on the current market evidence, the RPI assumption increased from **2.8% to 3.0%**. However, we continue to suggest that the CAA monitor and revisit this assumption in the run up to the H7 control period.
- Based on the current market evidence we increased the debt beta assumption from **0.05 to 0.1**.

1.5 The changes to the risk-free rate, the cost of embedded debt and the debt betas reduce the real vanilla WACC range for H7 'as is' from 3.0% - 3.9% to 2.5% - 3.4%.

Table 1: Initial WACC range for the 'as is' case from the December 2017 and February 2019 (based on data from the end of October 2018) consultations

	Dec 17: H7 'as is'		Feb 19: H7 'as is'	
	Low	High	Low	High
Gearing	60%	60%	60%	60%
Risk-free rate	-1.4%	-1.0%	-1.5%	-1.0%
Total market return	5.1%	5.6%	5.1%	5.6%
Asset Beta	0.42	0.52	0.42	0.52
Debt beta	0.05	0.05	0.10	0.10
Equity beta	0.98	1.23	0.90	1.15
Cost of equity (post-tax)	**4.9%**	**7.1%**	**4.4%**	**6.6%**
Cost of embedded debt	1.8%	1.8%	1.2%	1.2%
Cost of new debt	0.15%	0.65%	0.15%	0.65%
Weighting on new debt	12.5%	12.5%	12.5%	12.5%
Issuance costs	0.10%	0.10%	0.10%	0.10%
Real Cost of debt (pre-tax)	**1.7%**	**1.8%**	**1.2%**	**1.2%**
Vanilla WACC	**3.0%**	**3.9%**	**2.5%**	**3.4%**

Source: PwC analysis

Scope and structure of this report

1.6 This document is structured by the key issues we, in conjunction with the CAA, have identified in stakeholder responses with regards to assessing the WACC for the H7 'as-is' case (excluding runway expansion). Specifically, the document is divided into two sections:

- Section 2: Responses on total market return (TMR) - this section discusses stakeholder comments on TMR and outlines our responses.
- Section 3: Responses on debt betas – this section discusses stakeholder comments on debt betas and outlines our responses.

1.7 In Sections two and three, we structure our discussion of each issue into three parts. Firstly, we provide an issue overview, secondly, we provide a summary of the evidence provided (with specific focus on the new evidence), lastly, we provide our views on the evidence and on the TMR and debt beta estimates that the CAA should use for H7/RP3.

1.8 Further changes to the WACC to take account of the proposed capacity expansion are outside the scope of this report. They will be addressed separately by the CAA.

2. Responses on total market return (TMR)

2.1. In this section we set out comments and responses to issues raised on TMR.

Topic 2a – Evidence underpinning a lower TMR estimate relative to Q6

Topic overview

NERA

2.2. NERA argue that there is no evidence underpinning the lower estimate of TMR relative to the Q6/RP2 price review. Specifically, they find that realised returns, forward-looking survey evidence, US regulatory precedent and forward-looking DGM evidence do not support a lower TMR.

Summary of evidence

Realised returns

2.3. In terms of new evidence provided, NERA analyse returns from the five largest global equity markets to assess whether or not a lower TMR is supported by market evidence of realised returns. They find that there is a slight upward trend in returns in three of the five largest markets (US, Germany and Japan), while they suggest that there is no "discernible trend" in the other markets (UK and France). They also find that the realised return over the most recent period is not statistically different from the long run average, which they argue implies that there is no evidence for the reduction in realised returns.

Forward-looking Dividend Growth Model (DGM) evidence

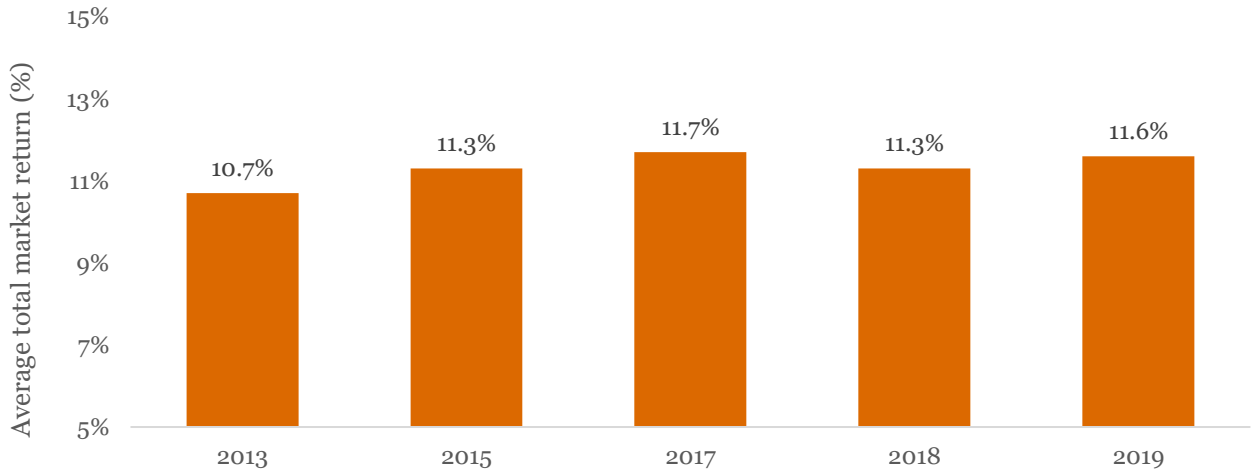
2.4. NERA also present charts showing TMR estimates from dividend growth models produced by PwC and the Bank of England. They note that while they have concerns with the use of DGM to inform the absolute value of TMR due to the sensitivity of the results to the input assumptions, they find that neither PwC's or the Bank's estimates show a decline in TMR since RP2.

Forward-looking survey evidence

2.5. NERA also consider survey evidence from the Fernandez et al[19] annual survey, which provides estimates of the risk-free rate and market risk premium used in 2019 (and the preceding years) for 69 countries. They calculate the average TMR for 39 countries across five years as shown in Figure 1 below and find that there has been no noticeable decline in TMR over the period considered.

[19] Fernandez (2019), 'Market Risk Premium and Risk-Free Rate used for 69 countries in 2019: a survey'

Figure 1: Average total market return for 39 countries, calculated by NERA

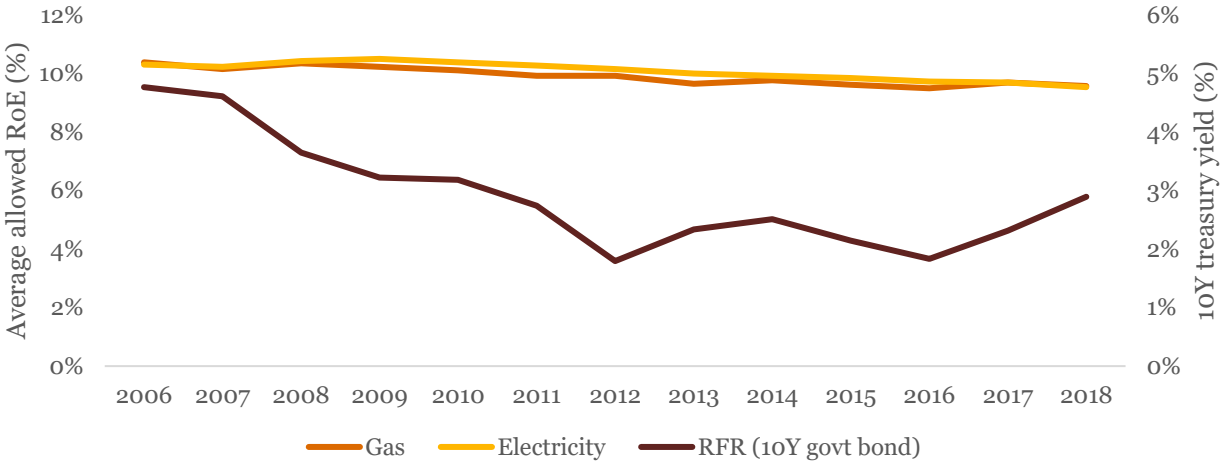


Source: NERA[20]

US regulatory precedent

2.6. NERA present the below chart which shows that despite decreases in the risk-free rate, the approved return on equity has remained relatively stable over the period considered. They argue that this is contrary to the view that lower interest rates are consistent with lower approved equity returns.

Figure 2: Average allowed return on equity approved by US regulators in electricity and gas



Source: S&P Global Market Intelligence (January 2019)

2.7. NERA conclude that the market evidence they have highlighted does not support a decline in realised or expected returns relative to Q6/RP2.

Comments and response

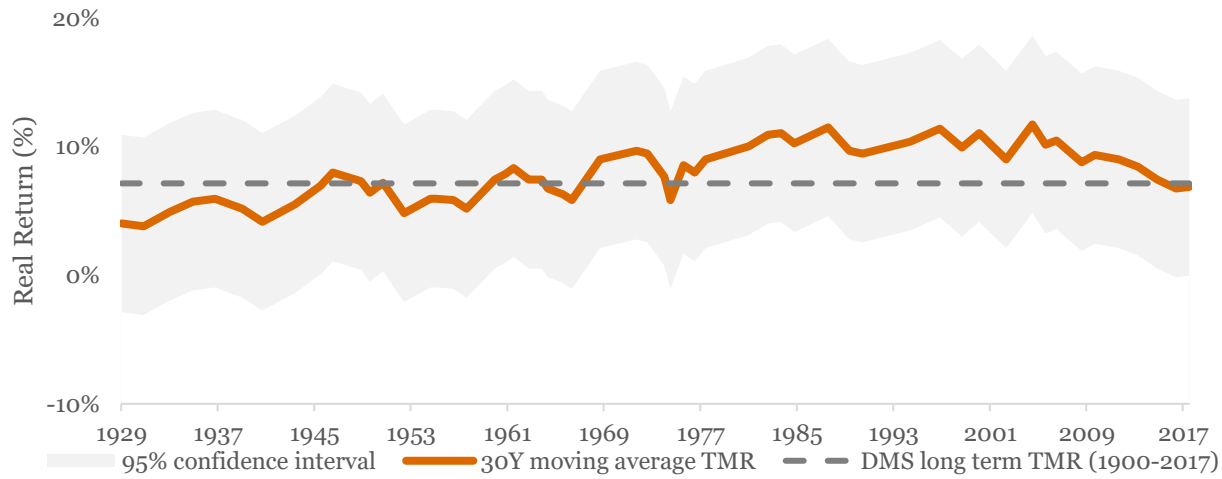
Realised returns

2.8. With reference to the equity returns evidence provided by NERA, given that the CAA's regulatory objective is to estimate a cost of capital for a UK based entity, the most important market to focus on is the UK. NERA's chart (Figure 3) shows a 30-year moving average TMR, which is a relatively long time period. The 30-year average is very slow moving and consequently it does not adapt to changes in the return outlook or economic environment. Despite the long time period in use, NERA's analysis still

[20] NERA (2019), 'Cost of Equity for HAL at H7'

shows that UK equity market returns have declined quite considerably in recent years and are lower than in previous decades.

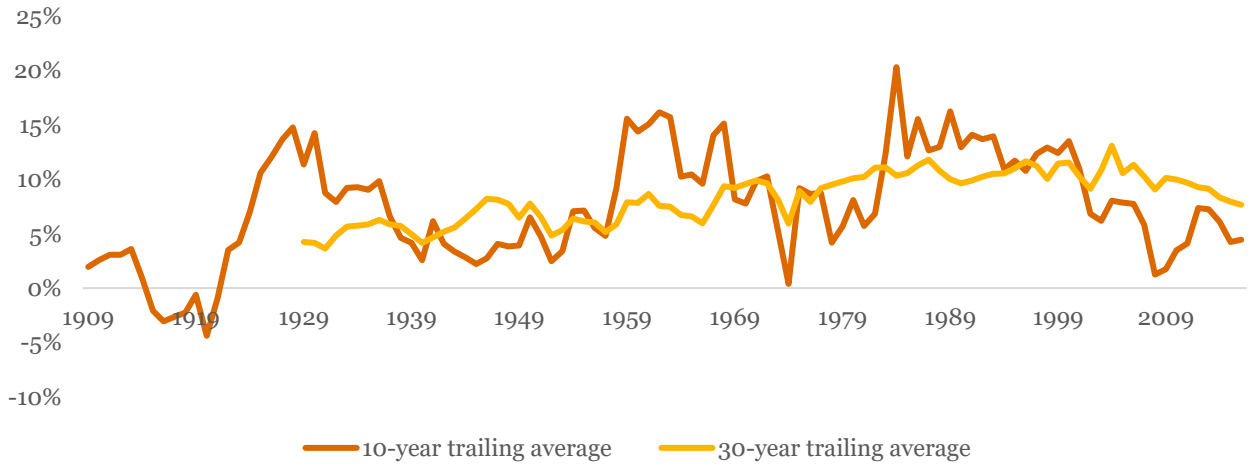
Figure 3: 30-year trailing average of UK equity market returns, NERA



Source: NERA

2.9. The figure below shows the 10-year trailing average of UK market returns (compared to the 30-year trailing average), which we consider is a more appropriate period over which to assess movements over time. It shows a considerable decline in realised returns in recent decades. There is a noticeable decline in returns during the 2008/09 financial crisis before the 10-year trailing average recovers to pre-crisis levels. Then there is another decline from 2012 onwards, which shows that there has been a downward trend in realised returns in recent years.

