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The impact of longer asset lives on the cost of equity: estimating cash flow betas

Prepared for Energy Networks Association

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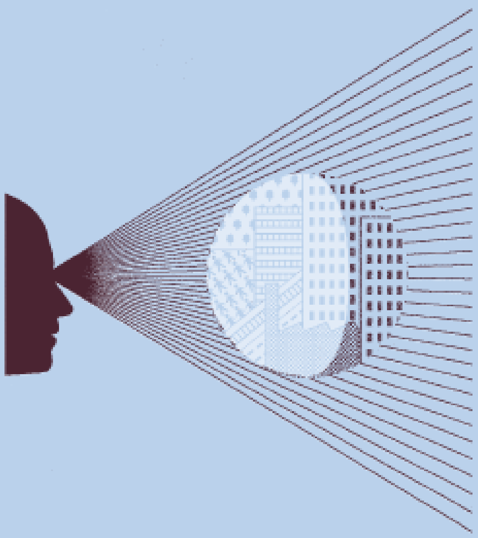

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Executive summary

The RIIO-T1 and -GD1 strategy decisions include a number of changes to the profiling of cash flows, which would be expected to lead to an increase in the duration of these cash flows.

– In the electricity sector, the move away from the current approach of using accelerated depreciation profiles to using the expected economic lives of the relevant assets will increase the regulated asset lives from 20 years to 45 years.[1]

– In the gas distribution sector, the current approach of capitalising 50% of REPEX, and expensing the other 50% in the year in which it was incurred, will be replaced. The RIIO-GD1 strategy decision is to capitalise 100% of REPEX, which will lead to cash flows being re-profiled away from the current regulatory period to future periods.[2]

For a single cash flow, duration is simply the time to realisation of that cash flow. For cash flows at multiple points in time, duration is the money-weighted average time to realisation.

Cash flows with longer duration will be exposed to a greater number of shocks, such as shocks to the economy and financial markets, company-specific events, and regulatory and political changes. A stream of cash flows with long duration will be more risky than one of cash flows with short duration. The critical issue is how duration influences the pricing of risk by investors in terms of annualised required returns or discount rate.

Europe Economics undertook an exercise to see whether there was empirical evidence to support a link between changes in cash flow duration and changes in equity betas. However, the assessment of the evidence by Europe Economics was that 'interpretation of these results is not straightforward' and that the evidence is inconclusive.[3]

> This statistical study is not in itself decisive, and if there were good theoretical grounds for supposing that betas are, in fact, affected by duration then a more extensive statistical analysis might be warranted.[4]

The theoretical grounds for understanding how betas are affected by duration have been presented in past Oxera reports and Energy Networks Association (ENA) submissions to Ofgem.[5] The standard model used to estimate the cost of capital is the capital asset pricing model (CAPM), which is, by construction, a one-period model. It therefore cannot capture the impact of different time profiles for cash flows on required returns. However, there is a significant body of theoretical research on multi-period models that can be used to understand the impact of profiling of cash flows on the cost of capital.

The particular theoretical framework presented in past reports is the one developed and applied by Brennan and Xia (2006) (the BX framework). This framework takes the form of an

[1] Ofgem (2011), 'Decision on strategy for the next transmission price control – RIIO-T1', March 31st.

[2] Ofgem (2011), 'Decision on strategy for the next gas distribution price control – RIIO-GD1', March 31st.

[3] Europe Economics (2010), 'The Weighted Average Cost of Capital for Ofgem's Future Price Control—Final Phase 1 Report', December 1st, para. 8.18.

[4] Europe Economics (2010), op. cit., para. 8.45.

[5] Oxera (2011), 'What is the cost of equity for RIIO-T1 and RIIO-GD1?', prepared for Energy Networks Association, February 14th. Energy Networks Association (2010), 'Implementing the RIIO recommendations in GD1 and T1: Determining the cost of capital: An ENA submission to Ofgem', November 10th. Oxera (2010), 'What is the impact of financeability on the cost of capital and gearing capacity?', prepared for Energy Networks Association, May 27th.

inter-temporal capital asset pricing model (ICAPM) which contains the CAPM as a restricted special case. Importantly, the BX framework is constructed as an extension to the well-established theoretical model developed in Merton (1973),[6] and is therefore more than just a description of the empirical data.

As outlined in previous Oxera submissions, under the BX framework, the equity beta for any company will increase as the duration of cash flows increases.[7] If the CAPM special case of the BX framework is a good approximation of the empirical data, the required excess return will increase with duration.

There is, however, both theoretical and empirical evidence to suggest that the CAPM is an imperfect approximation of the empirical data.[8] If this is the case, although increased duration will be associated with an increase in equity beta, there may be cases where required excess return decreases with duration. The BX framework shows that the critical parameter for distinguishing such cases is the cash flow beta, which forms a component of the equity beta.

In the BX framework, the cash flow beta measures the responsiveness of individual equity cash flows to returns for the broad equity market. The other component of the equity beta is the discount rate beta, which measures the sensitivities of equity values to changes in the market cost of equity.[9] The BX framework shows that the lower the cash flow beta, the more the required excess return will increase with duration. The threshold between cases where returns decrease rather than increase with duration is a cash flow beta of approximately 0.5.

While the BX framework does not present estimates of cash flow betas, previous Oxera reports have explained the intuition and presented relevant empirical evidence from pre-existing studies to show why regulated networks would be expected to have low cash flow betas relative to the market in general, and other industry sectors in particular. A relatively large proportion of utility equity betas is therefore attributable to the discount rate beta. This means that a relatively large proportion of the risk of an investment in a utility is due to the net present value of future cash flows being exposed to shocks to the market cost of equity.

This report builds on the pre-existing theoretical and applied studies, and undertakes new empirical analysis to estimate cash flow betas for listed UK equities, particularly utilities.

The findings from this study show that, for the FTSE utilities index, the cash flow beta estimated using the approach described by Campbell and Vuolteenaho (2004)[10] is approximately half the cash flow beta for the UK equity market (FTSE All-share index). Cash flow beta estimates for National Grid and Scottish and Southern Energy (SSE) are lower than those for the FTSE utilities index. This suggests that in comparison to other industry sectors and companies, the relationship between an increase in duration of cash flows and an increase in required returns will be strongest for companies with a significant proportion of activities in regulated networks.

As outlined in Oxera (2011), it is challenging to extrapolate from the raw beta estimates of National Grid and SSE to estimate an equity beta that is appropriate for all regulated energy networks for the forthcoming RIIO-T1 and RIIO-GD1 price controls.[11] Therefore, it is

[6] Merton, R. (1973), 'An intertemporal capital asset pricing model', *Econometrics*, **46**, pp. 1429–46.

[7] Brennan, M. and Xia, Y. (2006), 'Risk and Valuation under an Intertemporal Capital Asset Pricing Model', *Journal of Business*, **79:**1.

[8] For examples, see Oxera (2011), op. cit.

[9] The discount rate beta can be further decomposed (as in the BX framework) into risk-free rate and equity risk premium betas.

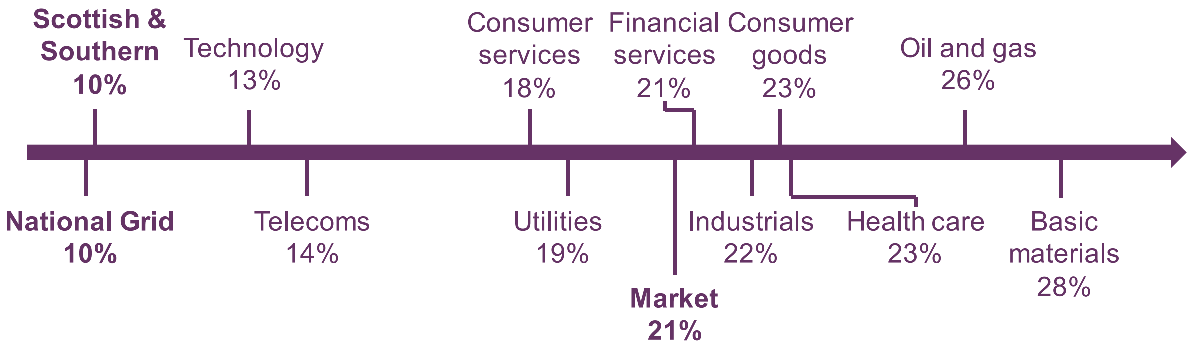
[10] Campbell, J.Y. and Vuolteenaho, T. (2004), 'Bad Beta, Good Beta', *The American Economic Review*, **94**, pp. 1249–75.

[11] Oxera (2011), op. cit.

important to check the relative levels of cash flow betas after normalising for differences in estimated equity betas across sectors.[12]

Figure 1 below shows the cash flow beta as a percentage of the equity beta (the residual is the discount rate beta). This provides an approximation to cash flow betas if each sector were to have an equity beta of one. The figure shows that, if this were the case, utilities in general, and National Grid and SSE in particular, would still be expected to exhibit a stronger positive relationship between cash flow duration and required return than the broad equity market. The industries in which a negative relationship between duration and required return are most likely to be found are basic materials, oil and gas, healthcare, consumer goods, and industrials. These estimates are in line with those reported by other studies, such as Campbell and Mei (1993).[13]

Figure 1 Estimates of the cash flow beta relative to the equity beta



Source: Oxera analysis.

The positioning of different companies and industry sectors according to cash flow beta relative to the equity beta—as in the spectrum in Figure 1—provides insight into where regulated energy networks are likely to be positioned in the BX framework. Figure 1 shows that cash flow betas as a proportion of equity betas for the group companies of National Grid and SSE are, at most, half the cash flow beta proportion of the market equity beta. The UK regulated network portions of these groups would be expected to have lower cash flow betas relative to the groups on account of the different risk characteristics of regulated networks.

The BX framework, which is calibrated on US market data, does not estimate cash flow betas directly. However, the framework shows that the cash flow beta for the broad equity market will be less than the equity beta of the market—which by definition is equal to one.[14] Figure 1 shows that cash flow betas as proportions of the equity betas for National Grid and SSE are less than half the cash flow beta proportion of the market equity beta. Therefore, the cash flow betas for these groups will be below the 0.5 threshold where the BX framework predicts that required returns will increase with the duration of cash flows.