Figure 4: 30-year and 10-year trailing average of UK equity market returns (DMS real, CPI post 1988, 1900 – 2016)



Source: Dimson, Marsh and Staunton (DMS) dataset, PwC analysis

2.10. We also consider evidence from Dimson, Marsh and Staunton (DMS)[21] in the figure below. DMS compare the relationship between real equity returns and real interest rates using data from 21 countries over 118 years. After excluding periods covering the hyperinflationary periods in Germany and Austria, they obtain 2,382 observations of overlapping 5-year periods. DMS then rank these

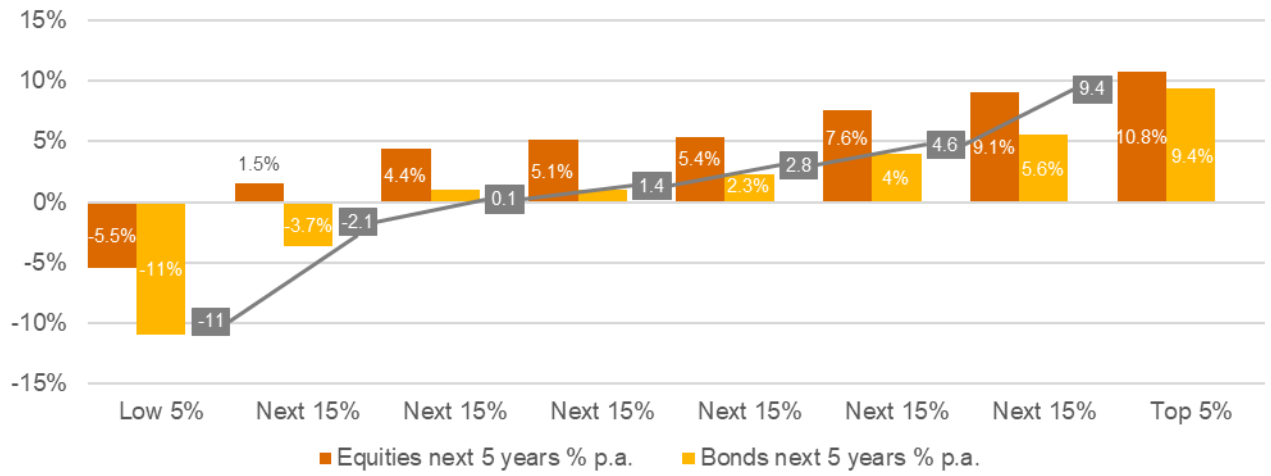
[21] DMS (February 2018), 'Credit Suisse Global Investment Returns Yearbook 2018'

periods from lowest to highest real interest rates and allocate them to the bands, with the 5% lowest and highest at the extremes and 15% bands in between.

2.11. The bars in the figure show the average real returns on bonds and equities over the subsequent five years within each band. For example, the first combination of orange (equities) and yellow (bonds) bars in the chart show that for the years in which a country experienced a real interest rate (grey) below −11%, the average annualised real return over the next five years was −5.5% for equities and −11% for bonds.

2.12. This analysis shows that there is a clear relationship between the current real interest rate and subsequent real returns for equities and bonds. In their report, DMS also refer to additional regression analysis they have conducted to test the relationship and they find that this supports their initial conclusions (with statistically significant results).

Figure 5: Real asset returns versus real interest rates (%), 1900 - 2017



Source: Dimson, Marsh, Staunton (2018)

2.13. In a response to RP3, NERA[22] dispute the interpretation made by some regulators that the lower the interest rate the lower the equity return. They refer to the following statement made by DMS: "historically, the bulk of the low real rates occurred in inflationary periods, in contrast to today's low-inflation environment"[23]. NERA therefore argue that the positive relationship between real interest rates and equity returns found in the DMS dataset is actually caused by a "negative relationship between both variables and inflation".

2.14. While we recognise DMS's acknowledgement that the majority of low real rates occurred in inflationary periods, they make no suggestion that the positive relationship between real rates and equity returns is in fact driven by a negative relationship between each variable and inflation. In fact, in next paragraph of the same report, DMS go on to say, "As one would expect, there is a clear relationship between the current real interest rate and subsequent real returns for both equities and bonds. Regression analysis of real interest rates on real equity and bond returns confirms this, yielding highly significant coefficients."

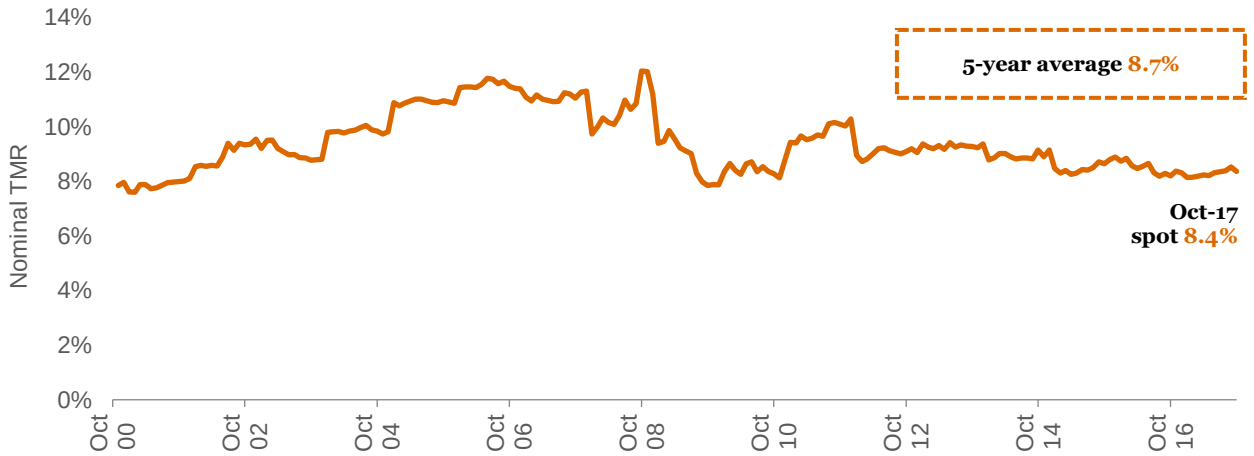
Forward-looking DGM evidence

2.15. As we noted in our December 2017 and February 2019 reports, dividend growth model/dividend discount model (DGM/DDM) outputs are one of the three forward-looking sources we use to inform our TMR estimate, the others being market valuation evidence and investor survey evidence. We acknowledge that DDM outputs are particularly sensitive to the assumptions used and can therefore

[22] NERA (2019), 'Cost of Equity for RP3'
[23] DMS (February 2018), 'Credit Suisse Global Investment Returns Yearbook 2018'

move around on a month-to-month basis, as seen in PwC's DDM output chart shown in NERA's response (see Figure 6 below, which can also be found in our December 2017 report).

Figure 6: Monthly output from PwC's DDM model



Source: PwC analysis

2.16. We still view that TMR estimates from DDM models are important estimates to use in conjunction with other approaches to form a view on TMR. In our February 2019 report we estimated a TMR range of 8.5% to 9.4% in nominal terms, with the lower end calculated using the five-year moving average and the upper end taken from the spot output. However, given that specific market events can drive fluctuations in monthly outputs, we consider that when using DDM models a better approach is to observe the five-year moving average as this smooths out these fluctuations.

Forward-looking survey evidence

2.17. The CAA are setting a cost of capital for a UK entity, and therefore, the average TMR for 39 countries shown by NERA does not appear to be the most appropriate point of comparison.

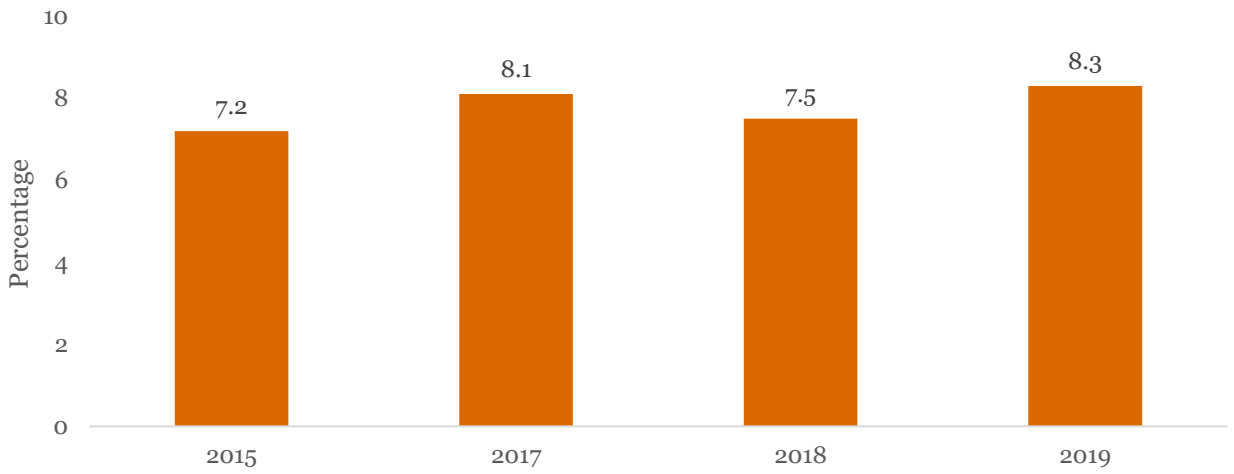
2.18. In the figure below, we show Fernandez's[24] estimates of TMR for the UK[25], which provides a useful cross-check on the TMR assumption. The estimates for each country are compiled by surveying c. 20,000 finance and economic professors, analysts and managers of companies. Participants are asked about the risk-free rate and market risk premium used "to calculate the required return to equity in different countries". Specifically for the UK in 2019, Fernandez received 86 responses.

2.19. We observe that estimates move around from year to year, which could be due to specific market events that occurred when the estimates were commissioned or perhaps changes in survey participants.

2.20. In our December 2017 report, we used the 2017 estimate of 8.1% as a cross check for TMR estimates. We observe that the current estimate of 8.3% remains within our RPI-deflated range of 5.1 – 5.6% (i.e. the estimate deflates to c. 5.3% using an RPI assumption of 3%).

[24] Fernandez (2019), 'Market Risk Premium and Risk-Free Rate used for 69 countries in 2019: a survey'
[25] It seems that the 2016 edition of the survey only collected data on the equity premium and not the risk-free rate. The average equity premium for the UK market was 5.3%.

Figure 7: Average TMR estimate for the UK, Fernandez survey



Source: Fernandez (2019)

2.21. As mentioned in our December 2017 report, evidence from investor surveys can provide a useful cross-check on outputs of TMR analysis. However, for the reasons mentioned above, we caution against assigning too much weight to survey outputs from one particular year or period.