This analysis assumes that the rate of information arrival regarding future cash flows is the same regardless of when the cash flow will occur. As outlined in Oxera (2011), the BX framework predicts an additional incremental increase in the cost of capital as a result of increasing cash flow duration if there is greater uncertainty about longer-duration cash flows than for shorter-duration cash flows.[15] For regulated energy networks, expectations for cash flows further in the future—particularly those that fall into price control periods from RIIO-T2

[12] For more detail on the interpretation of raw beta estimates for National Grid and SSE, see Oxera (2011), op. cit.

[13] Campbell, J.Y. and Mei, J. (1993), 'Where Do Betas Come From? Asset Price Dynamics and the Sources of Systematic Risk', *The Review of Financial Studies*, **6**:3, p. 575.

[14] Brennan, M. and Xia, Y. (2006), op. cit., figure 3, panel A.

[15] Oxera (2011), op. cit., section A3.3.2.

and RIIO-GD2 onwards—are likely to be less certain that expectations for cash flows that will occur sooner. This would exacerbate the increase in required returns associated with an increase in the duration of cash flows.

More generally, where the rate of information arrival is constant across all cash flow durations, the increase in required returns predicted by the BX framework does not make any allowance for the possibility of a regulatory time inconsistency problem. This arises because regulators cannot comprehensively bind the actions of their successors or offer commitment that cash flows expected at the time of investment will, on average, materialise in the future. To the extent that an increase in the duration of cash flows exposes a greater proportion of value to the time inconsistency problem, an additional increase in the required return would be expected, over and above that predicted by the standard BX framework.

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1 Introduction

Ofgem's RIIO strategy decisions are to move away from the current approaches of using accelerated depreciation profiles and partial expensing of REPEX, which advances cash flows from one regulatory period to another, and to adopt economic asset lives and 100% capitalisation of REPEX. The implication is an increase in the duration of cash flows to investors. The objective of this report is to understand how the increase in the duration of cash flows affects the returns required by investors.

The report follows earlier Oxera reports and Energy Networks Association (ENA) submissions to Ofgem, which have presented the theoretical evidence, as well as evidence from earlier empirical papers, behind the impact of increasing the duration of cash flows on the return required by investors. These reports have shown that the increase in the return required by investors is particularly significant for those companies with relatively low cash flow risk. Results from existing empirical papers, such as Campbell and Mei (1993), which have typically been based on US data, have shown that cash flow risk for utilities, as measured by the cash flow beta, is relatively low.

This report presents new empirical evidence on estimates of the cash flow betas for UK firms listed in the FTSE All-share index, including estimates specific to the utilities index, as well as to individual utilities. The results from this report therefore provide new evidence about how the systematic risk of cash flows for UK utilities compares with that of other sectors. These results are used to support the finding in earlier submissions that the increase in the duration of cash flows implied under RIIO-T1 and -GD1 would be expected to lead to higher required returns.

1.1 Structure of the report

The report is structured as follows.

– The methodology that has been followed to estimate cash flow betas is described in section 2.

– The estimates of the cash flow betas for firms listed in the FTSE All-share index, including estimates by sector, are presented in section 3.

– Section 4 concludes.

Further details on the methodology, as well as robustness checks on the resulting estimates of the cash flow betas, are provided in the appendix.

2 Methodology

The methodology that has been adopted to estimate cash flow betas follows the decomposition approach that has been applied to the equity beta in several previous papers, including Campbell and Shiller (1998), Campbell and Mei (1993), and Campbell and Vuolteenaho (2004).[16] The methodology adopted by these empirical papers has the advantage that it is not based on a particular asset pricing model. Instead, estimates of the cash flow betas are derived from the present-value relationship between stock prices, expected future cash flows and discount rates.

This report follows the methodology adopted by Campbell and Vuolteenaho (2004), which is similar to the approach followed by Campbell and Mei (1993). Under Campbell and Vuolteenaho's (2004) methodology, the equity beta for firms listed in the FTSE All-share index is decomposed so as to reflect news about the market's cash flows and news about market discount rates. The rationale for this is that stock prices change as either expected cash flows change or discount rates change, or both. An increase in expected future cash flows is associated with a capital gain today, while an increase in discount rates is associated with a capital loss.

The methodology to estimate the cash flow beta involves three steps, as outlined in Figure 2.1. The first step is to estimate a series of econometric equations to explain the drivers of excess returns on the market, the term yield spread, the price–earnings ratio, and the small stock value spread. Measures of news about cash flows and discount rates are calculated from the residuals—the unexplained components—from the econometric equations. These news measures are subsequently used to estimate the cash flow and discount rate betas.

Figure 2.1 Overview of the methodology

Source: Oxera.

Each of the steps is described in more detail below.

2.1 Step 1: estimate a system of econometric equations

The first step is to estimate a system of econometric equations to explain the drivers of excess returns on the market ($r^e_{M,t}$), the term yield spread (TY_t), the price–earnings ratio (PE_t) and the small stock value spread (VS_t). Each of these variables is explained by past and current values of all the other variables. In addition, each variable is regressed on lagged values of itself. The system of equations is estimated using weekly data over the period between July 1996 and January 2011.