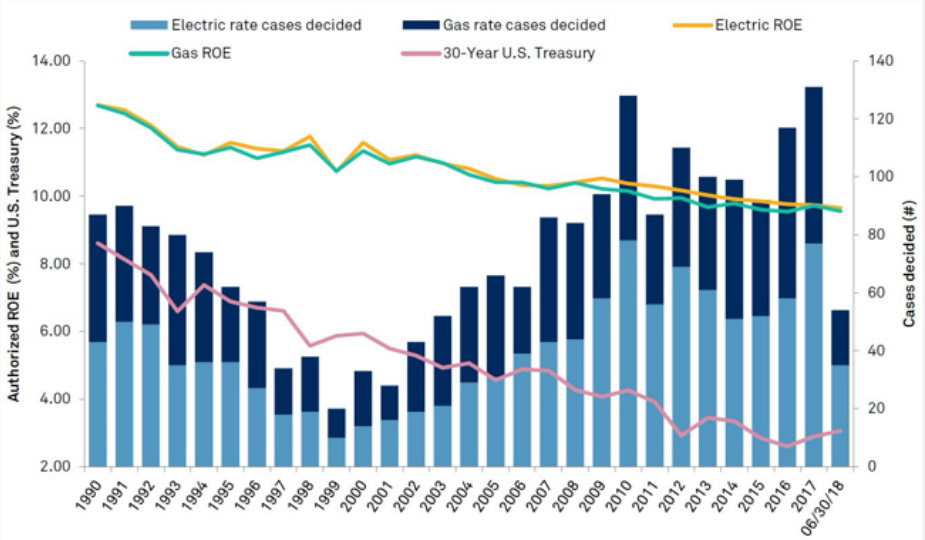
US regulatory precedent

2.22. As we have previously noted[26], there is not a perfect correlation between equity market returns and interest rates and it is not expected that TMR increases/declines at the same pace as interest rates. It is also important to recognise that our proposed reduction in TMR since Q6 is significantly less than the decrease in interest rates that has occurred over the same time period.

2.23. In our view, the evidence provided by NERA is specific to the US regulated market, which limits its direct relevance for UK regulators. In addition, when considering Figure 8 below, which shows authorised return on equity for regulated US gas and electricity providers for the full time period, rather than just 2006 onwards as presented by NERA, it shows that the decline in authorised return on equity has been more closely linked to the decline in US treasury yields before 2006. This supports the reduction in TMR estimates as UK bond yields have continued to fall since the setting of the Q6 price control.

[26] PwC (2017), 'Estimating the cost of capital for H7'

Figure 8: Average electric and gas authorised ROEs in the US and the risk-free rate



Source: S&P

Conclusion

2.24. Overall, we find that the new evidence provided by NERA on TMR does not support an increase to the TMR range proposed in our previous reports. The realised returns data does not show an upward trend for the UK equity market and when we estimate average equity returns using a ten-year trailing average, we find there has been a noticeable decline in returns across recent decades. While there has been a slight increase in the average TMR estimate provided in responses to the Fernandez survey for the current year, it still remains comfortably within our estimated TMR range of 5.1% to 5.6% RPI-deflated terms.

2.25. In our view, the evidence from US regulatory precedent has limited relevance for the UK given that it is focused on a different regulatory market. In addition, over the long term the US data shows that both approved return on equity and treasury yields decline over time.

2.26. Having considered this new evidence, we have not changed our view that the CAA should set a TMR in the range of 5.1 to 5.6% (RPI-deflated).

Topic 2b – Inflation measure used to estimate CPI returns

Topic overview

NERA

2.27. The 2018 UKRN[27] report on the role of the cost of capital in the regulation of UK utilities concludes that the Bank of England's back-projected measure of the consumer prices index (CPI) should be used in constructing and analysing historic real returns. In their April 2019 consultation response and in previous responses[28], NERA argue that this measure is not reliable and should not be used as a basis of estimating historical real TMR.

2.28. In our February 2019 report, we undertook additional review of the Bank of England CPI inflation series. Like UKRN, Ofgem[29] and Ofcom[30] we concluded that the deflation of nominal returns by the

[27] UKRN (2018), 'Estimating the cost of capital for implementation of price controls by UK Regulators'
[28] NERA (2018), 'Review of UKRN recommendations on the real TMR'
[29] Ofgem (2018) 'Consultation - RIIO-2 Sector Specific Methodology Annex: Finance'
[30] Ofcom, 'Business connectivity market review, publication updated on 19 December 2018', Annexes 1-22

Bank of England CPI series provides the most consistent and credible historical inflation data to interpret the history of market returns and set appropriate real allowances for the cost of capital.

Summary of evidence

2.29. In their April 2019 response, NERA suggest that instead of using the BoE CPI series, the CAA should estimate historical returns using the historical RPI index and then adjust the output for the estimate of the historical RPI-CPI wedge.

2.30. NERA use two estimates of the historical wedge. First, they estimate a wedge of 72 bps using the official indices published by the ONS from 1989 onwards. Second, then estimate a wedge of 28 bps using evidence from the official RPI index and the back-casted CPI index from the ONS. NERA then use these estimates to produce a historical estimate of the RPI-CPI wedge of between 47 bps (calculated since 1950) and 72 bps (calculated since 1988).

2.31. NERA estimate a historical RPI-deflated TMR range of 6.8 - 7.1% using a range of estimation approaches (i.e. using the Overlapping, Blume and JKM methods and up to a five year holding period). This is then converted to a CPI-equivalent using their estimated wedges of 47 bps and 72 bps respectively to calculate a historical CPI-deflated return of between 7.3 to 7.9%.

2.32. The CPI return is then converted into a forward-looking return using the forward-looking CPI-RPI wedge of 100 bps to produce a forward-looking RPI-deflated return of 6.2 - 6.8%. This is lower than the range presented in NERA's earlier report of 6.5 - 7.1%).

Comments and response

2.33. In our view, using two wedges calculated using data for different time periods is not a robust or accurate way to obtain CPI-deflated estimates of TMR. This approach does not accurately capture the differences between RPI and CPI back to 1899 when the DMS dataset, which is used to calculate TMR, begins.

2.34. In our February 2019 report, we undertook additional analysis on the Bank of England CPI inflation series. We found that while the two CPI measures[31] have tracked each other closely, a significant divergence between measured RPI and CPI inflation measures opened up from around the 1970s. This divergence explains much of the observed differences between CPI and RPI over the 1899-2013 period. More recent estimates of the wedge between CPI and RPI are therefore much higher.

2.35. As regulators are interested in estimating investors (unobservable) real return expectations from historical data, there is no definitive measure of inflation to use. Ofcom considered this issue in its 2018 BCMR consultation[32]. It concluded:

"The ONS has recently established that RPI is a flawed and upwardly biased measure of inflation. Hence, assuming investors target real returns, it seems plausible that expected returns would be shaped by an expectation that nominal returns would compensate investors for CPI (currently the headline measure of inflation) rather than RPI inflation. As such, using historical evidence on real returns as a guide for forward-looking real (CPI-deflated) returns is reasonable in our view."

2.36. This is consistent with the observation that RPI differences opened up from the 1970s, and the Bank of England inflation CPI measure provides a long-term estimate of to guide investor inflation expectations and real returns.

[31] We analysed the CPI preferred and CPI original measures produced by the Bank of England.
[32] Ofcom, 'Business connectivity market review, publication updated on 19 December 2018', Annexes 1-22

Conclusion

2.37. Consistent with UKRN, Ofgem and Ofcom, we continue to consider the deflation of nominal returns by the Bank of England CPI series provides a suitable estimate of ex-post real returns as the basis for calibrating forward-looking real returns for use with CPI inflation.

Topic 2c – Evidence of predictability at long horizons

Topic overview

NERA

2.38. When estimating TMR it is important to consider the degree to which returns are "predictable[33]" in equity markets. As we noted in our February 2019 report, if market returns are independent of all previous periods they follow a 'random walk'. We observe that while there is an element of 'random walk' in markets, numerous academic studies[34] find evidence of negative serial correlation, i.e. periods of good return performance are followed by periods of weak return performance and vice-versa. We also find evidence of negative serial correlation in UK equity returns data.

2.39. Consistent with previous consultation responses, NERA continue to dispute the existence of return predictability at long horizons.

2.40. In our February 2019 report, we undertook economic analysis to examine whether the different length holding periods impacted equity returns. We found that as the investment holding period increases, the predictability of returns also increases. This suggests equity return variance decreases as holding period increases, even when we control for autocorrelation.

2.41. Our findings are consistent with Mason, Miles and Wright (2003)[35] and Robertson and Wright (2002)[36], who also find evidence of the predictability of returns at longer horizons. In relation to the guidance from the UKRN study that regulators: "add an adjustment of 1 to 2 percentage points, depending on the extent to which regulators wish to take account of serial correlation of returns", our analysis suggests any adjustment should be at the bottom end of this range, and may indeed be lower.

Summary of evidence

2.42. NERA comment that, "predictability of returns at long horizons is a contentious issue and there is no consensus in financial literature which provides clear-cut evidence to support the notion of predictability".

2.43. NERA view that a holding period assumption of one to five years remains appropriate for estimating historical TMR. This is despite the UKRN recommendation that a longer-term perspective is taken to cost of capital estimation.

Comments and response

2.44. We refer back to the points we made in response to this topic in our February 2019 report. Specifically that to estimate TMR for H7 it is important to consider the wider regulatory context, as well as the investment-holding period and the degree to which returns exhibit serial correlation. Given that infrastructure investment is for long investment horizons and regulation is set for repeated five year

[33] i.e. exhibit serial correlation, so the returns in one period are influenced by the returns in prior periods. There may be other factors which can also predict returns.
[34] The evidence on negative serial correlation is widely cited, including analysis conducted by Fama and French (1988). While one year serial correlation is low, they find that five year correlations are strongly negative across all size classes. Fama, E.F. and K.R. French, 1992, The Cross-Section of Expected Returns, Journal of Finance, Vol 47, 427-466.
[35] Mason, R. Miles, D. Wright, S. (2003), 'A Study into Certain Aspects of the Cost of Capital for Regulated Utilities in the U.K.'
[36] Robertson D. and S, Wright. (2002), 'The Good News and the Bad News about Long-Run Stock Returns'

time periods, we recommend that the CAA consider a longer-term investment horizon in assessing the inputs to the cost of capital. This view is consistent with recommendation 2 of the UKRN report, which states that, "On balance, we are in favour of choosing a fairly long horizon, for example, 10 years, in estimating the CAPM-WACC".

2.45. As mentioned in the topic overview, our econometric analysis of UK equity returns found evidence of predictability of longer horizons and we recommended that adjustment for serial correlation of returns towards the lower end of the range proposed by Mason, Miles and Wright (2003) is appropriate.

2.46. We also refer to our previous point that many market investors typically have longer-term investment horizons, and are therefore unlikely to make significant changes to their equity holdings on an annual basis. Even short-term investors, such as traders, are basing their investment decisions on the valuation of investments made by long-term investors, and any arbitrage opportunity this may create. This means that the typical investment holding period for an asset cannot be used to infer the investment horizon used to value assets and set expected returns.

Conclusion

2.47. Having considered this evidence, we have not changed our view that the CAA should consider a longer-term investment horizon for assessing cost of capital inputs. Our econometric analysis also indicates that it is important to account for the predictability of returns at long investment horizons to estimate an appropriate TMR and we recommend that the CAA continue to adjust for this.

Topic 2d – DDM assumptions used in PwC's analysis

Topic overview

NERA

2.48. Consistent with previous responses, NERA argue that PwC's DDM assumptions are flawed. In particular, they argue that:

- Analyst forecasts should be used to proxy short-term dividend growth.
- Use of UK GDP growth to proxy FTSE dividend growth is incorrect.

Summary of evidence

2.49. NERA undertake a literature review to assess the evidence of historical optimism bias. They observe that much of the literature on optimism bias focused on US companies prior to institutional reform in 2003. NERA find that following the reforms to change analyst pay structures and place more weight on external analyst input, the biased forecast problem has been addressed. They cite Ashton et al. (2011)[37], who find that the bias in the long-run dividend growth rate due to analyst optimism is insignificant when using a US dataset up to 2006.

2.50. NERA also refer to analysis by Ryan and Taffler (2006)[38], who find that the ratio of sell and buy recommendations is less distorted than in the US. They also draw on evidence from France, specifically Galanti and Vaubourg (2017)[39], who find that optimism bias significantly reduced after the implementation of Commission Sharing Agreements (CSA), which unbundle brokerage and investment research fees.

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[37] Ashton et al. (2011), 'Analysts' Optimism in Earnings Forecasts and Biases in Estimates of Implied Cost of Equity Capital and Long-run Growth Rate'
[38] Ryan, P. and Taffler, R. (2006), 'Do Brokerage houses add value? The market impact of UK sell-side analyst recommendation changes'
[39] Galanti, S. and Vaubourgm A.G. (May 2017), 'Optimism bias in financial analysts' earnings forecasts: Do commission sharing agreement rules reduce conflicts of interest?'

2.51. NERA conclude that "based on our survey of these more recent studies, we conclude there is no evidence that optimism bias in the UK is as prevalent as it may have been in the US in the past".

2.52. They also cite a number of academic studies that use analyst forecast in DDM models and observe that the European Central Bank and Bank of England use them in their respective DDM models.

Comments and response

2.53. As we outline in our February 2019 report, there is also evidence that the use of analyst forecasts is not appropriate for regulatory purposes as they have been found to be both biased and inefficient[40]. While NERA provide evidence that suggests this problem has reduced following regulatory changes, there remains a sizeable body of literature that finds evidence of biased and event-driven analyst forecasts[41]. In addition, while there have been substantial changes to how the financial services industry is regulated following the 2008/9 crisis, it will take time to understand the impact that more recent legislation, such as MiFID II, has had on equity research.

2.54. Furthermore, regulators do not require a model which picks up high frequency variations in analyst return expectations, as they are typically concerned with setting longer-term parameters that are suitable for an entire price control. Chart 3 in the Bank of England's latest DDM research note[42] highlights why analysts forecasts are unsuitable for use in DDM models being used for regulatory purposes. The chart shows that there is significant variability in twelve-month ahead dividend growth forecasts, which suggests that analyst forecasts can be strongly impacted by specific market events and market sentiment. The future dividend growth forecasts for the FTSE All-Share range from -15% in 2009 to +17% in 2011, while the variation of dividend growth forecasts for Euro Stoxx and the S&P 500 is wider still.

2.55. We continue to consider that UK regulators require cost of capital assumptions which are sufficient to enable UK regulated companies to finance their activities. This typically requires use of UK input parameters to cost of capital estimates. Global assumptions could be used, on a consistent basis, but then adjustments would be required convert them back into a UK cost of capital (for example, for differential real yields or forecast inflation). Our preference is therefore to use UK based parameters, and proxies, wherever possible as it avoids the need for further adjustments.

Conclusion

2.56. Having considered this evidence, we view that the CAA should continue to use UK input parameters to cost of capital estimates and, more specifically, UK GDP growth assumptions to proxy dividend growth.

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[40] Analysis by the Bank of England in the past found that IBES aggregate forecasts of earnings and dividend growth in both the United Kingdom and the United States for the first, second and third year (fixed-event forecasts) are biased (non-zero average error) and inefficient (errors correlated with past information). In particular, analyst based forecasts are excessively optimistic during economic downturns and too pessimistic in recoveries. Harris (1999) found also that analysts' long-run earnings forecasts for US companies are biased and inefficient.

[41] Eames and Glover (2017) find that more unpredictable earnings are associated with earnings forecast pessimism. Their evidence is particularly prevalent for sample periods including years after 1996, i.e., years subject to the Public Securities Litigation Reform Act of 1995 and then to Regulation FD after 2000. Recent evidence finds that analysts piggyback their recommendations (Altınkılıç & Hansen 2009; Loh & Stulz 2011) and earnings forecasts (Altınkılıç, Balashov & Hansen 2013) on recent news and events.

[42] Bank of England (2017), 'An improved model for understanding equity prices'

Topic 2e –TMR and overall WACC estimate proposed in ADP's business plan

Topic overview

ADP

2.57. In April 2019, ADP[43] published its business plan for the 2021 to 2025 Economic Regulation Agreement. The proposal contained ADP's estimate of the weighted average cost of capital for the period (which is estimated using the Capital Asset Pricing Model with financial market data, and parameters considered for companies engaged in comparable activities).

2.58. ADP propose a vanilla WACC of 5.6% (nominal terms). This includes a TMR estimate of 8.0% and an equity beta estimate of 0.75.

2.59. By way of comparison, our February 2019 report produced a real vanilla WACC estimate for H7 of 2.5% to 3.4% (in RPI terms). When converted into nominal terms (using a 3% RPI inflation assumption) the range becomes 5.5% to 6.4%, which is closely aligned to the ADP estimate.

Summary of evidence

2.60. The table below shows the breakdown of ADP's WACC estimate.

Table 2: Groupe ADP's WACC estimate (nominal terms)

Component	Estimate	Comments
RFR	1.9%	10-year French, 10-year average
Tax rate	25.8%	Income tax rate applicable in France from 2022
Leverage (D/CE)	25.5%	Prospective leverage consistent with Groupe ADP historical 10-year average.
Market risk premium	6.1%	Ibbotson & Associes en Finance estimate, based on a 8.0% expected market return
Pre-tax cost of net financial debt	4.1%	Cost of Groupe ADP's net financial debt - 10 years historical average
Equity beta	0.75	Historical average based on the beta of the listed companies which are the most comparable to ADP's regulated activities, successively unlevered/relevered on the basis of their historical leverage/Group ADP's historical leverage.
Asset beta	0.56	Equity beta de-levered using leverage estimate of 25.5%. PwC calculation
Cost of equity	6.5%	PwC calculation
Vanilla WACC	5.6%	

Source: ADP business plan

Comments and response

2.61. The vanilla WACC proposed by ADP provides a useful point of comparison given that we use ADP as a relevant comparator for HAL. ADP's estimate of 5.6% in nominal terms is towards the lower end of the range proposed in our February 2019 report.

[43] Groupe ADP (2019), 'Public consultation document: Economic regulation agreement 2021 – 2025'

2.62. Compared to HAL, ADP has a significantly lower gearing assumption at 25.5% (based on ADP's actual capital structure) compared to the 60% notional assumption assumed by the CAA for H7. Hence, ADP has a higher share of (more expensive) equity in its structure.

2.63. ADP assume a cost of equity of 6.5% in nominal terms, which is lower than the range proposed in our February 2019 report (4.4% to 6.6% in real terms, which if inflated to nominal terms using a 3% RPI assumption would be c. 7.4% to 9.6%). This is in part due to a lower equity beta (and lower gearing).

2.64. When ADP's TMR assumption of 8.0% in nominal terms is deflated using a RPI assumption of 3%, this produces a real RPI-deflated TMR assumption of 5.0%, which is marginally lower than the 5.1% to 5.6% (real, RPI terms) proposed in our February 2019 report. Given that ADP are estimating a cost of capital for an entity operating in France, it is not surprising that they have assumed a slightly different TMR estimate. However, it provides reassurance that the estimates are relatively close given the similarities in the businesses and the respective economies.

2.65. ADP's equity beta of 0.75 is lower than the range proposed by PwC for H7 of 0.9 to 1.15, which is partially based on ADP's estimated beta (calculated using ADP's financial data). Notably, ADP observe that since the full consolidation of TAV Airports in July 2017, the beta of Groupe ADP is "no longer a relevant benchmark for estimating the level of risk of the regulated activities of ADP". ADP go on to state that: "the Groupe ADP (WACC) rate no longer faithfully reflects the risk inherent in the company's regulated business activities in Paris within the regulated scope".

2.66. Instead, ADP's beta estimate is based on the betas of listed companies which are considered to be most comparable to ADP's regulated activities. This list of comparators is determined according to the following criteria: availability of information, size of market capitalisation, free float size weight of international activities, and nature of the activity portfolio excluding international activities. However, ADP do not provide details on which entities are used to calculate the beta.

2.67. In an attempt to disentangle the impact of ADP's merger and acquisition activity on its equity beta, we assessed ADP's historical merger and acquisition (M&A) activity. We found that they have 26 direct investments across different industries (industrials, real estate, financials, information technology, consumer discretionary and communication services), including 11 subsidiaries/operating units. Over the past ten years, ADP, along with its direct investments and subsidiary companies, has undertaken numerous transactions of varying sizes. The complex nature of ADP's operations and its transactions means that it is difficult to establish an accurate relationship between their M&A activity and its equity beta. In addition, when looking specifically at the TAV Airports acquisition in 2017, we were unable to capture all of the impact of the acquisition when using regression analysis (e.g. the impact of this transaction cannot be captured when using a five-year regression using monthly data points).

2.68. Given the limited explanation as to how the ADP equity beta has been calculated, we suggest that caution is exercised with regards to how the CAA interprets the benchmark in the ADP business plan for the purpose of assessing HAL's beta.

2.69. In terms of asset betas, once ADP's equity beta estimate is de-levered using the gearing estimate, it produces an asset beta of 0.56, which is slightly above PwC's proposed range of 0.42 to 0.52.

Table 3: PwC's initial WACC estimate and ADP's WACC estimate

	Vanilla WACC estimate	Comments
H7 'As is' – real RPI terms (Feb 2019)	2.5% to 3.4%	
H7 'As is' – nominal terms (Feb 2019)	5.5% to 6.4%	3% RPI inflation wedge added
ADP 2021 to 2025 – nominal terms (April 2019)	5.6%	

Source: PwC analysis

Conclusion

2.70. The different approach taken by ADP to estimate its equity beta could warrant further investigation given that ADP beta estimates inform the HAL beta estimate. However, there is no information in the ADP business plan on which entities are used to estimate the equity beta.

2.71. The alignment between PwC's and ADP's TMR estimate demonstrates consistency between UK and French regulatory authorities. In our view, this new evidence supports a TMR in the range of 5.1 to 5.6% (RPI-deflated).

3. Responses on debt beta

3.1 In this section we set out comments and responses to issues raised on debt beta.

Topic 3a – Estimation of debt betas for NATS and HAL using regression analysis

Topic overview

Professor Ania Zalewska on behalf of NERA

3.2 In their September 2018 paper, NERA use the debt beta of 0.05 estimated by PwC in their initial view on the WACC for H7. For NATS, NERA comment that given NATS' stable outlook and relatively high credit rating, their view is that an increase in debt beta does not appear to be warranted.

3.3 In our February 2019 paper, we revisited our initial debt beta estimate. Based on empirical analysis of debt betas using iBoxx indices as well as HAL's bond data, we found an upward trend in debt betas over the past 18 months, implying that a higher debt beta is warranted for H7. Checking this empirical estimate against recent regulatory determinations, which generally support a debt beta in the region of 0.1, we revised our debt beta estimate upwards from 0.05 to 0.1 for H7.

3.4 In response to the new analysis and evidence provided by PwC and Europe Economics on debt betas, NERA asked Professor Ania Zalewska[44] to undertake further analysis of NATS (En-Route) plc debt beta. Zalewska's subsequent findings contrasted with the debt betas previously estimated by PwC and EE.

Summary of evidence

3.5 On behalf of HAL and NERA, Professor Ania Zalewska undertook additional analysis of the debt beta of the bond issued by NATS (En-Route) plc using a range of econometric estimation approaches. In particular, her aim was to assess whether there is any evidence that the NATS-bond's beta is higher than 0.1.

3.6 The analysis covered the period August 2003 – February 2019 using OLS, GARCH[45] (1,1) and Kalman Filter estimation methods. Several alternative proxies of the market were adopted; for example, the equity market portfolio was proxied by the FTSE All Share Index, FTSE All Europe and the Euro Stoxx 600. In addition, to test the reliability of the estimates, Professor Zalewska also analysed the betas of six bonds issued by Heathrow Funding Ltd.

3.7 Professor Zalewska finds that the NATS-bond's beta is statistically significantly negative for most of the investigated period, and statistically insignificantly different from zero in the last few years. These results are robust across various specifications and methods of estimation.