The system of equations is estimated through a vector autoregressive model (VAR). In contrast to the approach adopted by Campbell and Vuolteenaho (2004), which was based on

[16] Campbell, J.Y. and Vuolteenaho, T. (2004), 'Bad Beta, Good Beta', *The American Economic Review*, **94**, pp. 1249–75. Campbell, J.Y. and Shiller, R.J. (1988), 'The Dividend-Price Ratio and Expectations of Future Dividends and Discount Factors', *Review of Financial Studies*, **1**:3, pp. 195–228. Campbell, J.Y. and Mei, J. (1993), 'Where Do Betas Come From? Asset Price Dynamics and the Sources of Systematic Risk', *The Review of Financial Studies*, **6**:3, p. 575.

monthly data, this analysis uses the extra detail afforded by weekly data. The VAR is estimated with four lags—the current value for each variable is explained by its value in each of the previous four weeks—to make the analysis more comparable with the one-month lag structure used by Campbell and Vuolteenaho (2004).

The results from alternative lag lengths have been examined, with the results from the econometric equations with four lags found to be the most robust (see the appendix for further details).

The following four equations have therefore been estimated simultaneously.

1) $r^e_{M,t} = \alpha_{r,t} + r^e_{M,t-1},..,r^e_{M,t-4} + TY_{t-1},..,TY_{t-4} + PE_{t-1},..,PE_{t-4} + VS_{t-1},..,VS_{t-4} + error_{M,t}$
2) $TY_t = \alpha_{TY,t} + TY_{t-1},..,TY_{t-4} + r^e_{M,t-1},..,r^e_{M,t-4} + PE_{t-1},..,PE_{t-4} + VS_{t-1},..,VS_{t-4} + error_{TY,t}$
3) $PE_t = \alpha_{PE,t} + PE_{t-1},..,PE_{t-4} + TY_{t-1},..,TY_{t-4} + r^e_{M,t-1},..,r^e_{M,t-4} + VS_{t-1},..,VS_{t-4} + error_{PE,t}$
4) $VS_t = \alpha_{VS,t} + VS_{t-1},..,VS_{t-4} + PE_{t-1},..,PE_{t-4} + TY_{t-1},..,TY_{t-4} + r^e_{M,t-1},..,r^e_{M,t-4} + error_{VS,t}$

Each of the variables included in the above system of econometric equations is explained in further detail below.

– Excess market returns (reM,t)—defined as the weekly return on the FTSE All-share index in excess of a measure of the short-term risk-free rate—defined as yields on one-month UK Treasury bills. This is the most important econometric equation because its results are used to derive the measures of cash flow and discount rate news, which are subsequently used to estimate the cash flow betas.

– Term yield spread (TYt)—measured as the difference between yields on ten-year UK government bonds and yields on one-month UK Treasury bills. The rationale behind this measure is to proxy the stage of the business cycle.

– Price–earnings ratio (PEt)—defined as the ratio of total market value to total historical earnings for the FTSE All-share index as reported by Datastream. The price–earnings ratio is a measure of expected future returns.[17]

– Small stock value spread (VSt)—measured as the difference between book-to-market ratios of small value stocks and small growth stocks listed in the FTSE All-share index. There is some evidence that this measure provides a proxy for market-wide discount rates, and reflects the sensitivity of the stock prices to future changes in discount rates.[18]

To ensure the robustness of our results, we also estimated the model over shorter time periods. This led to only minor changes in the cash flow beta estimates.

2.2 Step 2: derive measures of news about future cash flows and discount rates

After estimating the system of econometric equations, the next step is to derive measures of news about future cash flows and discount rates. These measures reflect changes in market participants' expectations of future dividends and market returns.

The VAR model describes market participants' expectations of excess market returns. As the state vector (ie, the four variables described in section 2.1) in the VAR model changes between any two time periods t and t+1, the VAR model can be used to quantify the

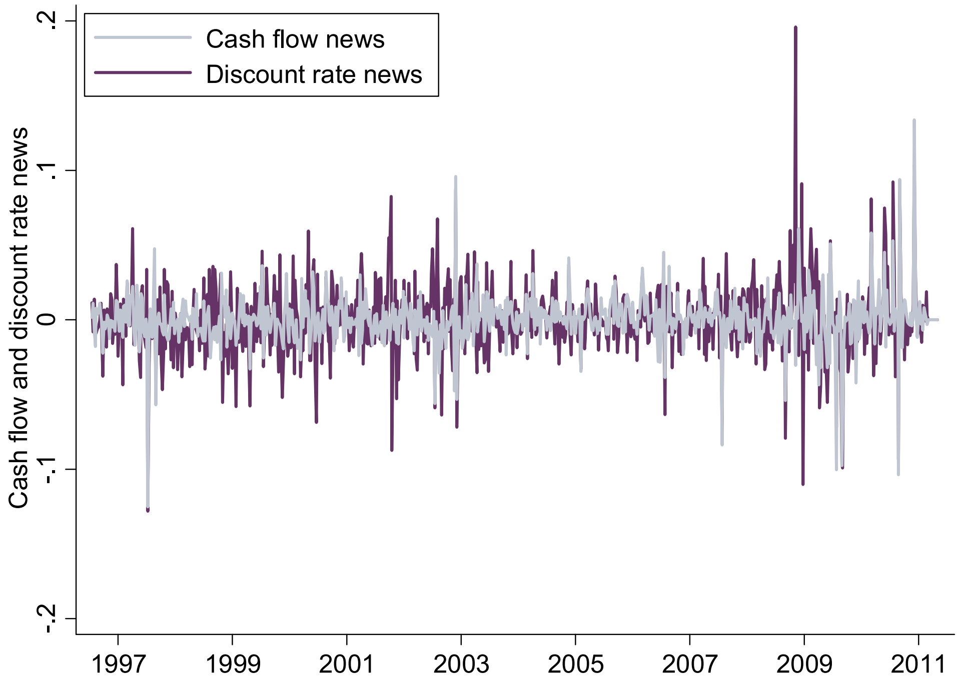
[17] Basu, S. (1977), 'Investment Performance of Common Stocks in relation to Their Price-Earnings Ratio: A Test of Efficient Market Hypothesis', *The Journal of Finance*, **32**:3, pp. 663–82.
[18] See, for example, Cohen, R.B., Polk, C. and Vuolteenaho, T. (2003), 'The value spread', *Journal of Finance*, **58**:2, pp. 609–42.