Comments and response

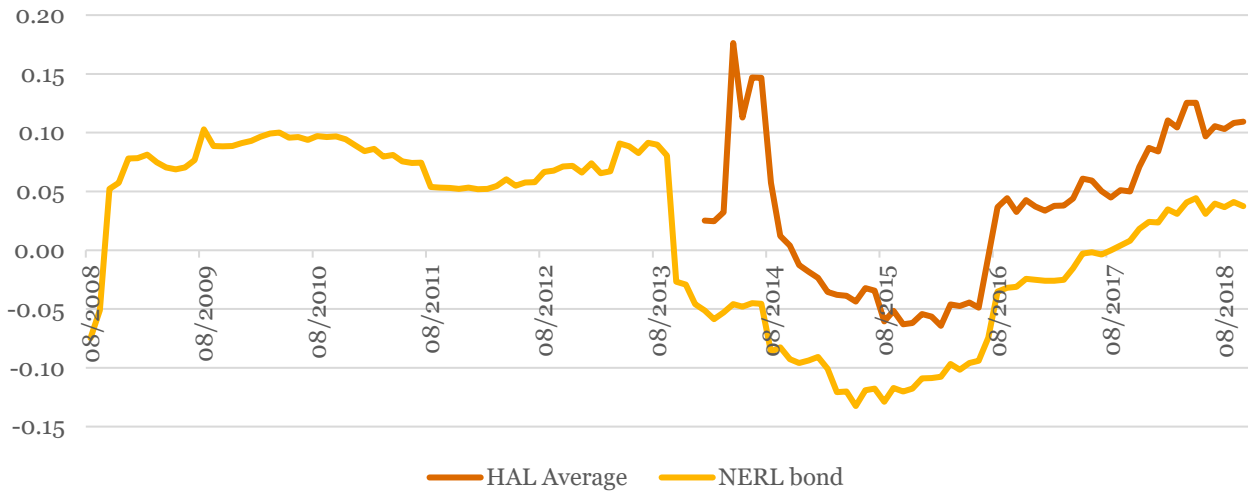
3.8 To analyse the approaches employed by Professor Zalewska, we first estimate the debt beta of the NATS bond using the same approach and time period used in our February 2019 report (i.e. 5-year betas using monthly observations).

3.9 The figure below shows that for the years in which there are comparable observations (the NATS bond was issued before the HAL bonds considered in the analysis) the NATS bond debt beta estimates are

[44] Zalewska (2019), 'Estimation of the debt beta of the bond issued by NATS (En-Route) plc'
[45] Generalized autoregressive conditional heteroscedasticity model.

consistently lower than the 'HAL average'. This indicates that the higher credit quality of NATS bond means it is less responsive to market movements.

Figure 9: OLS estimates of debt betas for HAL's bonds (average used in February 2019 report) and NATS bond



Source: Capital IQ, Refinitiv, PwC analysis

Analysis of Professor Zalewska's results

3.10 We review the regression analysis conducted by Professor Zalewska by using daily data for the same six HAL bonds used in Professor Zalewska's analysis and the NATS bond and for the same time period she considers. We use the market portfolio, as proxied by the equity market indices used by Professor Zalewska, given that this is the typical approach used by regulators and regulatory finance practitioners to estimate debt betas.

3.11 Table A1 in Appendix A shows that our regression analysis produces broadly similar results across all bonds and different specifications of the market portfolio. We observe that there are small differences across some of the debt betas, which could be due to slight differences in the number of observations[46], however the differences are not material across any of the debt beta estimates. Overall, we find that under this approach, debt beta estimates for the six HAL bonds and the NATS bond are generally in the region of -0.1 over the period considered i.e. 2006 – 2019. These findings are consistent with Professor Zalewska's.

3.12 We note, however, that this is a relatively long period from which to estimate a debt beta, and market conditions as well as correlations between asset classes have changed over this time period. In order to understand the trend over the recent years, we ran regressions for more recent time periods, 2010-2019 and 2016-2019. Table A3 in Appendix A shows that most beta estimates from the most recent time period are closer to zero. This change in profile aligns with our findings from the previous debt beta analysis conducted for Heathrow in our work on H7 as the debt beta estimates trended upwards in more recent periods.

3.13 We also ran more advanced estimation approaches such as the GARCH approach that was used by Professor Zalewska. Our results were again similar to Professor Zalewska's, and we reached the same conclusion that the shift from the standard OLS approach to GARCH does not make any material difference to the debt betas[47].

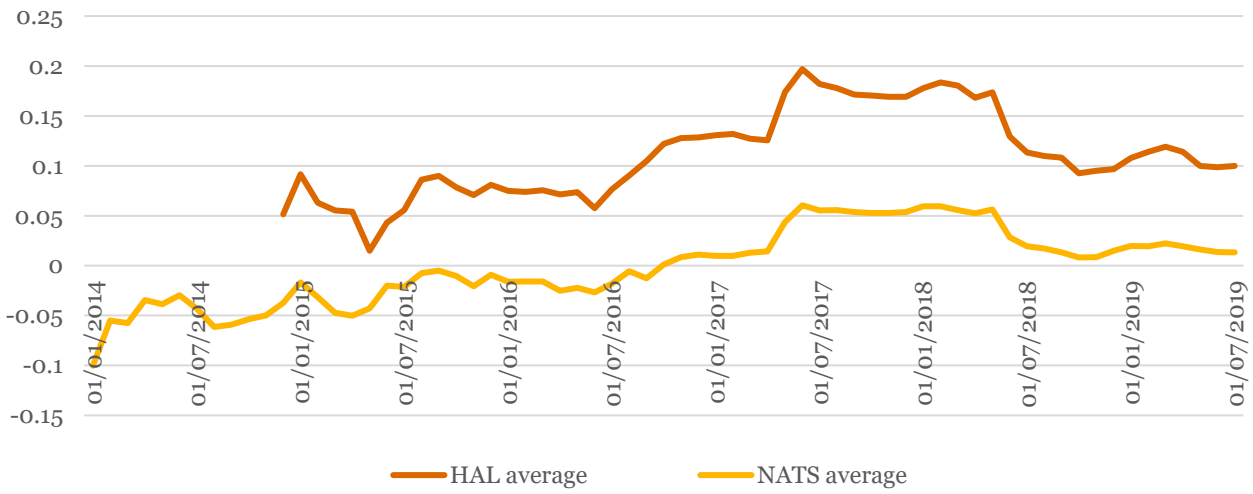
[46] Professor Zalewska's analysis runs up to February 2019 and the PwC analysis extends until July 2019. There could also be slight differences in data sources and data cleaning approaches which we cannot verify as we don't have access to Professor Zalewska's analysis.
[47] Professor Zalewska also estimates time-varying debt betas using a Kalman filter approach and finds that the estimates are very similar to those obtained through OLS.

Comparison of debt beta estimation using rolling OLS on daily and monthly data

3.14 Figure 10 below shows 5-year rolling estimates of debt beta for HAL (averaged across the six HAL bonds) and NATS averaged over the three equity indices using monthly data from 2009-2019. HAL debt betas estimates were above zero throughout the period considered. In contrast, the NATS debt beta was below zero for the first half of the period but experienced an upward trajectory since 2016, and was above zero in recent years. Appendix A shows the debt beta estimates for both HAL and NATS against each of the three equity indices separately[48].

3.15 There has been a wedge between the two average betas of approximately 0.1, with the NATS beta consistently lower than the HAL beta. Figure 10 also shows that since the middle of 2018, the average HAL beta has been around 0.1 – consistent with the estimate in our February 2019 paper, which uses a broader selection of Heathrow bonds to estimate debt betas.

Figure 10: Debt beta estimates for NATS bond and HAL bonds, averaged across different equity indices, using OLS on rolling 5-year monthly data

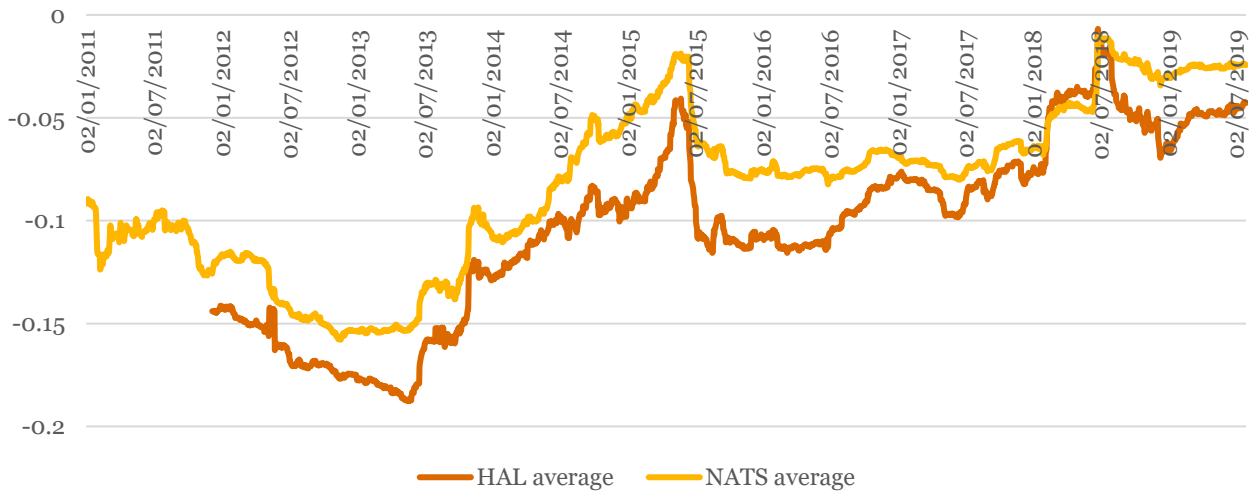


Source: Capital IQ, Refinitiv, PwC analysis

We then use daily data to obtain 2-year rolling OLS estimates of debt beta of NATS and the six HAL bonds against each of the equity market indices. Figure 11 below shows that the average HAL debt beta is below zero for most of the period, although it increases towards the end of the estimation period. The average NATS debt beta has followed a similar trajectory over the period considered and has remained below zero.

[48] The debt betas estimated using the FTSE All Share as the market portfolio are larger than the ones obtained against the European indices

Figure 11: Debt beta estimates for NATS bond and HAL bonds, averaged across different equity indices, using OLS on rolling 2-year daily data



Source: Capital IQ, Refinitiv, PwC analysis

3.16 Therefore, we find that the data frequency and time period used to estimate debt betas have a significant impact on debt beta estimation. In an attempt to disentangle the effect of the two factors, we estimated debt betas for HAL and NATS using 5-year rolling OLS on daily data (shown in Figure 12 below with estimates being averaged across the three equity indices)

3.17 Similar to the results obtained for 2-year rolling daily data, the HAL debt betas are below zero throughout the estimation period. They do exhibit an upward trajectory but they do not become positive even in the more recent years. This highlights that the wedge observed between the 2-year daily and 5-year monthly debt beta estimates (seen in Figure 10 and 11, respectively) is primarily driven by the frequency of data used i.e. monthly observations produce significantly higher debt beta estimates than daily observations.

3.18 We also observe that the HAL debt betas in Figure 12 below are slightly below the 2-year daily estimates. This suggests that based on this particular dataset, the longer the time period over which the debt betas are estimated, the more negative they become.

3.19 The average NATS debt beta, which is shown alongside the average HAL debt beta in Figure 12, has followed the same trajectory over the period considered. This pattern is similar to the 2-year rolling estimates obtained using daily data, but in the recent years the 5-year rolling betas have remained below -0.05 while the 2-year rolling estimates have come closer to zero. This again shows that a longer time period produces lower debt beta estimates using this dataset.

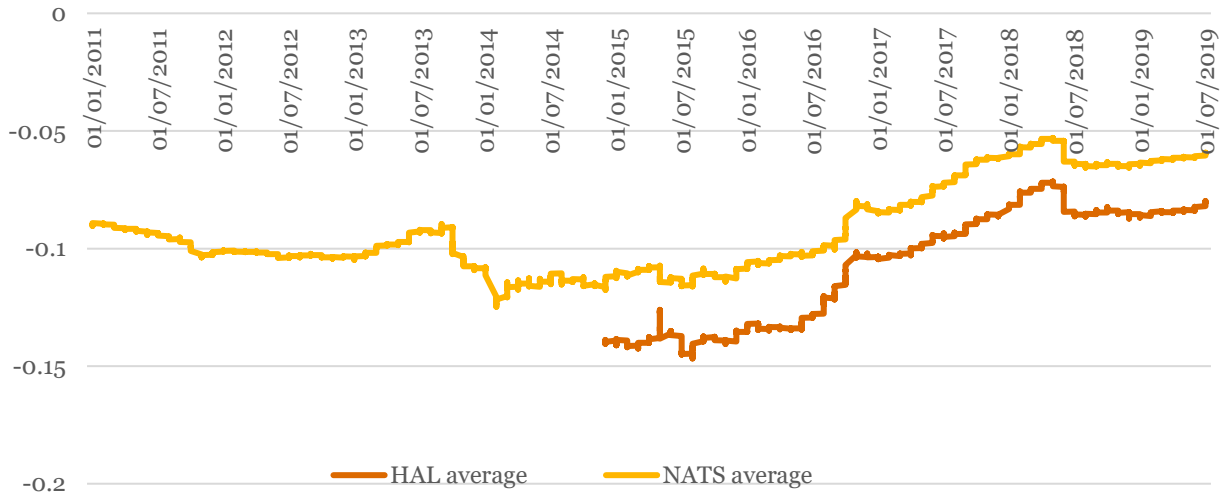
3.20 In Appendix B we further explore the impact of data frequency on debt beta estimation. We find that there is no clear general recommendation in the academic literature on the choice between daily and monthly data. Both have their merits and disadvantages and the choice should be made by carefully considering the specific circumstances.

3.21 In our view, the problems with daily data, especially around non-trading and slow response of the security to the market movements are likely to be more severe for the bond market than the equity market. Though the bond indices are heavily traded, this might not be true for individual bonds, which are typically much less liquid than the corresponding company equity.

3.22 In our analysis of NATS' bond, we found non-trading to occur for 105 days over a 5-year period of daily data, amounting to 3% of the data. This suggests caution is used in interpreting debt betas calculated using daily data.

3.23 While we recommend both daily and monthly estimates of debt betas are presented, we suggest more weight is given to monthly data in the selection of a debt beta assumption, in comparison to the selection of an equity beta assumption.

Figure 12: Debt beta estimates for NATS bond and HAL bonds, averaged across different equity indices, using OLS on rolling 5-year daily data



Source: Capital IQ, Refinitiv, PwC analysis

3.24 Table 4 summarises the debt beta estimates for HAL and NATS using 2-year rolling daily data, 5-year rolling daily data and 5-year rolling monthly data and for the last three years and the entire sample period over which the data is available. Three main points stand out:

- Using daily data (2-year and 5-year) produces more negative estimates when compared to the monthly frequency. Going from daily data (for both 2-year and 5-year regression period) to monthly data switches the sign of the debt beta for HAL, amounting to a +0.2 increase when using monthly data and a 5-year regression period. The increase is less pronounced for NATS but is clearly evident, with the monthly debt beta estimate being closer to 0 as opposed to the negative estimate obtained on daily data.
- Within the same data frequency i.e. daily data, estimates tend to be lower (i.e. more negative) when rolling averages are taken over a longer time period. For both NATS and HAL, 5-year rolling estimates are more negative than the 2-year rolling estimates.
- Estimation over the recent time period results in less negative debt betas. An average over the last three years produces a debt beta for NATS beta that is closer to zero and debt beta for HAL around 0.1. The increase in debt betas for the recent time period is consistent for both monthly and daily data.

Table 4: Impact of time period and data frequency on debt beta estimates

	HAL			NATS		
	Daily (2-year)	Daily (5 – year)	Monthly (5-year)	Daily (2-year)	Daily (5-year)	Monthly (5-year)
Average over last 3 years	-0.06	-0.09	0.13	-0.05	-0.07	0.03
Long run average over the period data is available	-0.10	-0.11	0.11	-0.09	-0.09	0.00

Source: Capital IQ, Refinitiv, PwC analysis

3.25 For comparison purposes we also look at the impact of data frequency and time period on equity beta estimates for ADP and Fraport in the below table. It shows that for Fraport, the 5-year monthly regression produces significantly higher equity beta estimates across both time periods when compared to the 2-year daily approach. These findings are similar to our debt beta analysis findings (i.e. the monthly approach produces consistently higher estimates).

3.26 The results are less conclusive for ADP. The 5-year monthly regression produces a lower beta estimate for ADP than the 2-year daily approach over the last 3 years. However, when we consider a longer time period (first beta estimate in 2012) the monthly approach produces a higher average beta estimate.

3.27 While this is a relatively small sample size from which to draw firm conclusions, it does appear that the 5-year monthly approach produces higher equity beta estimates than the 2-year daily approach for benchmark financial instruments relevant to HAL and NATS, but that estimation frequency has a more consistent impact on debt beta estimation. It also highlights that fact that there can be considerable variability across beta estimation approaches.

Table 5: Impact of data frequency on equity beta estimates (using local market indices)

	Fraport		ADP	
	Daily (2-year)	Monthly (5-year)	Daily (2-year)	Monthly (5-year)
Three year average	0.52	0.66	0.63	0.56
Long run average (since 2012)	0.61	0.80	0.59	0.63

Source: Capital IQ, Refinitiv, PwC analysis

3.28 In the table below we summarise the different factors affecting the debt beta, specifically for HAL and NATS.

Table 6: Key factors impacting debt beta estimates

Factor	Impact
Estimation approach: OLS versus GARCH	• Both estimation techniques produce very similar results.
Period of estimation	• Recent time periods (i.e. using data since 2016) produce higher debt beta estimates than longer time periods e.g. the entire life of the bonds used in the analysis.
Data frequency used for estimation	• 2-year regressions using daily data produces negative debt betas for both HAL and NATS (and 5-year daily regression produce slightly more negative results) • 5-year regressions using monthly data produces a debt beta estimate of around zero for NATS and above zero for HAL, in the range of 0.05-0.1.
Choice of equity index to proxy the market portfolio	• All three equity indices give broadly similar results in terms of the profile of debt betas, but FTSE All Share gives slightly higher debt beta estimates, especially for HAL and when using monthly data. • The difference between HAL debt betas estimated against FTSE All Share and other indices is around 0.01 for daily data and up to 0.07 for monthly data.
Company vs index	• The betas for the iBoxx index (used for assessing the cost of debt) are higher than for bonds from HAL in more recent years as shown in our February 2019 report.

Source: PwC analysis

Conclusion

3.29 In summary, empirical estimates of debt betas are highly sensitive to the time period used, frequency of data, and whether a company or the iBoxx index is used in the regression. Debt betas are less sensitive to the choice of the equity index used to proxy the market portfolio.

3.30 Most of our empirical analysis produces a lower debt beta for the NATS bond than the HAL bonds (with the exception of the regressions using daily data). In our view, this could be because NATS is a critical national asset with regulatory protections and government support. It also has significantly lower gearing[49], which reduces the probability of distress. These factors are reflected in the credit rating of the NATS bond, which at AA is higher than the rating of the HAL bonds considered in our analysis.

3.31 However, we also recognise that there is considerable variability under different estimation approaches and data frequencies. We explore this further in Appendix B, where we consider the regulatory precedent and guidance for the data frequency of beta estimation.

3.32 In preparing for H7/RP3, we recommend that the CAA takes a balanced view across a range of estimation approaches (empirical and decomposition) and aligns the time period used for debt beta estimation with that used for asset/equity beta estimation. While we recommend both daily and monthly estimates of debt betas are presented, we suggest more weight is given to monthly estimation frequency in the selection of a debt beta assumption, in comparison to the selection of an equity beta assumption (see Appendix B for further detail).

[49] HAL's actual gearing level is generally within the 75% to 80% range (see our December 17 report), whereas NATS' actual gearing has been closer to 30% in recent years.

Topic 3b – Estimation of debt betas using a decomposition approach

Topic overview

Europe Economics

3.33 In their December 2018 cost of capital paper for NERL[50], Europe Economics (EE) estimate a debt beta range of 0.1 – 0.19 for the NATS bond. The lower end is based on regulatory precedent while the top end is estimated using the probability of default and percentage loss given default.

Summary of evidence

3.34 EE estimate a debt beta for NERL using a decomposition approach, which is based on the following formula (see Appendix 2 of the EE paper for the complete formula):

$$\beta_D = (1 - P(default)) * debt\ premium - P(default) * (RFR + \%\ loss\ given\ default) / ERP$$

Where:

- β_D is the debt beta
- $P(default)$ is the probability of default
- RFR is the risk-free rate
- ERP is the equity risk premium or total market return

3.35 EE use PwC's estimate of RFR (the mid-point from our December 2017 paper) in combination with their own estimate of NERL's cost of debt to obtain the debt premium (i.e. cost of debt minus risk-free rate minus 7bps for transaction costs). They base their estimates of probability of default and percentage loss given default on external sources (such as credit rating agencies' reports) and input this into the above formula to obtain a debt beta of 0.19.

3.36 Taking into account previous advice to the CAA on debt betas, EE propose a range of 0.1-0.19 for NERL's debt beta.

Comments and response

3.37 One of the main benefits of the decomposition approach is that it can be less volatile than empirical approaches given that its inputs are less likely to experience daily changes. For instance, company and index returns typically change on a daily basis, whereas estimates for variables such as loss given default and probability of default are likely to be more stable over time. In contrast, empirical approaches as evidenced by our debt beta analysis can be volatile over time and approach used. In addition, there is regulatory precedent for using decomposition approaches. The Competition Commission[51] used a disaggregation of debt premium approach to obtain a debt beta for BAA.

3.38 However, a limitation of the decomposition approach is that it requires more assumptions than the empirical approach to obtain a debt beta estimate. It requires estimates of the probability of default and the percentage loss given default, which are subject to uncertainty and require judgement to reach an assumption.

[50] Europe Economics (2018), 'Components of the Cost of Capital for NERL'
[51] Competition Commission (2007), 'A report on the economic regulation of the London airports companies (Heathrow Airport Ltd and Gatwick Airport Ltd)'

Conclusion

3.39 In preparing for H7/RP3, we recommend that the CAA takes a balanced view across a range of estimation approaches (empirical and decomposition) and aligns the time period used for debt beta estimation with that used for asset/equity beta estimation.

Appendix A – Supporting analysis of debt betas

Analysis of Professor Zalewska's results

Table A1 below shows the results of our regression analysis alongside Professor Zalewska's results. Both sets of results are broadly similar across all bonds and different specifications of the market portfolio.

Table A1: Estimates of the debt betas obtained for OLS regressions for the NATS bond and six HAL bonds against the equity indices (2006-2019).[52]

Index	NATS	HAL_1	HAL_2	HAL_3	HAL_4	HAL_5	HAL_6
FTSE All Share - Zalewska	- 0.11***	-0.10***	-0.12***	-0.10***	-0.13***	-0.07***	-0.13***
FTSE All Share - PwC	-0.09***	-0.09***	-0.13***	-0.11***	0.018*	-0.10***	-0.10***
Stoxx 600 - Zalewska	-0.09***	-0.09***	-0.10***	-0.07***	-0.11***	-0.06**	-0.11***
Stoxx 600 - PwC	-0.10***	-0.10***	-0.14***	-0.12***	-0.01**	-0.11***	-0.12***
FTSE All Europe - Zalewska	-0.10***	-0.09***	-0.11***	-0.08***	-0.11***	-0.07***	-0.12***
FTSE All Europe - PwC	-0.10***	-0.10***	-0.13***	-0.12***	-0.02***	-0.11***	-0.12***

Source: Zalewska (2019), Capital IQ, Refinitiv, PwC analysis

Table A2 bellows presents the summary statistics for our data and the data used by Professor Zalewska and shows that the small differences across some of the debt betas could be due to slight differences in the number of observations[53].

[52] ***: significant at 1%, **: significant at 5%, *: significant at 10%.
[53] Professor Zalewska's analysis runs up to February 2019 and the PwC analysis extends until July 2019.