corresponding changes in those future expectations. The difference between the discounted streams of expected excess returns defines the value of the discount rate news in t+1.

Campbell (1991)[19] shows that the difference between realised and expected excess returns from one period to the next (ie, the residuals in the excess return regression in the VAR model) is equal to the difference between the news about future cash flows and discount rates. By estimating discount rate news as described above, and by extracting the residuals from the VAR model, it is possible to calculate cash flow news from this relationship. This approach is consistent with the approach adopted in Campbell and Vuolteenaho (2004).

The estimates of news about future cash flows and discount rates in the UK over the sample period are shown in Figure 2.1. The larger spike in the news measures around 2009 may be due to significant revisions of market participants' expectations during the onset of the financial crisis.

Figure 2.1 Estimates of news about cash flows and discount rates



Source: Oxera.

2.3 Step 3: estimate the cash flow and discount rate beta

The final step is to use these measures of news about future cash flows and discount rates to estimate the cash flow betas and discount rate betas. These betas describe the sensitivities between the firm's returns and the news measures.

The cash flow beta represents the exposure of equity value to changes in cash flows for the broad equity market, while the discount rate beta reflects the exposure of equity value to changes in discount rates for the market. For example, if an equity's return reacts strongly to positive news for future market earnings, it has a high cash flow beta.

The cash flow and discount rate betas have been estimated according to the formulae below.

[19] Campbell, J.Y. (1991), 'A variance decomposition for stock returns', *Economic Journal*, **101**:405, pp. 157–79.

Table 2.1 Estimation of the cash flow and discount rate beta

Definition of the cash flow beta	Definition of the discount rate beta
$\beta_{i,CF} = \frac{Cov(r_i, N_{CF,t})}{Var(N_{CF,t} - N_{DR,t})}$	$\beta_{i,DR} = \frac{Cov(r_i, -N_{DR,t})}{Var(N_{CF,t} - N_{DR,t})}$

Note: r_i represents returns on individual stocks. $N_{CF,t}$ and $N_{DR,t}$ represent news about cash flows and discount rates respectively.
Source: Campbell, J.Y. and Vuolteenaho, T. (2004), 'Bad Beta, Good Beta', *The American Economic Review*, **94**, pp. 1249–75.

As shown in Table 2.1, the cash flow beta has been defined as the covariance of an asset's return with good news about the stock market in the form of higher-than-expected earnings. The discount rate beta has been defined as the covariance of an asset's return with good news about the stock market in the form of lower-than-expected discount rates. Each beta divides by the total variance of unexpected market returns; this scales the estimates such that the sum of the cash flow beta and the discount rate beta approximately equals the equity beta.

3 Estimates of cash flow betas

Following the methodology outlined in section 2, this section reports estimates of cash flow betas for the market as a whole, as well as by sector and for listed utilities. The analysis is based on weekly FTSE All-share data from 1996 to 2011.

3.1 Estimates for the market index

As shown in Table 3.1, the cash flow beta for the market as a whole—in this case, the FTSE All-share index—is around 0.21, representing approximately 21% of the equity beta.

Table 3.1 Beta estimates for the FTSE All-share index (five-year weekly)

Price index	Cash flow beta	Discount rate beta	Ratio of cash flow beta to equity beta
FTSE All-share index	0.21	0.79	0.21

Note: The table reports rounded numbers.
Source: Oxera analysis.

3.2 Estimates by sector

The FTSE utilities index has an estimated cash flow beta of approximately 0.10, which represents approximately 19% of the equity beta (Table 3.2). The cash flow beta for utilities, expressed as a proportion of the equity beta, is low when compared to that for the majority of other sectors.

Table 3.2 Beta estimates by sector

Sector	Cash flow beta	Discount rate beta	Ratio of cash flow beta to equity beta
Technology	0.16	1.10	0.13
Telecoms	0.13	0.80	0.14
Consumer services	0.16	0.75	0.18
Utilities	**0.10**	**0.44**	**0.19**
Financial services	0.25	0.95	0.21
Health care	0.15	0.52	0.23
Consumer goods	0.19	0.63	0.23
Industrials	0.21	0.73	0.22
Oil and gas	0.26	0.72	0.26
Basic materials	0.35	0.88	0.28
Average excluding utilities	**0.21**	**0.79**	**0.21**

Note: The table reports rounded numbers.
Source: Oxera analysis.