Table A2: Summary statistics from OLS regressions listed in the previous table

	Observations [54]	Mean	Std. Dev.	Min	Max
NATS bond (2006-2019) PwC	3430	0.00%	0.4%	-7.2%	3.4%
NATS bond (2006-2019) Zalewska	3,256	0.00%	0.4%	-4.6%	2.5%
HAL bond 1 PwC	2583	0.03%	0.5%	-4.4%	6.2%
HAL bond 1 Zalewska	2,597	0.01%	0.6%	-7.7%	7.6%
HAL bond 2 PwC	2435	0.01%	0.5%	-5.8%	3.5%
HAL bond 2 Zalewska	2,276	0.01%	0.4%	-3.4%	2.2%
HAL bond 3 PwC	2435	0.03%	1.0%	-22.4%	25.6%
HAL bond 3 Zalewska	1,206	0.02%	0.7%	-2.6%	6.9%
HAL bond 4 PwC	743	-0.02%	0.1%	-0.4%	0.3%
HAL bond 4 Zalewska	2,595	0.00%	0.9%	-12.3%	28.2%
HAL bond 5 PwC	2583	0.03%	0.6%	-11.6%	5.8%
HAL bond 5 Zalewska	2,596	0.01%	0.7%	-8.9%	9.7%
HAL bond 6 PwC	2583	0.04%	0.6%	-8.5%	7.0%
HAL bond 6 Zalewska	2,596	0.02%	0.7%	-8.5%	8.7%

Source: Zalewska (2019), Capital IQ, Refinitiv, PwC analysis

Table A3 below shows beta estimates for the periods 2010-2019 and 2016-2019 for the NATS bond and each of the six HAL bonds and for different market portfolio indices. We find that most beta estimates have trended upwards and are now higher (i.e. closer to 0).

Table A3: Estimates of the debt betas obtained for OLS regressions for the NATS bond and six HAL bonds against the equity indices (2010-2019, 2016-2019).[55]

Index	NATS	HAL_1	HAL_2	HAL_3	HAL_4	HAL_5	HAL_6
FTSE All Share – 2010 to 2019	-0.09***	-0.10***	-0.13***	-0.11***	0.01*	-0.10***	-0.11***
FTSE All Share – 2016 to 2019	-0.03***	-0.04***	-0.05***	-0.05*	0.01*	-0.04***	-0.04**
Stoxx 600 - 2010 to 2019	-0.09***	-0.11***	-0.14***	-0.12***	-0.01**	-0.11***	-0.12***
Stoxx 600 - 2016 to 2019	-0.06***	-0.06***	-0.09***	-0.10***	-0.01**	-0.08***	-0.09***
FTSE All Europe - 2010 to 2019	-0.09***	-0.10***	-0.13***	-0.12***	-0.02***	-0.11***	-0.12***
FTSE All Europe - 2016 to 2019	-0.06***	-0.06***	-0.09***	-0.10***	-0.02***	-0.09***	-0.10***

Source: Zalewska (2019), Capital IQ, Refinitiv, PwC analysis

[54] Small differences in the number of observations between Professor Zalewska and PwC analysis arise from potential differences in data sources, data cleaning approaches and time period with Professor Zalewska's data ending at Feb 2019 and PwC data ending at July 2019. We did not have details on the sources and data cleaning steps followed by Professor Zalewska.

[55] ***: significant at 1%, **: significant at 5%, *: significant at 10%.

Table A4 below compares our GARCH estimates with the GARCH estimates obtained by Professor Zalewska for the period 2010-2019 using daily data. Our results are again similar to the results she obtains and similar to the OLS results shown previously.

Table A4: Estimates of the debt betas obtained for GARCH (1,1) regressions for the NATS bond and six HAL bonds against the equity indices for 2010-2019.[56]

Index	NATS	HAL_1	HAL_2	HAL_3	HAL_4	HAL_5	HAL_6
FTSE All Share – PwC	-0.10***	-0.10***	-0.11***	-0.12***	0.01**	-0.11***	-0.11***
FTSE All Share – Zalewska	-0.11***	0.09***	-0.12***	-0.10***	-0.07***	-0.12***	-0.13***
Stoxx 600 - PwC	-0.11***	-0.12***	-0.13***	-0.13***	-0.01***	-0.13***	-0.13***
Stoxx 600 - Zalewska	-0.09***	-0.07***	-0.10***	-0.07***	-0.06***	-0.10***	-0.10***
FTSE All Europe - PwC	-0.11***	-0.12***	-0.12***	-0.12***	-0.02***	-0.13***	-0.12***
FTSE All Europe - Zalewska	-0.10***	-0.08**	-0.10***	-0.08***	-0.06***	-0.11***	-0.11***

Source: Capital IQ, Refinitiv, PwC analysis

GARCH estimates are more robust to patterns of autocorrelation and heteroscedasticity in the data and give more accurate standard errors. In the presence of such issues, vanilla OLS gives incorrect standard errors, making any inference about the OLS estimates invalid. It is worth noting that the GARCH estimates are very similar to the OLS estimates we obtain over the same time period, with the average difference being -0.001. Moreover, the GARCH estimates are also highly statistically significantly different from zero across all bonds and equity indices.

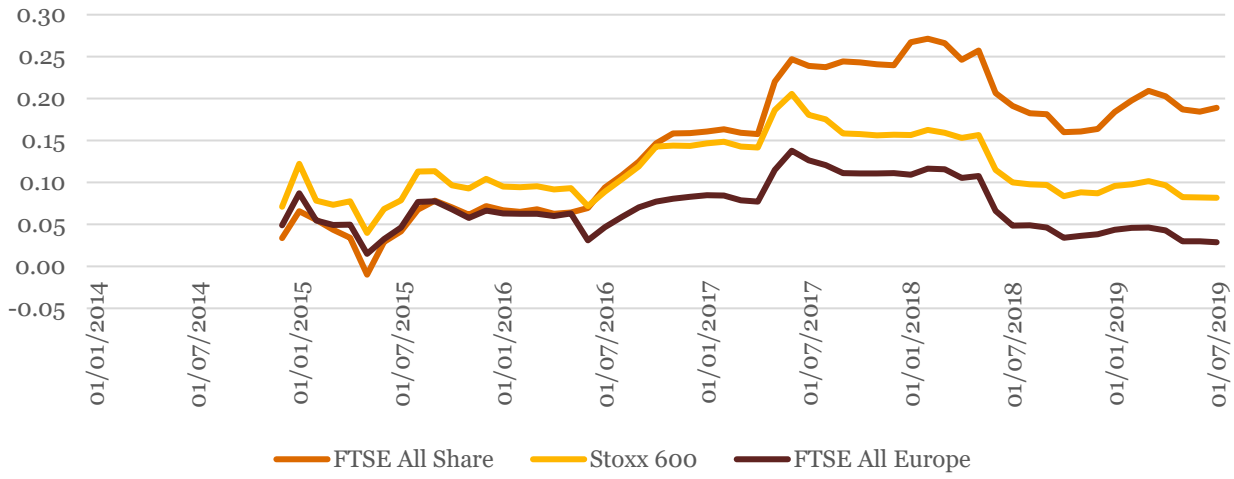
GARCH estimates are more robust to patterns of autocorrelation and heteroscedasticity in the data and give more accurate standard errors. In the presence of such issues, vanilla OLS gives incorrect standard errors, making any inference about the OLS estimates invalid. It is worth noting that GARCH estimates are highly statistically significantly different from zero across all bonds and equity indices. Consistent with Professor Zalewska's results, they are also very similar to the OLS estimates we obtained over the same time period, with the average difference being -0.001.

Debt beta estimation using rolling OLS on daily and monthly data

Figures A1 and A2 show 5-year rolling estimates of debt beta for each of the six HAL bonds and for the NATS bond against the three equity indices using monthly data from 2009-2019.

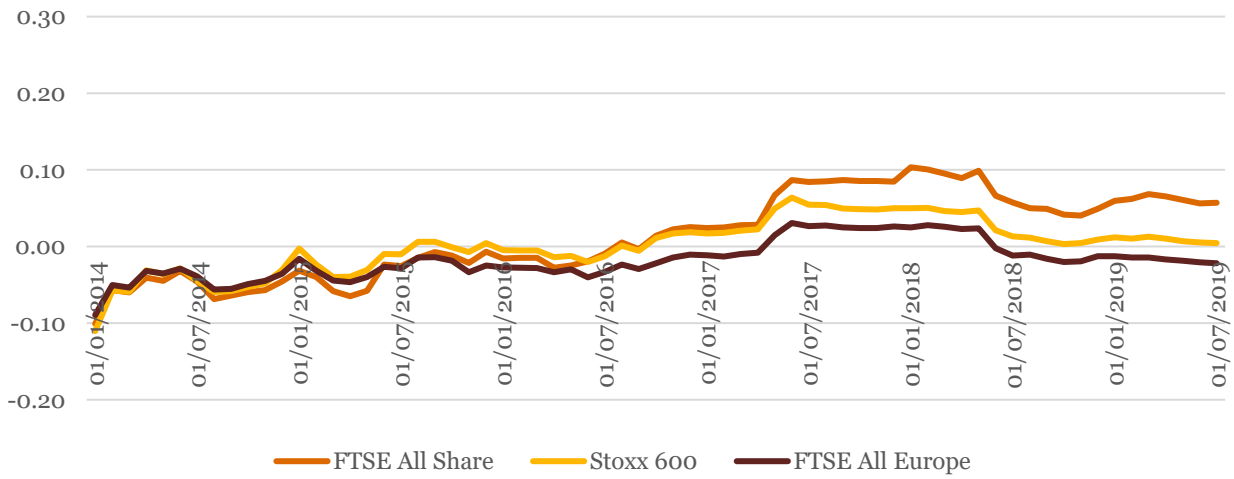
[56] ***: significant at 1%, **: significant at 5%, *: significant at 10%.

Figure A1: Average debt beta estimates for the six HAL bonds using OLS on rolling 5-year monthly data for different equity indices as the market portfolio



Source: Capital IQ, Refinitiv, PwC analysis

Figure A2: Debt beta estimates for the NATS bond using OLS on rolling 5-year monthly data for different equity indices as the market portfolio

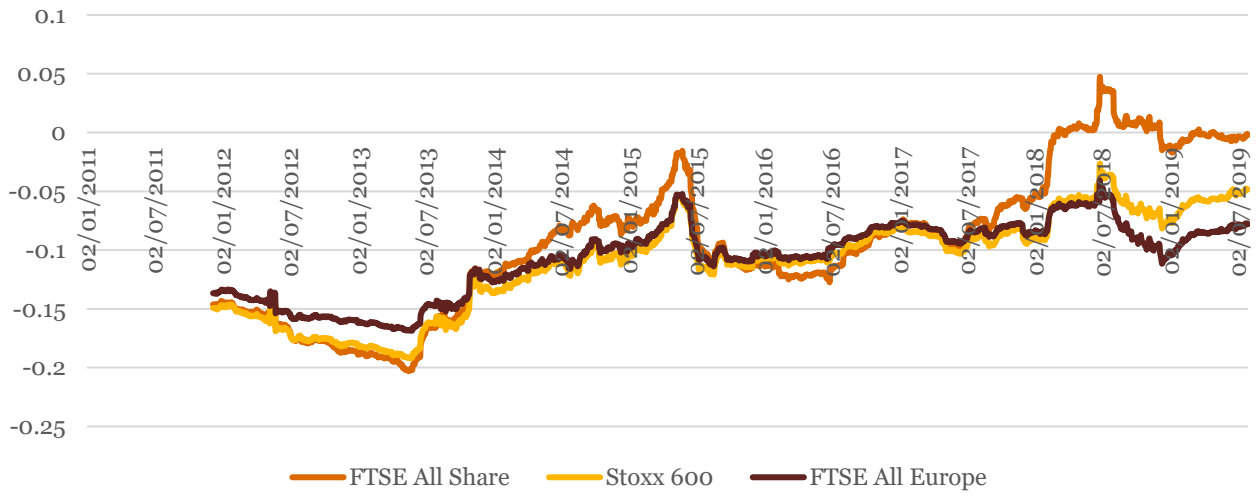


Source: Capital IQ, Refinitiv, PwC analysis

Both charts show that debt betas, particularly for HAL, are responsive to different equity indices. The debt betas estimated using the FTSE All Share as the market portfolio are larger than the ones obtained against the European indices.

Using daily data we obtain 2-year rolling OLS estimates of debt beta of NATS and the six HAL bonds against each of the equity market indices. Figure A3 below shows that the HAL debt betas are below zero for most of the period, although they increase towards the end of the estimation period. It clearly shows that the choice of equity index used to proxy the market portfolio has some impact, with the HAL debt beta higher when bonds are regressed against the FTSE All Share index.