These results are broadly in line with those reported by Campbell and Mei (1993), who find that, based on US data, sectors such as basic industries have relatively high cash flow betas of around 0.38, whereas industries such as utilities and services have significantly lower cash flow betas.[20]

3.3 Estimates by utility

Although the sample is very small, if cash flow betas are estimated separately for National Grid and Scottish and Southern Energy (SSE), the ratio of the cash flow beta to the equity beta is even lower than that for the utility index overall. Table 3.3 shows that the cash flow beta is around 10% of the equity beta for SSE and National Grid respectively.

Table 3.3 Beta estimates by company

Sector	Cash flow beta	Discount rate beta	Ratio of cash flow beta to equity beta
SSE	0.05	0.41	0.10
National Grid	0.06	0.54	0.10

Note: The table reports rounded numbers.
Source: Oxera analysis.

[20] Campbell, J.Y. and Mei, J. (1993), 'Where Do Betas Come From? Asset Price Dynamics and the Sources of Systematic Risk', *The Review of Financial Studies*, **6**:3, p. 575.

4 Conclusions

Previous Oxera reports and ENA submissions to Ofgem have presented the theoretical and empirical evidence from earlier studies on the reasons why the required return would be expected to increase for regulated networks as a result of an increase in cash flow duration.

This report extends the results of previous submissions by presenting new empirical evidence for estimates of cash flow betas for companies included in the FTSE All-share index. The methodology that has been followed in the report is based on peer-reviewed academic papers, such as Campbell and Mei (1993) and Campbell and Vuolteenaho (2004).

The findings from this report show that the cash flow beta is a relatively low proportion of the equity beta for UK utilities. The cash flow beta for the general UK utilities index is around 0.10, which represents around 19% of the equity beta. Estimates of the cash flow betas for National Grid and SSE are even lower proportions of their equity betas, at around 10%. This ratio is less than half that for the broad equity market (21%), and is in contrast to other sectors, such as oil and gas, and basic materials, where the cash flow beta is around 26–28% of the equity beta.

The Brennan and Xia (2006) framework (BX framework), is calibrated on US market data, does not estimate cash flow betas directly.[21] However, the framework shows that the cash flow beta for the broad equity market will be less than the equity beta of the market—which by definition is equal to one.[22] Since the cash flow betas for National Grid and SSE (as a proportion of the equity betas) are less than half the cash flow beta proportion of the market equity beta, the cash flow betas for National Grid and SSE will be below the 0.5 threshold where the BX framework predicts that required returns will increase with the duration of cash flows. As this result holds when the cash flow beta is expressed as a proportion of the equity beta, it will hold even if the equity betas of all sectors and companies are normalised to one.

The estimates therefore suggest that a positive relationship between cash flow duration and required returns holds for National Grid and SSE. Consequently, the increases in cash flow duration implied by the RIIO-T1 and -GD1 strategy decisions would be expected to materially increase the cost of equity for regulated energy networks.

This analysis assumes that the rate of information arrival regarding future cash flows is the same regardless of when the cash flow will occur. As outlined in Oxera (2011), the BX framework predicts an additional incremental increase in the cost of capital as a result of increasing cash flow duration if there is greater uncertainty about longer-duration cash flows than for shorter-duration cash flows.[23] For regulated energy networks, expectations for cash flows further in the future—particularly those that fall into price control periods from RIIO-T2 and RIIO-GD2 onwards—are likely to be less certain that expectations for cash flows that will occur sooner. This would exacerbate the increase in required returns associated with an increase in the duration of cash flows.

More generally, where the rate of information arrival is constant across all cash flow durations, the increase in required returns predicted by the BX framework does not make any allowance for the possibility of a regulatory time inconsistency problem. This arises because regulators cannot comprehensively bind the actions of their successors or offer commitment

[21] Brennan, M. and Xia, Y. (2006), 'Risk and Valuation under an Intertemporal Capital Asset Pricing Model', *Journal of Business*, **79:**1.

[22] Ibid., figure 3, panel A.

[23] Oxera (2011), 'What is the cost of equity for RIIO-T1 and RIIO-GD1?', prepared for Energy Networks Association, February 14th, section A3.3.2.

that cash flows expected at the time of investment will, on average, materialise in the future. To the extent that an increase in the duration of cash flows exposes a greater proportion of value to the time inconsistency problem, an additional increase in the required return would be expected, over and above that predicted by the standard BX framework.

A1 Technical appendix

A1.1 Results from the system of econometric equations

As described in section 2.1, the system of econometric equations has been estimated using a VAR with four lags. The results from the excess return equation are presented in Table A1.1.

Table A1.1 Coefficients of the excess return equation from the VAR

Variable	Lag 1	Lag 2	Lag 3	Lag 4	Constant
Excess market returns	–0.11*	0.04	–0.12*	–0.04	
Term-yield spread	–0.01	–0.00	0.03***	–0.01**	
Price–earnings ratio	0.07	–0.04	–0.01	–0.02	
Small stock value spread	0.00	–0.02*	0.02*	–0.01	
Constant					0.01

Note: *, ** and *** denote statistical significance at the 10%, 5% and 1% levels respectively.
Source: Oxera analysis.

The table shows that there is a negative relationship between current values of excess market returns and the previous week's values—for example, excess market returns would be expected to be higher in the following week if returns were lower in the previous week.

The coefficients on the first two lags of the term-yield spread are both negative and not significant, whereas the coefficient on the third lag is positive, relatively large and highly significant. This suggests an overall positive relationship between the term-yield spread and excess market returns, which is consistent with the results obtained by Campbell and Vuolteenaho (2004).

The parameters of all four lags of the price–earnings ratio, on the other hand, are not statistically significant. We nevertheless use this variable in our regression because the price–earnings ratio is generally considered to be a variable that reflects perceptions of future returns. Campbell and Shiller (1998), for example, show that the ratio of prices to average earnings over ten years is a good forecaster of future growth in stock prices, and Campbell and Vuolteenaho (2004) use this version of the price–earnings ratio in their analysis.

Due to the non-availability of a sufficiently long time series of earnings data for the FTSE All-share index, it has not been possible to replicate the smoothed price–earnings ratio used by Campbell and Vuolteenaho (2004).[24] Instead, the simple price–earnings ratio is used as a proxy.

Campbell and Shiller (1998) show that the simple price–earnings ratio has less forecasting power than the smoothed version of the ratio, due to the noise and cyclical patterns that characterise earnings data. This might explain why the coefficients reported in Table A1.1 are not significant, whereas Campbell and Vuolteenaho (2004) obtain a statistically significant coefficient of –0.014. A coefficient of –0.002 is obtained if the model in Table A1.1

[24] Since earnings data in the FTSE All-Share index goes back to 1998 only, the time horizon of the analysis would be significantly reduced by using a backward-looking moving average of earnings (for a ten-year moving average, for example, the sample period would reduce to 2008–11).

is re-estimated with only one lag, suggesting that the simple price–earnings ratio has a comparable but weaker effect on excess market returns.

Finally, the first lag of the small stock value spread seems to have no effect on excess market returns, whereas the second and third lags are significantly different from zero.

The summary statistics from the VAR are shown in Table A1.2. The R-squared of all equations, apart from the excess return regression, is relatively high at above 90%. It is not unexpected that the R-squared of the excess return regression is lower, at around 5%, given the body of evidence that shows that it is harder to predict excess market returns. This estimate for the R-squared is also consistent with findings from Campbell and Vuolteenaho (2004).

Four lags are included in the VAR model because several of the higher lags are statistically significant in the excess market returns equation, suggesting that those lags pick up relevant effects that are not covered by a one-lag model, such as monthly effects. This is consistent with the approach adopted in Campbell and Vuolteenaho (2004) which uses monthly data and one lag. As shown by the F-statistic, the variables that are used in each of the equations are jointly statistically significant. If, on the other hand, only one lag is used, the coefficients are not jointly significant.[25] This supports the choice of estimating the VAR with four lags.

Table A1.2 Summary statistics from the VAR

VAR equation	R-squared	F statistic
Excess market returns equation	0.04	29.01**
Term-yield spread equation	0.99	87,058.43***
Price–earnings ratio equation	0.99	65,580.20***
Small stock value spread equation	0.93	10,669.06***

Note: ** and *** denote statistical significance at the 5% and 1% levels respectively.
Source: Oxera analysis.

A1.1.1 Robustness checks

As a check on the robustness of the estimates from the VAR, the main diagnostic tests on the unexplained component—the residuals—from the VAR have been examined. To ensure the robustness of the results, it is important that there is no systematic pattern in the residuals from the VAR, and, therefore, that the news measures about future cash flows and discount rates reflect only unexpected changes in either cash flows or discount rates.

The robustness checks include the tests for:

– autocorrelation—to ascertain whether the residuals from the VAR are correlated over time;
– heteroscedasticity—to examine whether the spread of the residuals from the VAR are constant over time;
– stationarity—as a more general test of whether there is any pattern in the residuals from the VAR.

As shown in Table A1.3 below, the residuals from the VAR with four lags are stationary, and are also not correlated over time. Furthermore, the spread of the residuals from the main econometric equation that is used to calculate the measures about news of future cash flows and discount rates—the excess market returns equation—is constant over time (as indicated by the results from the heteroscedasticity test).

[25] It can be shown that the P-value of the joint significance test is equal to 0.3648 under the one-lag specification of the model, and equal to 0.0255 under the four-lag specification. The coefficients are therefore jointly significant at the 5% level in the model with four lags.

In contrast, if the VAR is estimated using only one lag, there is evidence that the spread of the residuals from the excess market returns equation changes over time, as indicated by the results from the heteroscedasticity test. This suggests that the VAR with four lags is preferable.

Table A1.3 Tests on the residuals from the VAR

	Autocorrelation test	Heteroscedasticity test	Stationarity test
VAR with four lags			
Excess market returns equation	Pass (0.17)	Pass (0.29)	Pass (0.00)
Term-yield spread equation		Pass (0.86)	Pass (0.00)
Price–earnings ratio equation		Fail (0.00)	Pass (0.00)
Small stock value spread equation		Fail (0.00)	Pass (0.00)
VAR with one lag			
Excess market returns equation	Pass (0.67)	Fail (0.00)	Pass (0.00)
Term-yield spread equation		Pass (0.91)	Pass (0.00)
Price–earnings ratio equation		Fail (0.00)	Pass (0.00)
Small stock value spread equation		Fail (0.00)	Pass (0.00)

Note: P-values are provided in brackets. Autocorrelation is tested using the Lagrange-multiplier test on the VAR—a P-value greater than 0.05 would indicate that there is no evidence of autocorrelation at the 5% level. Heteroscedasticity is tested using the Breusch–Pagan/Cook–Weisberg test individually for each equation from the VAR—a P-value greater than 0.05 would indicate that there is no evidence of heteroscedasticity at the 5% level. Stationarity is tested using the Dickey–Fuller unit root test individually for each equation from the VAR—a P-value less than 0.05 indicates that the hypothesis of stationary is rejected at the 5% level.
Source: Oxera analysis.