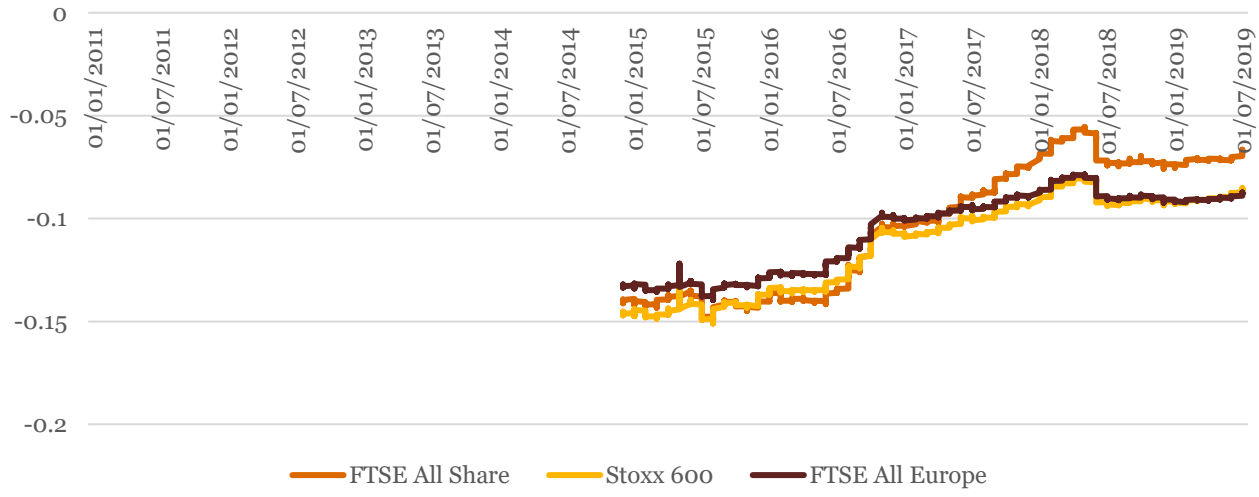
Figure A3: Average debt beta estimates for the six HAL bonds using OLS on rolling 2-year daily data for different equity indices as the market portfolio



Source: Capital IQ, Refinitiv, PwC analysis

Figure A4 below shows HAL debt betas (averaged over six bonds) when different equity indices are used to represent the market. Similar to the results obtained for 2-year rolling daily data, the debt betas are below zero throughout the estimation period.

Figure A4: Average debt beta estimates for six HAL bonds using OLS on rolling 5-year daily data for different equity indices as the market portfolio[57]



Source: Capital IQ, Refinitiv, PwC analysis

[57] We keep the scale of the axes the same as the 2-year daily chart for comparison purposes.

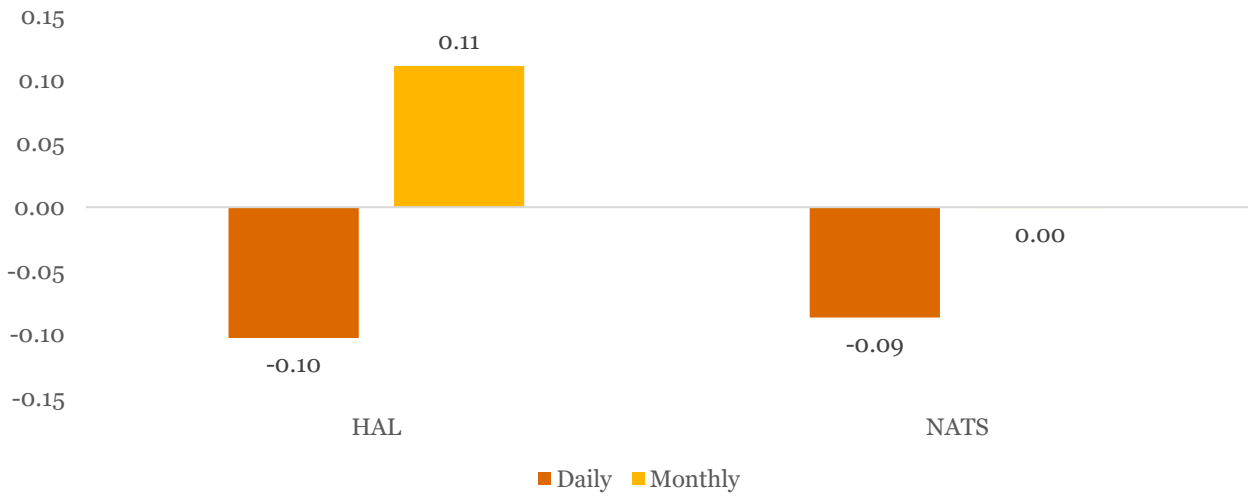
Appendix B – Impact of data frequency on the estimation of debt betas

We observe that debt betas for NATS and the six HAL bonds tend to be negative when estimated on daily data (for both 2-year and 5-year estimation periods) while monthly debt betas are positive (for the entire estimation period for HAL and in the recent years for NATS).

In particular, as shown in the figure below, moving from daily data (for both 2-year and 5-year regression period) to monthly data switches the sign of the debt beta for HAL, amounting to a +0.2 increase.

This single methodological difference explains the majority of difference between the findings of Professor Zalewska (debt betas are statistically close to zero) and PwC (debt beta assumption of 0.1).

Figure B1: Average debt betas for HAL and NATS using daily data (2-year and 5-year regression) and monthly data (5-year regression) across the whole time period of available data.



Source: Capital IQ, Refinitiv, PwC analysis

In this appendix, we review the academic literature and other regulatory precedent on the guidance they provide on the most suitable data frequency for estimating betas.

There is enough evidence in the academic literature to show that change in data frequency can produce significant variations in the estimated betas (this is largely drawn from equity beta estimation, rather than debt beta estimation). There is broad consensus of the trade-off between using daily and monthly data:

- Daily data tends to be a lot noisier i.e. it is likely to be affected by multiple one-off odd events. But it gives a greater number of observations for estimation purposes, typically resulting in lower standard errors and a more precise estimate of the beta. Additionally, daily data allows the use of shorter time windows in cases where parameters appear to be unstable.

- Monthly data is less noisy but shrinks the sample size, compromising the precision of the estimated beta. It requires a longer time period to be used over which company fundamentals may change. Monthly estimates can also be sensitive to the day of the month used.

However, there is no clear general recommendation in the academic literature on the choice between daily and monthly data. Both have their merits and disadvantages and the choice should be made by carefully considering the specific circumstances.

In order to investigate this further, we looked at the standard errors produced as part of our debt beta estimation exercise. We further reviewed the literature (including regulatory precedence) in this area to understand the appropriate data frequency that should be used.

Comparison of standard errors

Table B1 below shows the estimated standard errors of the average HAL and NATS debt instrument betas for daily and monthly data.

Table B1: Impact of data frequency on estimated standard errors of HAL and NATS debt betas

	5-year daily	2-year daily	5-year monthly
Estimated standard error of the estimated average HAL beta	0.024	0.043	0.044
Estimated standard error of the estimated average NATS beta	0.019	0.036	0.037

Source: Capital IQ, Refinitiv, PwC analysis

The analysis in Table B1 demonstrates that using daily data over a 5-year period provides a sufficiently large number of observations and yields the smallest standard errors. It is important to note that the standard errors produced using 2-year daily data are only marginally smaller than the ones produced using 5-year monthly data.

The analysis in Table B1 therefore supports the academic literature that using daily data provides greater precision.

Literature review of the impact of data frequency on beta estimation

Many academic studies (including ones written in the regulatory context) note that despite the precision benefits offered by the use of daily data, estimates should be used with caution, because they can carry a non-trading bias. A non-trading bias is introduced when the security in question does not trade every day, but the market does, which systematically reduces correlation with the market index for reasons that do not represent reduced market risk (Damodaran (2013)[58], Ofgem (2018)[59], Ofcom (2005)[60], Wright, Mason and Miles (2003)[61]). This means that use of daily data tends to underestimate beta of a security[62].

Secondly, as explained by Wright, Mason and Miles (2003), the increase in accuracy obtained with daily data is subject to the statistical assumption that the returns are identically and independently distributed (iid). Failure of the iid assumption is quite common in daily data as the returns tend to be heavily correlated over time. Serial correlation gets less severe on a month on month basis, though not fully absent. In addition to the iid assumption, the accuracy of the estimates is dependent on the returns having volatilities and a correlation structure that is constant over time (homoscedasticity). Wright et. al (2018)[63] point out that this assumption is

[58] Damodaran, A (2013), 'Estimating beta. working paper, http://people. stern. nyu.edu/adamodar/pdfiles/eqnotes/discrate2. pdf, 25.10.
[59] Cambridge Economic Policy Associates Ltd. (2018), 'Review of cost of capital ranges for new assets for Ofgem's networks division'
[60] Ofcom (2005), 'Ofcom's approach to risk in the assessment of the cost of capital'
[61] Wright, S., Mason, R., & Miles, D. (2003), 'A Study into Certain Aspects of the Cost of Capital for Regulated Utilities in the UK.'
[62] As per Hawawini (1982), this bias is dependent on the market value of the security. In particular, the betas of securities with a smaller market value than the average of all securities outstanding (the market) will decrease as the return interval is shortened i.e. as we move from monthly to daily data, whereas the betas of securities with a large market value relative to the market will increase

[63] Wright, S., Burns, P., Mason, R., & Pickford, D. (2018), 'Estimating the cost of capital for implementation of price controls by UK Regulators.'

usually violated, and heteroscedasticity is indeed a well-established property of financial returns, especially in high frequency data.

Thirdly, for infrequently traded stocks it may be some time before the impact of a general market movement is fully reflected in the stock price. Given the imperfect flow of information, a daily beta estimate for such a stock is likely to be downward biased.

In the next section, we summarise the guidance from regulators and advisors:

Guidance on data frequency by other regulators and advisors

Wright, Mason and Miles (2003)

- Depending on the severity of the serial correlation, daily data can still be used with Newey-West standard errors that correct for patterns of autocorrelation.
- In order to correct for the slow response of a stock to the market movements, lags of the market return can be introduced in the regression equation. However, there is inevitably some uncertainty about how many lags to include.
- Advantages of extra precision will need to be significant if these disadvantages of daily data, relative to using betas estimated on weekly or monthly data, are to be outweighed. If there do seem to be significant signs of these problems with daily data, and much less sign of them with weekly or monthly data, this is an argument for looking at beta estimates based on the latter.

Ofgem (2018)

- There is no consensus over the most appropriate returns frequency for estimating beta. They consider a broad range of evidence (using daily and weekly data) rather than focus on a single method.

Ofcom (2005)

- The problem of non-synchronous trading could be mitigated to some extent by using the "Dimson adjustment" which involves including additional lag and lead terms in the regression analysis.
- A prudent approach is to place a degree of weight on both daily and monthly estimation techniques, subject to statistical robustness of estimates, particularly given that published sources tend to focus on the latter estimation method.

Ofwat (2018)[64]

- They consider that estimates based on daily data are better than those derived using weekly or monthly data as they rely on larger sample sizes and are more precise, having narrower confidence intervals.

Wright *et. al* (2018):

- Stephen Wright and Donald Robertson point to strong evidence that the recent rise in daily beta estimates is temporary, and likely to be reversed. They argue for estimation on longer-term data and at lower frequencies (which they argue provide evidence more relevant to the long horizons used by regulators).
- Phil Burns summarises the standard approach to estimating equity betas. He uses the rolling OLS approach on daily, weekly and monthly data for 10 comparator companies, applied to 2, 5 and 10-year estimation windows, and recommends that estimation of beta is a component of the cost of equity where the regulator must use its judgement and discretion.

[64] Ofwat (2018), 'Delivering Water 2020: Our methodology for the 2019 price review Appendix 12: Aligning risk and return'

Overall recommendation

As shown above, there is no clear recommendation on the data frequency that should be used and most academic and regulatory sources suggest both daily and monthly data estimation can be used.

The problems with daily data, especially around non-trading and slow response of the security to the market movements are likely to be more severe for the bond market than the equity market. Though the bond indices are heavily traded, this might not be true for individual bonds, which are typically much less liquid than the corresponding company equity.

In our analysis of NATS' bond, we found non-trading to occur for 105 days over a 5-year period of daily data, amounting to 3% of the data. This suggests caution is used in interpreting debt betas calculated using daily data.

While we recommend both daily and monthly estimates of debt betas are presented, we suggest more weight is given to monthly data in the selection of a debt beta assumption, in comparison to the selection of an equity beta assumption.