A1.2 Sensitivity of beta estimates to assumptions

As described in section 2.2, the measures of news about future cash flows and discount rates are calculated from a present value relationship between stock returns, prices and dividends. This approach follows the methodology adopted by Campbell and Shiller (1988).[26]

Campbell and Shiller (1988) show that the return on an equity is approximately proportional to the weighted average of the change in the equity price and its dividend, with the weight on the change in the equity price denoted by ρ, and the weight on the dividend denoted by (1- ρ).[27] It can be shown that the weight on the stock's price (eg, ρ) is inversely related to the average dividend–price ratio for companies listed in the FTSE All-share index, or the average consumption–wealth ratio.[28] In other words, if the stock's price is high relative to dividends, greater weight is placed on that particular stock. This section analyses the sensitivity of our results to the choice of ρ.

The value of ρ could, in principle, be estimated from the available market data in each time period. Most papers, however, do not estimate ρ from the data, but assume a 'reasonable' value for ρ, which is held constant throughout the period. The main justification for this approach is that beta estimates are insensitive to the choice of ρ within a plausible range. For the purposes of the results presented in this report, this approach has been followed.

[26] Campbell, J.Y. and Shiller, R.J. (1988), 'The Dividend-Price Ratio and Expectations of Future Dividends and Discount Factors', *Review of Financial Studies*, **1**:3, pp. 195–228.
[27] Specifically, if p_t and d_t denote log price and log dividend in year t respectively, it can be shown that the log return in year t satisfies: $r_t \approx \text{constant} + \rho\, p_t + (1-\rho)\, d_t - p_{t-1}$.
[28] Campbell, J.Y. (1993), 'Inter-temporal asset pricing without consumption data', *American Economic Review*, **83**:3, pp. 487–512.

Specifically, it has been assumed that ρ equals 0.999, which is consistent with Campbell and Mei (1993) and Campbell and Vuolteenaho (2004).[29] This value for ρ is consistent with an average consumption–wealth ratio of around 5%, which, as pointed out by Campbell and Vuolteenaho (2004), is an appropriate assumption for a long-term investor.

In order to examine the sensitivity of the beta estimates to changes in ρ, two alternative scenarios have been considered around the central-case scenario.

– In the **low scenario**, an annualised ρ of 0.93 is assumed. This corresponds to an average dividend–price or consumption–wealth ratio of 7.5%, and a weekly ρ of 0.9986.[30]

– In the **high scenario**, an annualised ρ of 0.97 is assumed. This corresponds to an average dividend–price or consumption–wealth ratio of 3.1%, and a weekly ρ of 0.9994.[31]

Table A1.4 summarises the sensitivity of the resulting beta estimates to the choice of ρ. As shown, varying the assumption on ρ leads to only relatively small changes in the cash flow betas of around 5bp. This is minor when compared with the variation in dividend–price or consumption–wealth ratios across the different scenarios.

Table A1.4 Sensitivity of beta estimates to ρ

	Low scenario (ρ=0.9986)		Central case scenario (ρ=0.9990)		High scenario (ρ=0.9994)	
Sector	Cash flow beta	Discount rate beta	Cash flow beta	Discount rate beta	Cash flow beta	Discount rate beta
Market	0.25	0.75	0.21	0.79	0.17	0.83
Technology	0.22	1.05	0.16	1.10	0.10	1.17
Telecoms	0.17	0.77	0.13	0.80	0.09	0.84
Consumer services	0.20	0.71	0.16	0.75	0.12	0.79
Utilities	0.12	0.41	0.10	0.44	0.08	0.46
National Grid	0.08	0.51	0.06	0.54	0.03	0.57
SSE	0.07	0.40	0.05	0.41	0.03	0.43
Financial services	0.30	0.90	0.25	0.95	0.20	1.00
Healthcare	0.18	0.49	0.15	0.52	0.13	0.55
Consumer goods	0.22	0.60	0.19	0.63	0.15	0.66
Industrials	0.24	0.69	0.21	0.73	0.17	0.77
Oil & gas	0.29	0.69	0.26	0.72	0.21	0.77
Basic Materials	0.39	0.84	0.35	0.88	0.30	0.93
Average excluding utilities	**0.25**	**0.75**	**0.21**	**0.79**	**0.16**	**0.83**

Source: Oxera analysis.

[29] For the purposes of the results in this report, an annualised ρ of 0.95 is used, which is consistent with the approach adopted by Campbell and Vuolteenaho (2004). This corresponds to a weekly ρ of $(0.95)^{1/52}$= 0.9990 and an average consumption–wealth ratio of 5.2%.

[30] Specifically, this is derived as $(0.93)^{1/52}$.

[31] Specifically, this is derived as $(0.97)^{1/52}$.

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